Nov. 27, 1962 F. B. HARMAN 3,065,703

FREE PISTON ENGINE PUMP

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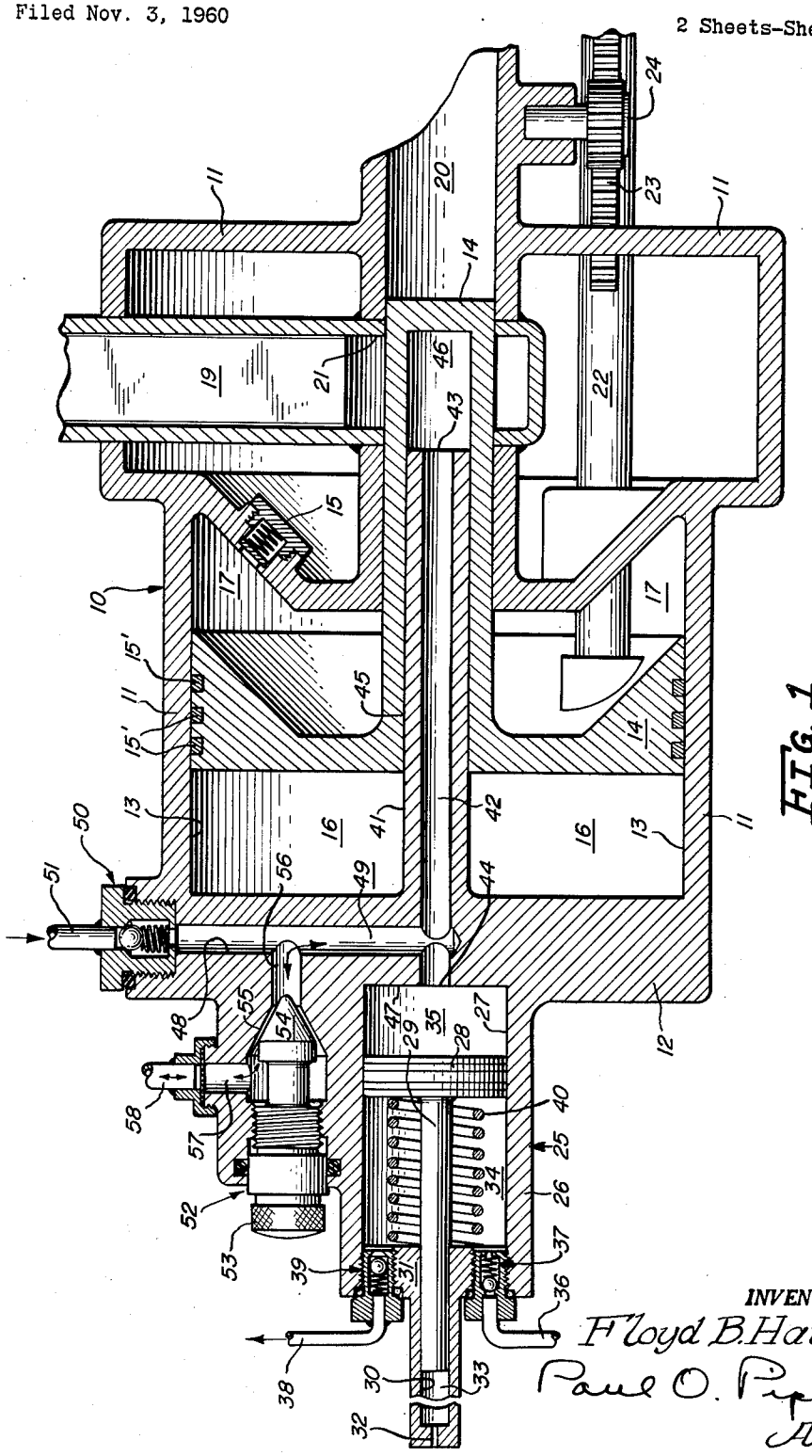


