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FLUID PUMPS

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FIG. 1

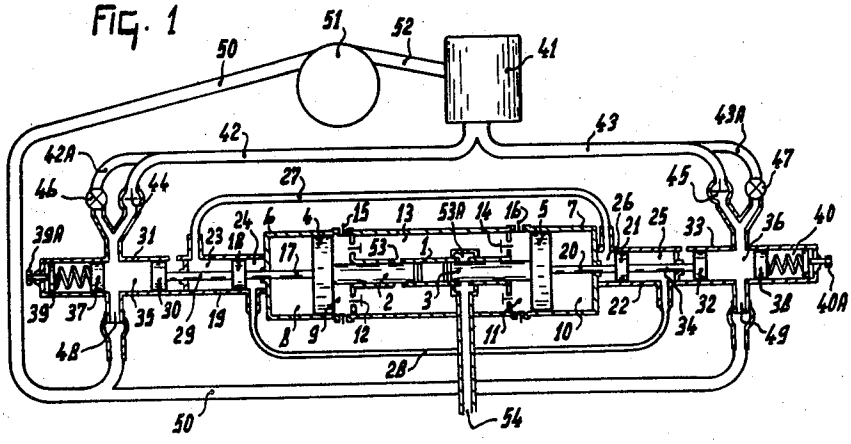
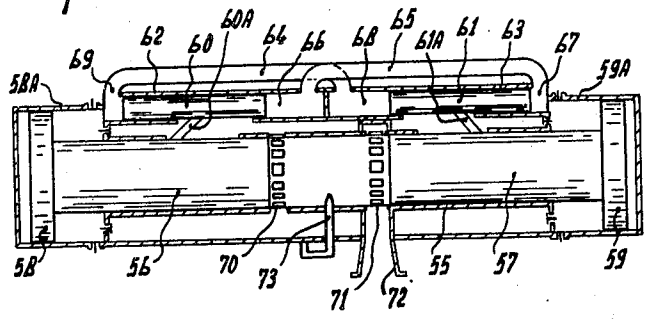



FIG. 2




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3,106,896

# FLUID PUMPS

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This invention relates to a fluid piston pump combined with a piston engine so as to be driven thereby.

According to a first aspect of the present invention, there is provided a combination of a reciprocating fluid piston pump, and an engine having at least one reciprocating working piston, the working piston, or at least one of the working pistons, of the engine being connected with a pump piston, or respective pump pistons, wherein the pump has first means arranged to alter the volume of the working space(s) thereof in response to fluctuations of the pressure of the fluid in such working space(s), so that when the fluid pressure in the working space(s) increases the volume thereof can similarly increase, there being also second means against which said first means acts when said first means increases the volume of the working space(s), the arrangement being such that energy used for the increase of the volume of the working space(s) is stored by said second means, and the arrangement being further such that all or part of the stored energy may be employed to perform an extra pumping action when the pressure decreases in the working space(s) and the volume of the latter is accordingly reduced by said first means.

This invention also relates to a free-piston engine having more than one reciprocating working piston. According to a second aspect of the present invention, there is provided a free-piston engine having more than one reciprocating working piston, wherein the working pistons are interconnected by a positive-displacement hydraulic coupling so as to maintain a fixed phase difference between the strokes of the working pistons.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made by way of example of the accompanying diagrammatic drawing in which:

FIGURE 1 is a longitudinal section of a combination of a fluid pump and a first embodiment of a free-piston engine and,

FIGURE 2 is a longitudinal section of a second embodiment of a free-piston engine.

As shown in FIGURE 1, the combination includes a free-piston engine having a single cylinder 1 in which two working pistons 2 and 3 are arranged to reciprocate freely in opposite directions. The cylinder 1 has inlet ports 53, and has outlet ports 53A communicating with an outlet pipe 54. The working pistons 2 and 3 are fixed to compressor pistons 4 and 5, respectively, which are arranged to move in compressor cylinders 6 and 7, respectively. The piston 4 divides the cylinder 6 into two spaces 8 and 9, and the piston 5 divides the cylinder 7 into two spaces 10 and 11, the spaces 8 and 10 constituting cushion chambers. The cylinder spaces 9 and 11 communicate through non-return valves 12 and 14, respectively, with a reservoir 13 surrounding the cylinder 1. Also, the cylinder spaces 9 and 11 communicate through non-return valves 15 and 16, respectively, with the atmosphere. The compressor piston 4, fixed to the working piston 2, is connected by a rod 17 with a plunger 18 which is arranged to move in a cylinder 19. Similarly, the compressor piston 5, fixed to the working piston 3, is connected by a rod 20 with a plunger 21 which is arranged to move in a cylinder 22.



