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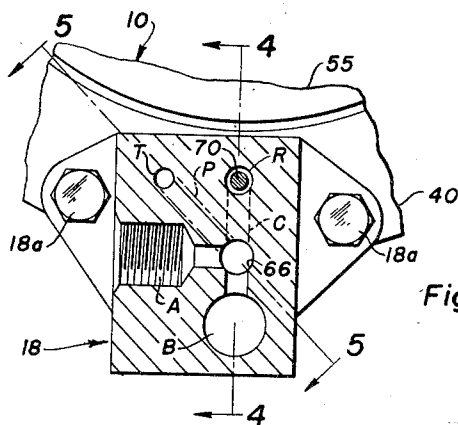
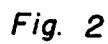
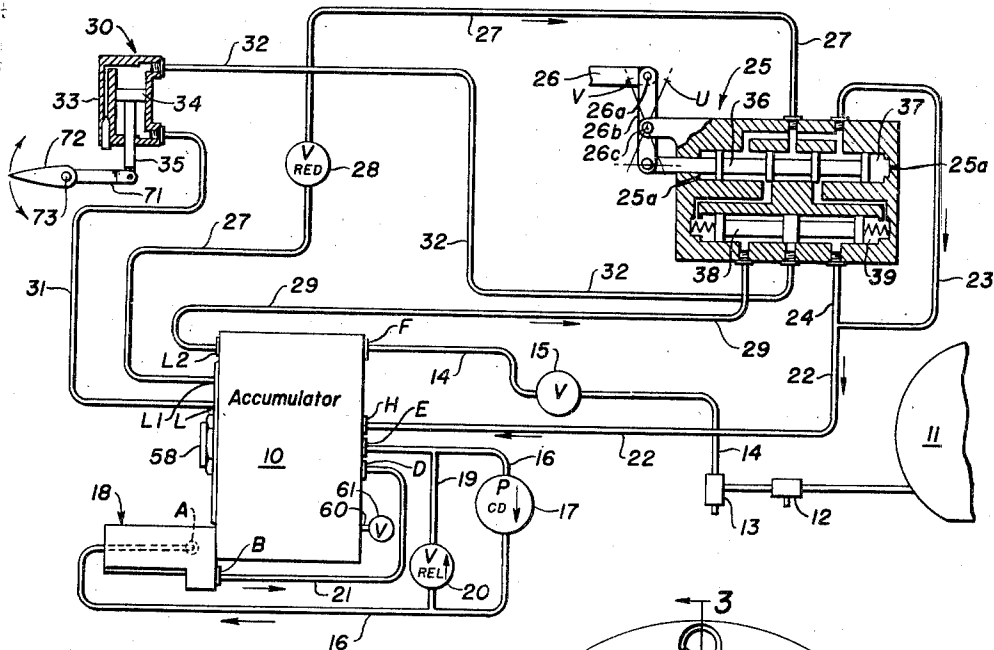
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ACCUMULATOR FOR HYDRAULIC SYSTEMS

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2 Sheets-Sheet 1



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ACCUMULATOR FOR HYDRAULIC SYSTEMS

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The present invention relates generally to hydraulic actuating systems and more particularly to improved components of closed type hydraulic actuating systems.

The present invention is directed to improved hydraulic systems and components thereof wherein a novel constant pressure type accumulator provided with multiple chambers and pistons is pressurized by a compressed air source which serves to develop a high pressure actuating fluid medium and a relatively low pressure circulating fluid medium with automatic means for providing make-up fluid for the high pressure medium. The improved hydraulic system is of the closed type and includes in addition to the novel constant pressure pump type accumulator, a suitably powered circulating pump, a by-pass valve in the pump circuit, a servo control valve and the actuating cylinders or motors, in addition to the customary accessories of such systems comprising pressure regulators, relief valves, filters, etc. The present hydraulic system is particularly adapted for the actuation of the control surfaces of aircraft and other vehicles and the characteristics and advantages of the improved system and its components are especially adapted for the actuation of the control surfaces or other movable portions of guided missiles and the like.