FIG. 1

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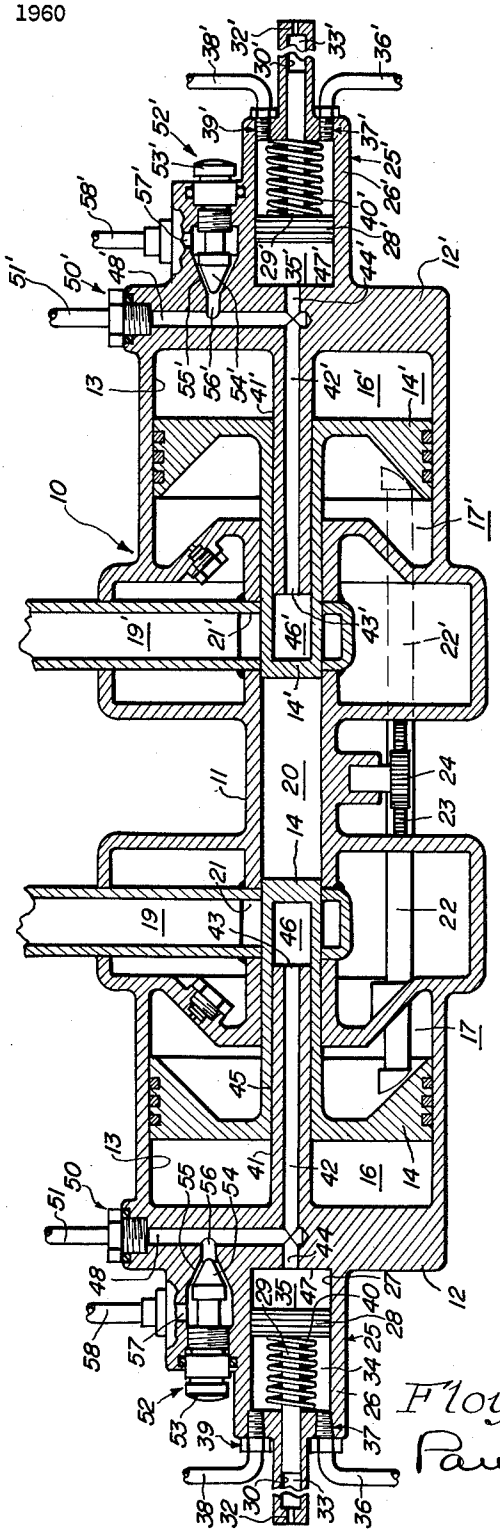


FIG. 2

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FREE PISTON ENGINE PUMP

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This invention relates to a free piston engine hydraulic pump. More in particular this invention relates to a free piston engine hydraulic pump wherein the motion of a pump piston is imparted by the motion of a power piston of the engine during its power stroke by a fluid connection therebetween.

In previous designs of free piston engine pumps a connecting rod is employed having one end connected to a power piston and extending slidably through the corresponding engine head and the other end connected to the hydraulic pump piston thus moving the pump piston in a stroke equal to that of its associated power piston. This arrangement has numerous disadvantages such as loss of power when the outlet side of the pump has reached its maximum limit set by, for example, a relief valve, or if hydraulic block occurs the engine stalls or alternatively damage occurs. Variation in fluid delivery of such engines can only be achieved in a limited degree by varying the speed of the engine. Another difficulty in these engines is the difficulty in starting because reciprocating movement of the power piston also actuates the associated pump piston.

The present invention overcomes the above referred to disadvantages by employing controllable resilient means for moving the pump piston responsive to movement of its associated power piston. It is therefore a prime object of this invention to provide an elastic fluid coupling between a power piston of a free piston engine and the piston of a hydraulic pump.

It is a further object of this invention to provide means for controlling elastic fluid pressure in the fluid coupling means of the preceding object whereby the stroke of the pump piston may be controlled between maximum and substantially zero without necessarily altering the speed of the engine.

Another object of the invention is to provide means for limiting the output pressure of hydraulic fluid delivery from the pump automatically.