The plunger 18 divides the cylinder 19 into two spaces 23 and 24, and the plunger 21 divides the cylinder 22 into two spaces 25 and 26. The cylinder spaces 23 and 26 communicate with each other by way of a duct 27, and the cylinder spaces 24 and 25 communicate with each other by way of a duct 28.

The plunger 18 is connected by a rod 29 with a pump piston 30 of a fluid pump 31, and the piston plunger 21 is connected with a pump piston 32 of a fluid pump 33 by a rod 34. The pump pistons 30 and 32 are arranged to move in working spaces 35 and 36, respectively. The working spaces 35 and 36 are each bounded by one face of a plunger 37 or 38, respectively, the latter being backed by springs 39 and 40, respectively, which oppose movement of the respective plungers in one direction. The compression in the springs 39 and 40 may be adjusted with the aid of screws 39A and 40A, respectively.

Fluid may be fed from a container 41 through pipes 42 and 43 to the fluid pumps 31 and 33, respectively, the pipes 42 and 43 having inlet valves 44 and 45, respectively. Fluid may alternatively be fed from the container 41 to the pumps 31 and 33 through pipes 42A and 43A, by operation of cocks 46 and 47 respectively. Fluid may be allowed, by non-return outlet valves 48 and 49, to flow out of the working spaces 35 and 36 of the pumps 31 and 33, respectively, into a pipe 50. The pipe 50 leads to a device or machine which is indicated at 51 in FIGURE 1 and which is intended to be driven by the pumped fluid. A pipe 52 provides a return communication between the machine 51 and the fluid container 41.

Before the pumps are set in operation, the working spaces 35 and 36 thereof are filled with fluid from the container 41 by opening the cocks 46 and 47, respectively. These cocks are then closed and remain closed during the operation of the pumps.

The operation of the combination shown in FIGURE 1 is as follows:

Upon fuel combustion in the cylinder 1 between the opposed working pistons 2 and 3, the latter are forced outwards, causing the compressor pistons 4 and 5 to compress the air in the cushion chambers 8 and 10, respectively. At the same time, the valves 12 and 14 close, and the valves 15 and 16 open, these valves 15 and 16 allowing air from the atmosphere to be sucked into the cylinder spaces 9 and 11. Near the end of the outward stroke of the pistons 2 and 3, the inlet ports 53 and the outlet ports 53A are uncovered, thus allowing the hot spent gases to flow through the outlet 54 as fresh air enters from the reservoir 13. The air compressed in the cushion chambers 8 and 10 then urges inwards the compressor pistons 4 and 5, with the working pistons 2 and 3, the air in the cylinder 1 being thus compressed as the ports 53 and 53A are covered by the pistons 2 and 3. As a result of the compression of the air in the cylinder 1, such air is raised to a high temperature. During the movement of the pistons inwards, the valves 15 and 16 close, and the valves 12 and 14 open, the air in the cylinder spaces 9 and 11 being therefore forced into the reservoir 13. Thus the reservoir 13 contains air at a raised pressure. At the end of the inward stroke of the pistons 2 and 3, fuel is sprayed into the small space left in the cylinder 1 with the aid of an injection nozzle (not shown in FIGURE 1), and this fuel ignites spontaneously, since the compressed air within the cylinder 1 is at a high temperature. A rapid increase in pressure follows the ignition, so that the pistons 2 and 3 are again forced outwards, thus restarting the working cycle of the engine.

As described above, the working pistons 2 and 3 of the free-piston engine are directly connected with the plungers 18 and 21, respectively, and the plungers 18 and 21 are arranged to move in the cylinders 19 and 22, which

are interconnected via the ducts 27 and 28. The cylinders 19 and 22 and the ducts 27 and 28 are filled with a liquid, for example, oil. When the working piston 2 moves outwards, the oil contained in the cylinder space 23 is displaced by the plunger 18 along the duct 27 into the cylinder space 26 behind the other plunger 21. Since the oil cannot be compressed, the plunger 21 is constrained to move outwards in dependence upon the outward movement of the other plunger 18. The oil contained in the cylinder space 25 is similarly forced through the duct 28 into the cylinder space 24. Thus the plungers 18 and 21 in the cylinders 19 and 22, together with the ducts 27 and 28, constitute a positive-displacement hydraulic coupling between the working pistons 2 and 3, ensuring that the pistons have equal strokes and have a fixed phase difference of 180° between their strokes.