It is, accordingly, a major object of the present invention to provide an improved hydraulic system of the closed type. It is a corollary objective to provide improved components of such closed hydraulic actuating systems, as well as a novel and advantageous relationship of those components. It is a further object of this invention to provide an improved hydraulic system and its components for the actuation of the control surfaces of aircraft and guided missiles. A further object of the invention resides in the provision of a hydraulic system which is pneumatically charged from a propellant source and which develops a much higher hydraulic actuating pressure, the volume and replenishment of which is automatically maintained by a power-driven circulating pump in a low pressure hydraulic circulating portion of the system.

It is a further object of the present invention to provide an improved air driven automatic pump type accumulator which through the use of differential area pistons converts low pressure air into higher pressure hydraulic fluid or oil. A further object is to provide a high output hydraulic system which may be installed in a minimum of space, which is free from oil flow pulsations and is self-replenishing. It is a further object to provide a hydraulic system in which the rate of delivering energy is not limited by the size of the unit, a system which has the advantage of not causing electrical interference with other components of the vehicle, one which may be used in explosive atmospheres and does not require cooling. It is a still further object to provide an improved hydraulic system of the type described and more particularly an improved multiple piston type accumulator and a novel inter-relationship of the same with the other components of the hydraulic system.

Other objects and advantages of the present invention

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will occur to those skilled in the art, after reading the following description taken in conjunction with the accompanying drawings, forming a part hereof, in which:

Fig. 1 is a diagrammatic view of a form of the improved hydraulic system;

Fig. 2 is an end elevational view to a larger scale of the improved accumulator forming an essential component of the system of Fig. 1;

Fig. 3 shows a cross-sectional view of the improved accumulator as taken along the lines 3—3 of Fig. 2;

Fig. 4 is an enlarged cross-sectional view of the by-pass valve associated with the accumulator, as taken along the lines 4—4 of Fig. 2;

Fig. 5 is a further cross-sectional view of the by-pass valve of Fig. 4 as taken along the lines 5—5 of Fig. 2; and

Fig. 6 is a cross-sectional view of the by-pass valve of Figs. 4 and 5 as taken transversely along the lines 6—6 of Fig. 4.

Referring now to Figs. 1 to 3, inclusive, the improved accumulator is indicated generally by the numeral 10 and comprises a normally balanced piston type device having a fixed casing 40 provided with a large cylindrical bore 43 in which is reciprocably mounted the primary or main differential area piston 55. The accumulator also has a secondary or smaller bore 45 within which is reciprocably mounted the double inner differential area piston 50 which may be referred to as the secondary or control piston. The accumulator 10 is activated or charged by compressed air from the air tank or receiver 11, which air enters the accumulator at the air inlet F and is interposed between the primary and secondary pistons 55 and 50, respectively, to develop a high pressure working hydraulic fluid on the outside working face 56 of the primary piston 55 exerted through the ports L, L1 and L2 due to the differential areas of the exposed portions of the piston 55. The actuating air also exerts an opposite inward force upon the secondary piston 50 which develops a low pressure in the circulating control hydraulic fluid within the sump chamber S having the sump ports D, E, and H. In its normally balanced state, and in a preferred form of the accumulator due to the differential areas of piston 55 at which an air pressure of approximately 480 p. s. i. is admitted through the port F into the chamber G, a hydraulic fluid working pressure of 1500 p. s. i. is developed within the chamber K and is available through the ports L, L1 and L2. Under the same balanced conditions, and also due to differential areas, the compressed air at 480 p. s. i. exerted on the smaller exposed area of the secondary piston 50 develops on the larger area piston portion 52 a pressure of 20 p. s. i. in the circulating control hydraulic fluid. As will be more particularly described hereinafter, the primary purpose of the low pressure fluid within the sump S of the accumulator is to provide for fluid return from the servo control valve 25 and also to cooperate, through a circulating portion of the system between the ports D and E in cooperation with the by-pass valve 18, to provide make-up fluid in the high pressure working portion of the system to compensate for leakage or other loss of working fluid.