A still further object of the invention is to provide the fluid coupling means according to the previous objects with an elastic fluid having a critical temperature below the operating temperature of the engine which limits the maximum pressure of the elastic fluid in the coupling which in turn limits the force applied to the power piston during periods when the engine temperature is below the critical temperature of the elastic fluid.

These and other desirable and important objects inherent in and encompassed by the invention will be more readily understood from the ensuing description, the appended claims and the annexed drawing wherein:

FIGURE 1 is a longitudinal section, partly broken away, showing a portion of a free piston engine block, and a power piston thereof, with a hydraulic pump of the piston type mounted outboardly and the elastic fluid coupling between the power piston and pump piston wherin the resiliency is controllable externally.

FIGURE 2 is a longitudinal section in reduced scale from that of FIGURE 1, partly broken away, showing a free piston engine with a hydraulic pump of the piston type mounted outboardly on each opposed end of the engine including the elastic fluid coupling of this invention between each power piston and its associated pump piston wherein the resiliency of each coupling is controllable externally.

In FIGURE 1 of the drawings the numeral 10 designates a free piston engine of conventional design except as hereinafter stated. At this point it should be apparent from FIGURE 2 that the engine 10 comprises a second power piston 14' in opposed relation with the power piston 14 and the rightward portion of the engine is symmetrical with the leftward portion. Thus the free piston engine 10 is conventional in that it is provided with two power pistons in axially opposed relation as illustrated in FIGURE 2. Since the rightward half of the unit shown in FIGURE 2 is constructed similar to the leftward half as shown enlarged in FIGURE 1, only the left side will be described and it is to be understood that the right half is a duplicate thereof and numerals designating corresponding parts being primed as shown.

The engine 10 is provided with the usual block member 11 having an end wall or head 12. The block 11 is provided with a longitudinal cylinder bore 13. Within the bore 13 is a power piston 14 in slidable relation. The power piston may be provided with the usual sealing rings 15' for preventing passage of air between the piston 14 and block 11. Outboardly of the piston 14 is an elastic reaction chamber 16 sometimes referred to as a "bounce chamber." Immediately inboardly of the piston 14 is a compartment 17 for compressing air for use in scavenging and providing compressed air for combustion in a conventional manner. As the piston 14 moves inboardly air is compressed and discharged through a relief valve 15 communicatively connected (not shown) to the engine's air inlet 19 for admitting compressed air into the engine's combustion chamber 20. When combustion occurs in the combustion chamber 20 the extreme pressure created drives the piston outboardly thereby compressing the air in the bounce chamber 16. As the piston 14 uncovers the port 21 another port, the exhaust port (not shown) is also uncovered and compressed air from inlet 19 scavenges the exhaust gases in the combustion chamber 20 and replaces it simultaneously with fresh air for the next combustive cycle. During this interval a fresh charge of fuel is injected into the chamber 20 by a fuel injector (not shown) to provide a combustive mixture for the next cycle. Movement of the piston 14 outwardly under the influence of combustive pressure compresses the air in the bounce chamber 16 while at the same time a fresh supply of air is admitted to the compartment 17 through a check valve (not shown). When the force of the combustion is spent the piston 14 is urged inboardly by the compressed air in the bounce chamber 16 and the cycle is completed. From this it is apparent that the outboard movement of piston 14 is the power stroke thereof because it is moved under the direct influence of the power created by the combustion of fuel in the combustion chamber 20. The combustion of the fuel-air mixture in the chamber 20 serves to energize in outboard direction both power pistons 14 and 14' of the engine 10 simultaneously.

In order to maintain both power pistons 14 and 14' synchronized in opposed relation a conventional synchronizing mechanism is employed. Conveniently the synchronizing mechanism may comprise a rack member 22 having teeth 23 connected to the inboard side of each power piston 14 as shown in the drawing. Each of the two rack memers 22 is engaged in diametrically opposed relation with a pinion gear 24. Thus when the pistons 14 and 14' move outboardly the pinion gear 24 rotates in one direction and when they move inboardly the pinion 24 rotates in the other direction thereby maintaining both power pistons 14 and 14' in synchronized relation.