Since the two fluid pumps are of identical construction, and since they operate identically, it will suffice to describe only the operation of the fluid pump 31. As the working piston 2 moves outwards, the pump piston 30 moves towards the plunger 37. The fluid between the piston 30 and the plunger 37, if compressible, will be compressed. The fluid displaced by the pump piston 30 is, however, allowed by the nonreturn outlet valve 48 to pass into the pipe 50.

The piston velocity of each working piston of the free-piston engine is not normally constant over the length of its stroke, so that the velocity of the pump piston connected with such working position, is correspondingly not constant. Under certain conditions therefore, the pump piston velocity will be so great as to displace more fluid in a given time than can flow through the non-return outlet valve 48 in that time, so that the pressure in the working space 35 of the pump 31 would rise considerably if no special pressure reducing means were provided. As the pressure in the working space 35 increases, the plunger 37 is urged away from the piston 30 against the action of the spring 39. Thus the volume of the working space 35 is increased and the pressure of the fluid in that space is not undesirably increased. The behaviour of the spring 39 can be altered with the aid of the adjusting screw 39A, movement of which alters the setting of one end of the spring 39. When the spring 39 is compressed as a result of the raised pressure in the working space 35, part of the energy supplied by the free-piston engine is stored in the spring. Each working piston of the free-piston engine moves with increasing velocity during the outward stroke, so that the velocity of movement of each working piston is less during the first part of its outward stroke. In general, therefore, an equilibrium is established between the quantity of fluid displaced by the pump piston 30 and the quantity of fluid flowing through the outlet valve 48. However, the quantity of fluid displaced by the pump piston 30 in a given time may be less than that which could flow through the outlet valve 48 in that time, for example, during the last part of the outward stroke of the working piston. In this case, the pressure in the working space 35 decreases and the plunger 37 moves towards the pump piston 30. Therefore, the fluid displaced by the plunger 37 passes through the outlet valve 48, so that the plunger 37 tends to maintain the flow of fluid through the valve 48. Thus part of the energy stored in the spring 39 is usefully employed to perform an extra pumping action. The energy stored in the spring 39 may be sufficient to increase the pressure of the fluid in the working space 35 to a valve above the pressure on the other side of the outlet valve 48 in the pipe 50, during the first part of the inward stroke of the pump piston 30. Thus fluid is caused to flow through the valve 48 even during part of the inward stroke of the pump piston 30, so that a further part of the energy stored in the spring 39 is usefully employed.

During the inward stroke of the pump piston 30, the outlet valve 48 closes, after which the inlet valve 44 opens. Fluid is thus allowed to flow from the container 41 into the working space 35 of the pump. At the beginning of the outward stroke of the pump piston 30, the inlet valve 44 closes and the outlet valve 48 opens, so that the whole cycle may be repeated.

Since the compression in the spring 39 can be adjusted with the aid of the screw 39A, the maximum fluid pressure arising in the working space 35 can be controlled in a sample manner.

The fluid pumped through the outlet valves 48 and 49 into the pipe 50, passes to the machine 51, from which the fluid is returned to the container 41 by way of the pipe 52. The combination according to the invention is particularly suitable for driving a hydraulic motor. In this case, the fluid pumped through the machine 51 is a liquid, and is, for example, oil.

The pumps are adaptable to fluctuations in the fluid pressure and to variations in the quantity of fluid to be supplied to the machine 51, in the event of variations in the power to be supplied by the machine 51 and/or in the event of variations on the speed of revolution of the machine.

Since all the pistons of the combination shown in FIGURE 1 are aligned, the combination is of simple constructions.

It will be appreciated that the pump pistons may be driven by means other than the free-piston engine described with reference to FIGURE 1.

Referring now to FIGURE 2, there is shown a free-piston engine having a single cylinder 55 in which two working pistons 56 and 57 are arranged to reciprocate freely in opposite directions. The cylinder 55 has inlet ports 70, and outlet ports 71 communicating with an outlet pipe 72. The working pistons 56 and 57 are fixed to compressor pistons 58 and 59, respectively, which are arranged to move in compressor cylinders 58A and 59A, respectively. The operation of the engine is identical with that of the free-piston engine in the combination described with reference to FIGURE 1, the fuel being sprayed into the cylinder 55 through an injection nozzle 73.