As will be noted by reference to Fig. 1, the compressed air is stored within, and is supplied from, the air tank or receiver 11, passing through the air filter 12, the hand arming valve 13 and through the air line 14 to the pressure regulating valve 15 which reduces and controls the pressure of the air passing therethrough to an air pressure of 480 p. s. i. From the pressure regulating valve 15 the compressed air is carried by the air line 14 through the air inlet port F and to the annular passages G between the inside of the primary piston 55 and the fixed outer limits of the outer chamber K or the bore 43, through which passages the air pressure enters the main

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chamber G and is exerted upon the large inner area of the primary piston 55 and the small inner area of the secondary piston 50. One of these annular passages communicates through the connection 60 with an air relief valve 61 which is normally set to open to the atmosphere or other open space at a pressure of about 550 p. s. i. A large internal chamber M is formed between the fixed end plate or plug 46 of the bore of inner cylinder 45 and this chamber M is open through the port 54 to the atmosphere or to a suitable vent connection. The low hydraulic pressure within the sum S (on the right side of piston 50—52 as viewed in Fig. 3) is therefore opposed only by atmospheric pressure on the inner or left face of the large end of the secondary piston 52 exposed to the atmospheric chamber M and by the actuating or charging air pressure within the chamber G exerted upon the inner and smaller end areas 51 and 51a of the secondary piston portion 50. It will be understood that the compressed air receiver 11 may be of any suitable shape to withstand the compressed air pressure (in excess of 480 p. s. i.) and that it is particularly suited in the case of guided missiles, rockets and the like, to be disposed in otherwise unoccupied space or to be formed by the shell of the missile, or a portion thereof.

Referring now more particularly to the details of the improved accumulator 10 as shown in Fig. 3, and the supplementary figures, the fixed portion of the accumulator casing comprises an outer annular casing member 40 internally bored as at 43 to form chamber K for the piston portion 56 of the primary piston 55. The fixed casing head or plate 41 engages the annular casing member 40 in a rotationally locking bayonet type joint 42 provided with a locking bolt 41a which maintains the casing portions 40 and 41 in their locked position. As indicated above, the outer casing 40 is apertured for the high pressure ports L, L1 and L2, and is provided with an inwardly facing seal 44 adjacent its open end to provide a liquid-tight seal between the end of the casing portion 40 and the main outer surface of the cylindrical wall of the primary piston 55. This flanged portion of the casing 40 is also suitably tapped to receive the mounting bolts 18a for attachment of the by-pass valve 18 which will be described further below. The fixed casing head 41 is provided with the ports D, E, and H, all in communication with the sump S, as well as the port F for connection to the charging air pressure line 14, and the passageway 60 for the relief valve 61. The casing head 41 is also provided with a cylindrical wall portion internally bored as at 45 to define the atmospheric chamber M to which communication is provided through the passageway 54. The inner end of the cylindrical bore portion 45 is closed by the apertured end plug 46 having its periphery attached to the cylindrical wall portion 45 and suitably sealed thereagainst at 47, and with its internal bore suitably sealed at 48 to provide fluid-tight contact against the outer cylindrical surface of the secondary piston portion 50. The end plug 46 is locked in position within the cylindrical wall portion 45 by the apertured retaining ring 49 through the central opening of which the compressed air is free to flow to all portions of the chamber G.

The inner or secondary multiple piston 50 is provided with a fixed joint 50a by which the inner end 51a of the piston 50 is secured to the wall of the large piston portion 52. The latter is provided at its periphery with the fluid seal 53 for sliding engagement with the bore 45 and the outer end 51 of the small piston 50 is slidably sealed within the member 46 by the O ring seal 48, as indicated above. The outer or primary piston assembly 55 is provided with the small area shouldered working piston portion 56 reciprocable within the cylinder bore 43 against which it is sealed by the peripheral seal 57. The central portion of the primary piston assembly 55 is provided with the plug fitting 58 threadedly engaging the threaded opening in the portion 55 at the threads 59, the plug

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fitting 58 being provided with an internal bore forming an extension of the chamber G into which the end 51 of the secondary piston portion 50 is permitted to move under certain operating conditions of the accumulator. The casing portion 40 is also suitably bored at its lower portion to permit passage of the piston rod 69 disposed within the chamber K and in contact with the piston portion 56.