The description of the drawing up to this point is in general intended to be in accordance with that of a free piston engine of conventional construction. The par-

ticular construction of the illustrated embodiment will now be described.

Referring again to FIGURE 1 of the drawing, on the head or end wall 12 of the engine 10 is preferably mounted an hydraulic pump 25 of the fluid pressure actuated type. It will be apparent later herein that the pump 25 is not necessarily mounted integrally or rigidly on the engine 10 but may be disposed elsewhere. The pump 25 may comprise a cylinder casing 26 having a cylinder bore 27. Within the bore 27 is disposed an hydraulic pump piston 28 in slidable relation. The pump piston 28 is provided with a connecting rod 29 adapted to slide within a small bore 30 in the end member 31. Thus the rod 29 serves as a guide for the pump piston 28. A vent 32 is provided at the outer end of the end member 31 for venting the small chamber 33 to avoid compression of air therein. At this point it should be mentioned that it is preferable to construct the pump piston 28 and its associated rod 29 from low density material such as, for example, aluminum or alloys thereof. This reduces the force required to move the piston 28 in either direction arising from its inertia as compared to a high density material such as iron.

The pump piston within the bore 27 forms an hydraulic pumping chamber 34 and a fluid actuating chamber 35. The hydraulic pumping chamber 34 is communicatively connected with a source of hydraulic fluid (not shown) through inlet conduit 36 and ball type inlet check valve 37. In addition the hydraulic pumping chamber 34 is communicatively connected to a receiver (not shown), such as an accumulator or hydraulic motor and the like, through outlet conduit 38 and outlet check valve 39. Thus it is apparent that movement of the pump piston 28 rightwardly as shown in the drawing permits hydraulic fluid intake into the chamber 34 and conversely movement in the leftward direction discharges hydraulic from the chamber 34 into the outlet conduit 38. However, a captive compression spring 40 is disposed in the hydraulic pumping chamber 34 positioned to urge the piston 28 in a rightward or inboard direction as shown. It will be apparent that the spring 28 should possess selected characteristics according to the operating characteristics of the engine 10 to achieve maximum displacement of the piston 28 during pumping cycle.

The head 12 of the engine 10 is provided with an inboardly extending axially disposed sleeve element 41 as shown in the drawing. The sleeve element 41 and head 12 is provided with a bore 42 in co-extensive relation. One end 43 of the bore 42 is open and the other end 44 is in communication with the fluid actuating chamber 34 as shown. The power piston 14 is provided with an axial bore 45 in alignment with the sleeve element 41 in slidable relation therewith. The power piston 14 or sleeve element 41 may be provided with conventional sealing rings (not shown) to function in a similar manner as the rings 15' if desired.

It will be seen that the bore 45 of the power piston 14 opens on the outboard side thereof to accommodate the sleeve element 41. The bore 45 extends inboardly slightly greater in length than the maximum stroke of the power piston 14 and the sleeve element 41 extends inboardly a sufficient distance so that the sleeve element 41 is still in slidable relation with the bore 45 when the power piston 14 is in the inboard position. It will be noted that the bore 45 is not open on the inboard end thereof. From this it can be seen that the sleeve element 41 and bore 45 of the power piston 14 form a variable volume, depending on the position of the power piston 14, gas compression chamber 46 and the bore or passage 42 forms a fluid passage between the gas compression chamber 46 and the fluid actuating chamber 35 of the hydraulic pump 25.