The working pistons 56 and 57 of the embodiment shown in FIGURE 2 are coupled with plungers 60 and 61, respectively, by rigid connecting rods 60A and 61A, respectively. The plunger 60 is adapted to move in a cylinder 62 and the plunger 61 is adapted to move in a cylinder 63. The cylinders 62 and 63 communicate one with the other by ducts 64 and 65 which are filled with a liquid, for example, oil. The plungers 60 and 61 divide the cylinders 62 and 63 into cylinder spaces 66, 69 and 68, 67, the duct 64 affording a communication between the spaces 68 and 69, and the duct 65 likewise affording a communication between the spaces 66 and 67.

FIGURE 2 shows the working pistons 56 and 57 in their outermost positions. As the pistons 56 moves inwards, oil is forced by the plunger 60 from the space 66 into the duct 65 and into the space 67 behind the plunger 61. Thus the plunger 61, together with the working pistons 57, is urged inwardly by the oil. Likewise, the plunger 61 forces oil from the space 68 into the duct 64 and into the space 69. Since the plungers 60 and 61 are of equal diameters, and since the oil is incompressible, the distance moved by one plunger is the same as the distance moved by the other plunger, and due to the fact that each plunger is rigidly coupled with its respective working piston, the distances moved by the working pistons are equal. Thus the positive-displacement hydraulic coupling constituted by the plungers 60 and 61, and the ducts 64 and 65, ensures that the working pistons 56 and 57 have equal strokes, and have a fixed phase difference between their strokes.

It will be appreciated that various modifications may be made to the hydraulic couplings described above. For example, the diameters of the plungers 18 and 21, or 60 and 61, may be different, so that the oil displaced by these plungers causes the distances moved by the working

pistons 2 and 3, or 56 and 57 to be different, while still maintaining the fixed phase different between the strokes thereof. It is also possible to provide, for example, an off-centered transfer lever for transmitting motion between each working piston and the associated plungers, so that the strokes of the working pistons 56 and 57 are again different.

As an alternative to the spontaneous ignition of a fuel mixture in the cylinder 1, or 55, a gas mixture may be ignited therein with the aid of a sparking plug.

What we claim is:

1. In combination with a reciprocating fluid pump including a piston, an internal combustion engine comprising a combustion cylinder including a cylinder head, fuel injection means in said cylinder proximate to its head, an exhaust port and an air inlet port in said cylinder away from said cylinder head, an exhaust conduit leading from said exhaust port to the atmosphere, a combustion piston to reciprocate in said cylinder, an air reservoir in communication with said inlet port, an air compression piston connected to said combustion piston, an air cushion chamber receiving said compression piston, said air cushion chamber being closed to the atmosphere at one end and having in its other end an inlet valve in communication with the atmosphere and an outlet valve in communication with said air reservoir, rod means rigidly aligning and connecting said combustion piston to said pump piston through said compression piston whereby when said combustion piston moves as a result of an explosion in said combustion cylinder said air compression piston is moved in said air cushion chamber to compress air on one of its sides and to draw air from the atmosphere into said chamber from the other of its sides, and when said explosive gases escape through said exhaust port by reason of said combustion piston uncovering said exhaust port, air enters said air inlet port from said air reservoir and compressed air in said air cushion chamber forces said air compression piston and said combustion piston in an opposite direction and forces air from said other end of said air cushion chamber into said air reservoir, and said pump piston is correspondingly reciprocated.

2. In combination with a pump including a pump piston, an internal combustion engine comprising a combustion cylinder including a cylinder head, fuel injection means located near the head of said cylinder, an exhaust port in the wall of said combustion cylinder away from said combustion cylinder head, an air inlet port in the wall of said cylinder also away from said combustion cylinder head, an exhaust conduit to the atmosphere in communication with said exhaust port, a combustion piston to reciprocate in said combustion cylinder, an air reservoir surrounding said combustion cylinder and in communication with said inlet port, an air compression piston connected to said combustion piston, an air cushion chamber receiving said air compression piston, said air cushion chamber confined at one end whereby air is compressed in said confined space when said combustion and said air compression pistons are moved as a result of an explosion in said combustion cylinder, an air inlet valve in communication with the atmosphere in the other end of said air cushion chamber, an air outlet valve in the other end of said air cushion chamber in communication with said air reservoir, and rod means rigidly aligning and connecting said combustion piston to said pump piston through said compression piston.