Referring again to Fig. 1, there is disclosed a preferred form of a servo system to which the improved accumulator 10 is particularly adapted. In the portion of the system which is disclosed diagrammatically for illustrative purposes, there is provided the servo control valve 25 to which suitable control forces may be applied. In the case of a control system for a guided missile, these forces may be applied by such automatic control components as a gyroscope, radio control or electronic instrumentalities, or in other vehicles by the human pilot, or the automatic substitute therefore. The component to be moved or controlled is suitably connected to the piston rod 35 of the piston 34 of the hydraulic servomotor 30. For illustrative purposes the piston 35 is shown pivotally connected to the control arm 71 of the control surface 72 pivotally mounted at 73. The actuating cylinder or motor 30 may preferably be of the double area type with the small area piston side of the cylinder 33 supplied by high pressure working hydraulic fluid at 1500 p. s. i. through the conduit 31 connected to the port L of the accumulator 10 and the opposite portion of the cylinder exposed to the large area face of the piston 34 (which is uninterrupted by the piston rod 35) connected through the conduit 32 with the servo control valve 25. In this type actuating cylinder, the servo valve selects the large area from pressure to return, thus controlling the movement of the actuating piston 35 of the motor.

The servo control valve 25 is actuated by the push-pull link 26 suitably connected to the pilot instrumentality and pivoted at 26a to the rocking link or lever 26b in turn connected to the valve piston 36 and rockably mounted upon the casing of the valve 25 by the pivot 26c. The valve piston 36, preferably having four land portions, is reciprocally mounted within the cylindrical bore of the chamber 37 the ends of which are vented to the atmosphere by the passages 25a. Operating fluid is supplied to the valve from the high pressure chamber K of the accumulator 10 through the port L1 and the conduit 27 at the working pressure of 1500 p. s. i. which is also transmitted through the conduit 31 to the servomotor 30. By means of the pressure-reducing valve 28, however, this pressure is reduced to 450 p. s. i. at which it is conducted through the continuation of the conduit 27 to the central portion of the chamber 37 of the valve 25. The latter is also provided with a further cylindrical chamber 39 within the bore of which is reciprocally disposed the second valve piston 38. The latter is provided with three land portions which are normally centrally disposed in a balanced condition by means of end centering springs, or similar resilient means, and the central land normally covers the port communicating with the conduit 32 extending to the large area side of the piston 34 of the servomotor 30. The valve piston 38 accordingly divides the chamber 39 into two end portions, one of which is open to the high pressure conduit 29 from the outlet port L2 of the accumulator 10 conducting hydraulic fluid at 1500 p. s. i. into this end chamber, whereas the opposite end chamber is open to the return line 22 to the return port H to the sump S of the accumulator 10 by means of the connection 24 from the valve 25. The piston valve 36, provided with four land portions, forms a central chamber open to the 450 p. s. i. hydraulic line 27 and a pair of end chambers which communicate through the return line 23 with the main return line 22—24 connected to the opposite side of the valve 25 and to the accumulator 10.