At this point it is apparent that when ignition of a fuel-air charge in the combustion chamber 20 occurs the power piston 14 moves outboardly (power stroke) and the volume of the gas compression chamber 46 diminishes resulting in the displacement of gas therein to the elastic fluid actuating chamber 35 of the pump 25. This displacement of gas now increases the fluid pressure in chamber 35 which in turn acts upon the pump piston 28 in a direction to discharge hydraulic fluid under pressure from the hydraulic pumping chamber 34 through the outlet conduit 38. Conversely when the power piston 14 moves inboardly the elastic fluid in the chamber 35 returns to the gas compression chamber 46 because the volume of the chamber 46 is then progressively increasing. Further, the spring 40 urging the pump piston 28 inwardly as shown assists the movement of elastic fluid from chamber 35 to chamber 46 and at the same time drawing hydraulic fluid into the hydraulic pumping chamber 34. Thus the pump 25 discharges hydraulic fluid during the power stroke (outboard movement) of the power piston 14. It may also be apparent to those skilled in the art that instead of employing the hydraulic pumping chamber 34 for pumping hydraulic fluid, the rod 29 may alternatively be connected to a separate piston pump and the entire structure 25 then becomes the power actuating means for such pump. This affords means for pumping hydraulic fluid at higher pressure with low displacement or vice versa as may be selected. Further the relative size of the chamber 46 with respect to the chamber 35 should be chosen so that the proper displacement of gas is obtained during operation for operating the pump 25 in accordance with requirements.

From the above it will now become apparent that as the differential hydraulic pressure rises between the inlet pressure in conduit 36 and outlet pressure 38, the stroke of the pump piston 28 decreases and reaches a limiting maximum value as the stroke of pump piston 28 approaches zero. As the hydraulic pressure differential increases the resistance to leftward movement of the pump piston 28 correspondingly increases and thus the gas in chambers 35 and 46 and passage 42 is subjected to greater compression due to reduction in mean volume. Therefore in order to obtain maximum output of the pump 25 the gas pressure in the passage 42 should be slightly above atmospheric pressure when the power piston 14 is at its inboard position. The reason for the gas pressure at slightly above atmospheric pressure is to prevent the pump piston 28 at the urging of the spring 40, from reaching an abutting position against the wall 47 during operation.

Now in order to control the length of stroke of the pump piston 28 and thereby control the output of the pump 25 to any selected value below its maximum output as above described, a means for controlling the mean gas pressure in the passage 42 and associated chambers 35 and 46 is provided.

A radial bore 48 is provided in the head 12 forming a passage 49 which communicates with the passage 42 as shown in FIGURE 1 of the drawings. Mounted on the head 12 in communication with the passage 49 is a conventional gas inlet check valve 50 which may, for convenience, be constructed similar to the hydraulic inlet check valve 37 of the pump 25. The inlet side of the check valve 50 is communicatively connected to gas conduit 51 as shown. The conduit 51 in turn is communicatively connected to a source of gas (not shown) preferably whose pressure is controllable. The pressure of the source of gas may conveniently be controlled by conventionally known means such as a pressure regulator. If desired however, the conduit 51 may communicate directly to the atmosphere but for reasons already stated it is preferable that the minimum gas pressure in conduit 51 should be at least slightly above atmospheric and controllable for higher pressures. It will be noted that bore 48 is approximately the same diameter as the passage 42 for reasons to be described later.

Also mounted on the head 12 is a conventional adjustable needle valve 52 having a manually operable rotative

knob 53 for adjusting the position of the valve element 54 with respect to its valve seat 55. The needle valve 52 should be adjustable from closed position to unrestricted open flow position. One port 56 leading from the needle valve 52 communicates with passage 49 and the other port 57 is connected to conduit 58 leading to a gas reservoir (not shown) at approximately atmospheric pressure.

When the needle valve 52 is in closed position gas enters passage 42 and chambers 35 and 46 until the selected minimum pressure is reached which will be attained when the power piston 14 is completely at inboard position. Thereafter the check valve 50 closes unless gas leakage occurs between the sliding components. Should leakage occur the check valve 50 will open to replenish the loss. Now if the engine 10 is operated the pump piston 28 will reciprocate substantially with that of the power piston 14. As the hydraulic pressure differential increases the length of the stroke of the pump piston 28 diminishes until the maximum hydrualic pressure differential is reached at which time movement of pump piston 28 will cease. However, the power piston 14 continues to reciprocate and thus the engine 10 will not stall.