3. A combined engine and pump construction which comprises a combustion chamber including a head, fuel injection means near the head of said combustion chamber, an exhaust port and an air inlet port disposed in the wall of said combustion chamber away from said combustion chamber head, an exhaust conduit to carry exhaust gases from the exhaust port to the atmosphere, a combustion piston received in said combustion chamber to reciprocate therein, an air reservoir in communication with said air inlet port, an air compression piston connected to said piston, an air cushion chamber receiving said air compression piston, said air cushion chamber being closed at one end whereby when said air compression piston is moved by said combustion piston together with said piston rod in response to an explosion in said combustion cylinder, air is compressed in the closed end of said air cushion chamber, an air inlet valve incorporated in the other end of said air cushion chamber in communication with the atmosphere, an air outlet valve in the other end of said air cushion chamber in communication with said air reservoir, reciprocating pump structure including a pump cylinder and a pump piston received therein, a fluid inlet valve and a fluid outlet valve in communication with said pump cylinder, a spring-loaded plunger included in said pump cylinder to permit enlargement of the internal volume of the pump cylinder in response to internal fluid pressure increases, adjustment means in association with said spring-loaded plunger to vary selectively the spring compression of said spring-loaded plunger, and rod means rigidly aligning and connecting said combustion piston with said pump piston through said compression piston.

4. A combined engine and pump construction which comprises a combustion cylinder including a cylinder head, fuel injection means, an exhaust port and an air inlet port in the wall of said combustion chamber away from said cylinder head, an exhaust conduit interconnecting the atmosphere and said exhaust port, a combustion piston received in said combustion cylinder to reciprocate therein, an air reservoir surrounding said combustion chamber and in communication with said inlet port, an air compression piston connected to the other end of said combustion piston, an air cushion chamber receiving said air compression piston, said air cushion chamber closed at one end whereby a gas therein is compressed when said combustion piston moves in response to an explosion in said cylinder, an air inlet valve in the other end of said air cushion chamber in communication with the atmosphere, an air outlet valve in the same end of said air cushion chamber as said inlet valve in communication with said air reservoir, a reciprocating pump structure including a pump cylinder and a pump piston received therein, a fluid inlet valve and a fluid outlet valve in communication with said pump cylinder, a spring-loaded plunger in said pump cylinder to permit internal enlargement of said pump cylinder in response to internal fluid increases, adjustment means associated with said spring-loaded plunger to vary selectively the spring compression of said plunger in said cylinder, and rod means rigidly aligning and connecting said combustion piston to said pump piston through said compression piston.

5. In combination with a reciprocating fluid pump including a pump piston, an internal combustion engine which comprises a combustion cylinder, a fuel injection means centrally located in said combustion chamber, an exhaust port located to one side of said fuel injection means in the wall of said combustion chamber, an exhaust conduit in communication with said exhaust port and the atmosphere, an air inlet port disposed in the wall of said combustion cylinder on the other side of said fuel injection means, first and second combustion pistons received in said cylinder in opposed relationship to each other, an air reservoir substantially surrounding said combustion chamber in communication with said inlet port, a first air compression piston connected to said first compression piston, a second air compression piston connected to said second compression piston, a first air cushion chamber receiving said first air compression piston and a second air cushion chamber receiving said second air compression piston, each of said air cushion chambers being closed at one end whereby gas therein is compressed when said air compression piston moves therein in response to an explosion in said combustion cylinder, an air inlet valve in communication with the atmosphere

and an air outlet valve in communication with the said air reservoir in the other ends of each of said air cushion chambers, a positive displacement hydraulic coupling means equalizing said combustion pistons' strokes with a fixed phase of 180° between strokes of said combustion pistons, and rod means rigidly aligning and operatively connecting at least one of said combustion pistons with the pump piston through said compression piston.