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The operation of the servomotor 30 by the servo control valve 25 in conjunction with the improved accumulator 10 is accordingly as follows: Assuming that a pilot force is exerted upon the actuating link 26 to move the pivot 26a to the position indicated by the letter U, the piston valve 36 is drawn to the left by the link 26b and the hydraulic fluid at a pressure of 450 p. s. i., which enters the central chamber from the conduit 27, is permitted to pass downwardly through the channel in the casing of the valve 25 to the left end of the valve piston 38. Movement of the valve piston 38 to the right in Fig. 1 is thereby initiated and accordingly the center land exposes or opens the port to the conduit 32, permitting high pressure fluid from the conduit 29 to pass through the left portion of the chamber 39 and out through the conduit 32 to the large area side of the piston 34 thereby overcoming the smaller force at the same pressure exerted at the opposite side of the piston. This moves the piston rod 35 downwardly or outwardly from the casing 33 of the motor 30, to thereby actuate the control instrumentality, such as a control surface 72 or other component, to the desired extent. At the same time the fluid which is displaced from the right end of the chamber 39 by movement of the valve piston 38 to the right is transmitted upwardly through the passages and outwardly through the return line 23 and thence to the main return line 22 and back to the accumulator 10 through the port H. With the return of the link 26 to its normal or its neutral position as shown in full lines in Fig. 1, the valve pistons 36 and 38 again become centralized in their normal balanced positions. On the other hand, however, should the actuating link be drawn to the left such that the pivot 26a is moved toward the position V, the valve piston 36 is moved toward the right and the fluid pressure from the conduit 27 and the central portion of the chamber 37 passes to the right end of the chamber 39 causing the valve piston 38 to move to the left to cause the conduit 32 from the servomotor 30 to be placed in communication with the return line 24 through the right portion of the chamber 39. This causes a corresponding reduction in pressure on the face of the piston 34 causing it to be withdrawn further within the cylinder 33 and causes the component 72 attached to the piston rod 35 to be moved in the opposite direction to the desired extent. At the same time, the fluid which is displaced by the movement of the valve piston 38 to the left is permitted to be placed in communication with the return line 24. Whereas but a single servomotor 30 has been shown and described, it will be understood that a plurality of such motors may preferably be provided in the control system with suitable servo control valve connections thereto.

Referring now to Figs. 3 to 6, inclusive, there are shown the details and operation of the low pressure circulating system and the novel by-pass valve 18 which cooperate with the improved accumulator 10 to provide make-up fluid to the working side of the system in the event of leakages, or due to other losses. On the low pressure hydraulic fluid side of the accumulator 10, the port E supplies fluid from the sump S through the conduit 16 to the continuously operating motor driven fluid pump 17. This circulating pump delivers hydraulic fluid through the discharge portion of the conduit 16 and into the by-pass valve 18 through the normally open port A. As shown in Figs. 3 and 4, under normal balanced operating conditions of the accumulator 10, the port A is open through the intermediate passageway C to the outlet B of the by-pass valve 18 from which the circulating fluid at a pressure of approximately 20 p. s. i. passes into the conduit 21 and is returned through the inlet port D to the sump S of the accumulator. The pump 17, under certain operating conditions, is capable of developing pressures in excess of 1500 p. s. i. when its discharge is restricted or opposed and as a release of excessively high pressures a relief valve 20 set to crack or open at about 1750 p. s. i. is disposed across the pump 17 to relieve the high pres-

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sure discharge through the relief line 19 back to the sump S or to the suction side of the pump. The actuating connection between the three-chamber accumulator 10 and the by-pass valve 18 is the above-mentioned rod 69 within the high pressure chamber K in contact with the outer cylinder portion 56.