Now if it is desired to lower arbitrarily the hydraulic pressure differential between conduits 36 and 38 the gas pressure in conduit 51 is increased. This has the effect of moving the mid-stroke position of the pump piston 28 leftwardly as viewed in the drawing. Moving of the mid-stroke position of the pump piston 28 leftwardly has the effect of increasing the force of the spring 40 which increases the resistance of the pumping stroke of the piston 28. The increased resistance of the pumping stroke of piston 28 is compensated by a corresponding reduction in the hydraulic pressure differential between the conduits 36 and 38.

Assuming for the moment that the pump 25 is operating and it is desired to reduce the output of the pump 25, the needle valve 52 is opened progressively until the desired reduced output is obtained. Opening of the needle valve 52 has the effect of reducing the maximum gas pressure in the chambers 35 and 46 resulting in a lower displacement of the pump piston 28 thereby reducing the output of the pump 25.

If the needle valve 52 is opened wide, free and substantially unrestricted flow of gas therethrough in both directions results. Thus no work is done to displace pump piston 28 and the output of pump 25 is zero because in effect both chambers 35 and 46 are in vented relation with the conduit 58. If the needle valve 52 is adjusted to permit restrictive flow therethrough the pump piston will be actuated and the restriction in valve 52 increases, the length of stroke of piston 28 correspondingly increases. This feature is of particular importance for it not only provides a control means for the output of the hydraulic pump 25 but it also provides a means for de-actuating the pump 25 during the starting operation of the engine 10. Thus the engine 10 can be started under a no-load condition.

From the above it is seen that a means is provided for pumping hydraulic fluid by employing a portion of the energy obtainable from the engine 10 and the balance of the engine's recoverable energy is available for conventional use such as operating a turbine.

Another useful feature of this invention is the employment of non-corrosive gases having certain physical characteristics in the chambers 35 and 46. Ordinary atmospheric air may be satisfactorily employed. However if the gas entering through conduit 51 is selected such that its critical temperature is below the operating temperature of the engine so that it can be liquified under pressure another advantage is achieved. In connection with the use of these gases it should be borne in mind that the term "operating temperature" of the engine 10 does not refer to the temperature of the liquid used to cool the engine but refers to the mean temperature of the gas in passage 42 and chambers 35 and 46 which is considerably higher than the temperature of the coolant liquid.

Suppose, for example, that symmetrical dichlorotetrafluorethane gas, known commercially as Freon-114, is introduced into the chambers 35 and 46 through the conduit 51. Now this gas has a boiling point at atmospheric pressure of about 38.4° F., and a critical temperature of about 294.3° F. at which critical temperature the critical pressure is about 474 pounds per square inch absolute. Now when the engine 10 is started the mean temperature of the gas is low and will liquify at a low pressure. The liquifying pressure at a given temperature (below critical temperature) represents the maximum pressure attainable in the chamber 35 at that temperature. As the operating temperature of the engine 10 increases from the starting temperature, the mean temperature of the gas also increases since its liquifying pressure increases with temperature rise until critical temperature is reached. In effect, this limits the maximum effective pressure on the pump piston 28, thereby limiting the load upon the engine 10 by the pump 25. When the operating temperature of the engine 10 reaches its normal operating range the mean temperature of the gas will then exceed its critical temperature and thereafter the gas will function in accordance with the well-known gas laws and cannot be liquified irrespective of pressure. It may now be apparent that an important factor is the proper choice of relative sizes or displacement of chambers 35 and 46.

From the above, it can be seen that depending upon the operating temperature characteristics of the engine 10, a non-corrosive gas having appropriate physical characteristics, can be selected to achieve the above described advantage. For examples, trichlorofluromethane (Freon 11), dichlorodifluromethane (Freon 12), trifluorochloromethane (Freon 13), chlorodifluoromethane (Freon 22), propyl chloride, methyl chloride, methyl fluoride, propane, pentane, butane and ethyl chloride may be advantageously employed.