6. A combined engine and pump construction which comprises a combustion cylinder, fuel injection means centrally disposed in said combustion cylinder, an exhaust port in the wall of said combustion cylinder at one side of said fuel injection means, an exhaust line interconnected with said exhaust port and the atmosphere, an air inlet port in the wall of said cylinder on the opposite side of said fuel injection means from said exhaust port, first and second opposed combustion pistons reciprocating in said combustion cylinder, an air reservoir surrounding said combustion cylinder in communication with said inlet port, a first piston rod connected to said first combustion piston, a second piston rod connected to said second combustion piston, a first air compression piston connected to the other end of said first piston rod, a second air compression piston connected to the other end of said second piston rod, a first air cushion chamber receiving said first air compression piston, a second air cushion chamber receiving said second air compression piston opposite said first air cushion chamber, each of said air cushion chambers closed at one end whereby gas is compressed therein when said air compression pistons move in response to an explosion in said combustion cylinder, an air inlet valve in communication with the atmosphere and an air outlet valve in communication with said air reservoir in the other end of each of said air cushion chambers, a positive displacement hydraulic coupling associated with said combustion pistons whereby said combustion pistons have equal strokes and a fixed phase difference of 180° between their strokes, a first fluid pump operatively connected to said first combustion piston, a second fluid pump operatively connected to said second combustion piston, each of said fluid pumps including a pump cylinder with a spring-loaded plunger to permit enlargement of internal volume of the pump cylinder in response to an internal fluid pressure increase, and with adjustment means to vary selectively the spring pressure of said spring-loaded plunger, each of said fluid pumps also including a reciprocating piston in said pump cylinders and one-way inlet and outlet fluid valves in communication with said pump cylinders.

7. In a fluid pumping system, an internal combustion engine comprising a combustion cylinder, fuel injection means centrally located in said combustion cylinder, an exhaust port located apart from the said fuel injection means in the wall of said combustion cylinder, an exhaust conduit leading from said exhaust port, an air inlet port in the wall of said combustion chamber disposed on the opposite side of said fuel injection means from said exhaust port, first and second opposed combustion pistons received in said combustion cylinder, an air reservoir substantially surrounding said combustion cylinder in communication with said inlet port, a first piston rod connected to said first combustion piston, a second piston rod connected to said second combustion piston, a first air compression piston connected to the other end of said first piston rod, a second air compression piston connected to the other end of said second piston rod, a first air cushion chamber receiving said first air compression piston, a second air cushion chamber receiving said second air compression piston opposite said first air cushion chamber, each of said air cushion chambers closed at one end whereby gas in said closed end is compressed by said air compression pistons when they are moved by said combustion pistons and piston rods in response to an explosion in said combustion cylinders, the other end of each air cushion chamber having an air outlet valve in communication with said air reservoir and an air inlet valve in communication with the atmosphere, a first hydraulic piston interconnected with said first combustion piston, a second hydraulic piston interconnected with said second combustion piston, a first hydraulic cylinder means receiving said first hydraulic piston, a second hydraulic cylinder means receiving said second hydraulic piston, fluid in said hydraulic cylinders, conduit means cross connecting said hydraulic cylinders whereby when said hydraulic cylinders are moved by said combustion pistons fluid is forced from one end of said first hydraulic cylinders to the non-opposite end of said second hydraulic cylinders and at the same time from the opposite end of said second hydraulic cylinder to the other end of said first hydraulic cylinder thereby ensuring that said combustion pistons have equal strokes and a fixed phase difference of 180° between their strokes, and connection means operatively connecting said combustion pistons to the reciprocating pistons of fluid pumps.

8. An internal combustion engine comprising a combustion cylinder, a centrally located fuel injection means in said combustion chamber, an exhaust port in the wall of said combustion chamber longitudinally removed from said fuel injection means, an exhaust line interconnecting said exhaust port and the atmosphere, an air inlet port in the wall of said combustion chamber located longitudinally removed from said fuel injection means opposite said exhaust port, first and second opposed combustion pistons received in said combustion cylinder, an air reservoir substantially surrounding said combustion chamber in communication with said inlet port, a first air compression piston in alignment to said first combustion piston, a second air compression piston rigidly connected in alignment to said second piston rod, a first air cushion chamber receiving said first air compression piston, a second air cushion chamber receiving said second air compression piston, each of said air cushion chambers being closed at one end whereby gas entrapped therein is compressed by said air compression pistons when they are moved in response to an explosion in said internal combustion cylinder, each of said air cushion chambers having in their other ends an air inlet valve in communication with the atmosphere and an air outlet valve in communication with said air reservoir, a first hydraulic piston interconnected and aligned with said first combustion piston, a second hydraulic piston interconnected and aligned with said second combustion piston, a first hydraulic cylinder receiving said first hydraulic piston, a second hydraulic cylinder receiving said second hydraulic piston, fluid in said hydraulic cylinders and conduit means connecting said hydraulic cylinders whereby when said hydraulic pistons are moved by said combustion pistons fluid is forced from one end of said first hydraulic cylinder to the non-opposite end of said second hydraulic cylinder and at the same time from the opposite end of the second hydraulic cylinder to the other end of the first hydraulic cylinder thereby ensuring that each of the combustion pistons have equal strokes and a fixed phase difference of 180° between their strokes.

9. In combination with an internal combustion engine having opposed free floating pistons with reciprocating fluid pistons rigidly interconnected in alignment with said floating pistons, a positive displacement hydraulic coupling comprising a first hydraulic piston rigidly interconnected in alignment with one of said free floating pistons, a second hydraulic piston rigidly interconnected in alignment with the other of said free floating pistons, a first hydraulic cylinder receiving said first hydraulic piston, a second hydraulic cylinder receiving said second hydraulic piston, fluid in said hydraulic cylinders, conduit means connecting said hydraulic cylinders whereby when said hydraulic pistons are moved by said opposed free floating pistons fluid is forced from one end of said first hydraulic cylinder to the non-opposite end of said second

hydraulic cylinder and at the same time from the opposite end of said second hydraulic cylinder to the other end of said first hydraulic cylinder thereby ensuring that said free floating pistons have equal strokes and a fixed phase difference of 180° between their strokes.

10. In combination with an internal combustion engine having free floating opposed pistons, a positive displacement hydraulic coupling comprising a first hydraulic piston interconnected in alignment with one of said free floating pistons, a second hydraulic piston rigidly interconnected in alignment with the other of said free floating pistons, a first hydraulic cylinder receiving said first hydraulic piston, a second hydraulic cylinder receiving said second hydraulic piston, fluid in said hydraulic cylinders, conduit means cross connecting said hydraulic cylinders whereby when said hydraulic cylinders are moved by said opposed pistons fluid is forced from one end of said first hydraulic cylinder to the non-opposite end of said second hydraulic cylinder and at the same time from the opposite end of said second hydraulic cylinder to the other end of said first hydraulic cylinder, thereby ensuring that said opposed pistons have equal strokes and a fixed phase difference of 180° between their strokes.

11. A combined internal combustion engine and reciprocating pump construction which comprises a combustion cylinder, a fuel injection means centrally located in the wall of said combustion cylinder, an exhaust port located in the wall of said combustion cylinder longitudinally removed from said fuel injection means, an exhaust line interconnecting said exhaust port and the atmosphere, an air inlet port disposed in the wall of said combustion cylinder opposite to said exhaust port, first and second opposed combustion pistons received in said combustion cylinder, an air reservoir substantially surrounding said combustion chamber and in communication with said air inlet port, a first piston rod connected to said first combustion piston, a second piston rod connected to said second combustion piston, a first air compressor piston connected to the opposite end of said first piston rod, a second air compressor piston connected to the opposite end of said second piston rod, a first air cushion chamber receiving said first air compression piston, a second air cushion chamber receiving said second air compression piston, both of said air cushion chambers confined at one end to entrap gas which is compressed by said air compression pistons when they are moved by said combustion pistons in response to an explosion in said combustion cylinder, the other ends of each of said air cushion chambers including an air inlet valve in communication with the atmosphere and an air outlet valve in communication with said air reservoir, a first hydraulic piston interconnected with said first combustion piston, a second hydraulic piston interconnected with said second combustion piston, a first hydraulic cylinder receiving said first hydraulic piston, a second hydraulic cylinder receiving said second hydraulic piston, fluid in said hydraulic cylinders, conduit means connecting said hydraulic cylinders whereby when said hydraulic pistons are moved by said combustion pistons fluid is forced from one end of said first hydraulic cylinder to the non-opposite end of said second hydraulic cylinder and at the same time from the opposite end of said second hydraulic cylinder to the other end of said first hydraulic cylinder thereby ensuring that the combustion pistons have equal strokes and a fixed phase difference of 180° between their strokes, a first fluid pump operatively connected with said first combustion piston, a second fluid pump operatively connected with said second combustion piston, each of said fluid pumps including a pump cylinder with a spring-loaded plunger to permit enlargement of the internal volume of the pump cylinder in response to an internal fluid pressure increase and with adjustment means to vary selectively the spring compression of said plunger, each pump also including a reciprocating piston in said pump cylinder and an inlet fluid valve and an outlet fluid valve in communication with said pump cylinder.

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