Having thus described preferred embodiments of the invention, it can now be seen that the objects of the invention have been fully achieved and it must be understood that changes and modifications may be made which do not depart from the spirit of the invention nor from the scope thereof as defined in the appended claims.

What is claimed is:

1. A free piston engine hydraulic pump comprising a free piston engine of the opposed power piston type having an inboard combustion chamber and an externally mounted hydraulic piston pump having fluid pressure actuatable means connected in operative relation for actuation by each of said power pistons, each of said power pistons having an axial bore opening on the outboard end thereof, a stationary sleeve element positioned for cooperative slidable engagement with each of said bores, a fluid passage disposed in each of said sleeve elements communicatively connecting said sleeve elements with said fluid actuatable means of said pump whereby said pump is actuated for pumping hydraulic fluid responsive to elevation of fluid pressure in said sleeve elements during the power stroke of said power pistons.

2. A free piston engine hydraulic pump according to claim 1 wherein the actuating fluid in said sleeve elements is a non-corrosive gas having a critical temperature below the normal operating temperature of said power pistons.

3. A free piston engine hydraulic pump according to claim 1 wherein the actuating fluid in said sleeve elements is selected from the group of fluids consisting of halogenated hydrocarbons of less than six carbon atoms.

4. A free piston engine hydraulic pump comprising,

in combination, a block member having a pair of power pistons axially disposed in synchronized opposed slidable relation, and a fuel combustion chamber positioned between said pistons, each of said power pistons having an axial bore extending from the outer surface thereof inboardly a distance at least equal to the maximum stroke thereof, said axial bores of said power pistons being closed at the inboard ends thereof, an axially disposed sleeve element mounted on the inner side of each end wall of said block member and extending inboardly into each of said axial bores of said power pistons in cooperative slidable relation, each of said sleeve elements being of a length greater than the maximum stroke of said power pistons and less than the length of said axial bores in said pistons thereby defining an air compression chamber in the inboard portions of said axial bores, a piston type hydraulic pump mounted externally on each of the outer ends of said block member, each of said hydraulic pumps having a hydraulic pump chamber adjacent the outer surface of the pump piston thereof and an air actuating chamber adjacent the inner surface of the said pump piston, resilient means positioned to urge the pistons of said hydraulic fluid pumps inboardly, and air passage means in said sleeve elements communicatively connecting said air compression chambers respectively with said air actuating chambers of said fluid pumps whereby outboard movement of said power pistons compresses air in said air compression chambers for actuating said fluid pumps to exhaust hydraulic fluid under pressure from said pump chambers and said resilient means actuating said fluid pump pistons in a direction for hydraulic fluid intake to said pump chambers upon movement of said power pistons inboardly.

5. A source of variable delivery hydraulic pressure having, in combination, a free piston engine of the inboard combustion chamber type and a pair of pneumatically powered external hydraulic pumps each being actuated on the power stroke of the opposed power pistons of said engine, one of said pumps being actuated by intermittent impulse of compressed air from one of said power pistons and the other of said pumps being actuated by intermittent impulse of compressed air from the other power piston, each of said power pistons having an air compression chamber therein adapted to compress air during the power stroke of said power pistons, a first air passage means disposed in said engine communicatively connecting the air compression chamber of one power piston to the actuating means of one of said pumps and a second air passage means disposed in said engine communicatively connecting the air compression chamber of the other power piston to the actuating means of the other of said pumps whereby air is compressed in said air compression chambers during the power stroke of said pistons for actuating said pumps to discharge hydraulic fluid under pressure and de-actuating said pumps for hydraulic fluid intake during the return stroke of said power pistons.

6. A source of variable delivery hydraulic pressure having in combination, a free piston engine of the opposed power piston inboard combustion chamber type and a pair of externally mounted hydraulic piston pumps actuated by intermittent air pressure differential, each of said power pistons having a variable displacement air compression chamber therewithin positioned to compress air during the power stroke of said power pistons and de-compress said air during return stroke of said power pistons, a first air passage means disposed in said engine communicatively connecting the air compression chamber of one power piston with the actuating means of one of said pumps and a second air passage means disposed in said engine communicatively connecting the air compression chamber of the other power piston with the actuating means of the other of said pumps whereby during the power stroke of said power pistons air in said air compression chambers is compressed and transmitted through said passage means to actuate said pumps for discharging hydraulic fluid under pressure and during the return stroke of said power pistons said air in said air compression chambers is de-compressed thereby reversing air flow in said passage means for de-actuating said pumps and intake of hydraulic fluid thereto.

7. A free pistton engine variable delivery hydraulic pump comprising a free piston engine of the opposed power piston type having an inboard combustion chamber, and an externally mounted hydraulic piston pump having fluid pressure actuatable means connected in operative relation for actuation by each of said power pistons during the power stroke thereof, each of said power pistons having an axial bore opening on the outboard end thereof, a stationary sleeve element positioned for cooperative slidable engagement with each of said bores, a first fluid passage disposed in said sleeve elements communicatively connecting each of said sleeve elements independently with said fluid pressure actuatable means of each of said pumps, a second fluid passage disposed in said engine communicatively connected to each of said first fluid passages and a fluid intake means, and an adjustable valve interposed in each of said second fluid passages whereby the stroke of said associated pumps is reduced controllably by adjustably bleeding a portion of the fluid in said sleeve elements through said adjustable valves.

8. A free piston engine variable delivery hydraulic pump comprising a free piston engine of the opposed power piston type having an inboard combustion chamber, and an externally mounted hydraulic piston pump having fluid pressure actuatable means connected in operative relation for actuation by each of said power pistons during the power stroke thereof, each of said power pistons having an axial bore opening on the outboard end thereof, a stationary sleeve element positioned for cooperative slidable engagement with each of said bores, a first fluid passage disposed in said sleeve elements communicatively connecting each of said sleeve elements independently with said fluid actuatable means of each of said pumps, a second fluid passage disposed in said engine communicatively connected to each of said first fluid passages, a check valve having its inlet communicatively connected to a source of fluid and its outlet communicatively connected to each of said second passages for controlling the minimum fluid pressure in said sleeve elements whereby the stroke of said pumps is increased progressively to maximum limit responsive to increased pressure of fluid in said fluid source.

9. A free piston engine variable delivery hydraulic pump comprising a free piston engine of the opposed power piston type having an inboard combustion chamber, and an externally mounted hydraulic piston pump having fluid pressure actuatable means connected in operative relation for actuation by each of said power pistons during the power stroke thereof, each of said power pistons having an axial bore opening on the outboard end thereof, a stationary sleeve element positioned for cooperative slidable engagement with each of said bores, a first fluid passage disposed in said sleeve elements communicatively connecting each of said sleeve elements independently with said fluid actuatable means of each of said pumps, a second fluid passage disposed in said engine communicatively connected to each of said first fluid passages and a fluid intake means, an adjustable valve interposed in each of said second fluid passages for controllably reducing the stroke of said pumps by adjustably bleeding a portion of the fluid in said sleeve elements through said adjustable valves, a check valve having its inlet communicatively connected to a source of fluid and its outlet communicatively connected to each of said second passages for controlling the minimum fluid pressure in said said sleeve elements for progressively increasing the stroke of said pumps responsive to increased pressure of fluid in said fluid source.

10. A free piston engine hydraulic pump according to claim 9 wherein the actuating fluid in said sleeve elements

is a non-corrosive gas having a critical temperature below the operating temperature of said power pistons.

11. A free piston engine hydraulic pump according to claim 9 wherein the actuating fluid in said sleeve elements is selected from the group consisting of halogenated hydrocarbons of less than three carbon atoms.

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