The by-pass valve 18 comprises essentially a casing or block of rectangular cross-section provided with a plurality of longitudinal bores parallel to the axis of the rod 69 and the central axis of the accumulator 10. The valve body 18 is provided with the bore R within which the enlarged sealed piston portion 70 of the rod 69 is adapted to reciprocate as the piston portion 56 of the accumulator moves in the axial direction within the bore 43 of the outer chamber K. The opposite end of the bore R is closed by the threaded plug 68 and parallel to the bore R there is provided a larger and also parallel bore 65, the end portions of which are connected to the bore R by the oblique channels or passages R1 and R2. Within the bore 65, there is disposed a movable piston element 62 having a shank portion slidably fitted within the fixed piston guide fitting 63 which is retained in the valve casing by the retainer disc 64. The opposite end of the piston element 62 is provided with a necked valving portion 62a arranged to slidably fit within the aligned but smaller bore 66 in alignment with the axis of the larger bore 65. The enlarged valving portion 62a of the valve piston 62 is normally disposed, as shown in Fig. 4 between the above-mentioned port A through which the pump 17 discharges and an adjacent port P which also extends transversely of the bore 66 and communicates with a further longitudinal passage T, as shown in Fig. 5. The outer end of the passageway T is in fluid communication by means of the inclined passage T1 with one or more of the radially extending ports Q of the piston guide fitting 63. The contacting end surfaces of the by-pass valve body 18 and the outer casing member 40 are squared and well finished, and are provided around the openings for the rod 69 and the passage T with suitable seals to prevent leakage through the joint of the high pressure working fluid. Under the normal operating conditions of the accumulator 10 in which the several fluid pressures are in balance, the outer piston 55 is substantially telescoped within the fixed casing portion 40, and the rod 69 and its piston portion 70 are maintained in contacting relationship with the piston portion 56 as shown in Figs. 3 and 4 by virtue of the greater pressure exerted upon the exposed end of the piston portion 70 as compared to the smaller end in contact with the piston 56 and the shoulder of the piston 70 which is open to the low pressure of the circulating port C. The end of the latter port is closed by the plug 67a.

When, however, any loss of working fluid or drop in pressure occurs on the high pressure side of the accumulator, the pressure of the compressed air maintained within chamber G automatically recharges the high pressure chamber K and the high pressure side of the accumulator in the following manner. When a reduction in volume occurs (in a preferred form of the accumulator this has been established as a loss of six cubic inches equivalent to a position extension from its normal position of approximately .63 inch) the outer piston 56 moves outwardly of the outer casing 40 away from the end plate 41 to a position at which the piston 70 on the rod 69 reaches the position W, in Fig. 4. In the full line position of the control piston 70, as also shown in Fig. 4, it will be seen that the high pressure fluid which reaches both ends of the chamber 65 through the channels T, T1 and P also reaches the bore R and both ends of the larger bore 65 through the passages R1 and R2. The greater fluid pressure on the enlarged piston of the piston element 62 causes it to occupy its retracted position as shown in the full lines in Fig. 4 in which its valving portion 62a is disposed between the pump discharge port A and the transverse port P and the low pressure circulating fluid from

the pump 17 passes through the open port A, the passage C and the outlet B into the conduit 21. When, however, the control piston 70 is moved to the dotted position W due to loss of fluid or pressure on the high pressure side of the accumulator, the trailing or shouldered portion of the piston 70 reaches the transverse passage R1 cutting off the adjacent end of the chamber 65 from the high pressure fluid and relieving the residual pressure within this portion of the chamber through the passage R1 around the rod 69 and into low pressure passages C and B. As the fluid pressure on the adjacent side of the piston 62 is reduced, the high pressure which is still maintained on the outer end of the piston within the guide 63 causes the same to move toward the accumulator with the result that the port P is placed in communication with the port A by the valving portion 62a of the piston reaching the dotted line position indicated at Y in Figs. 4 and 5. This causes the circulating flow from the pump 17 to the sump S through the line 21 to be interrupted and it opens the pump discharge to the high pressure through the passage P. The pump 17, accordingly, picks up its load and immediately develops pressures in excess of that imposed upon its discharge by the fluid passing from the passage P through the port A in the direction opposite to the normal flow and the increased pressure gradually causes the outer piston 55—56 to telescope within the outer casing portion 40 and to return the primary piston 55—56 toward the end casing head 41 to its normal operating position. As the piston portion 56 again telescopes or returns it is followed by the control rod 69 and its piston 70 due to the increased pressure on the outer end of the piston 70 until the latter finally resumes its initial position as indicated by the full lines in Figs. 3 and 4. When this occurs, the high pressure fluid again is permitted to enter the transverse passage R1 and the piston 62 is caused to move outwardly again to its normal position with the residual air displaced from the mid-portion of the chamber 65 being displaced to the atmosphere through the vent passageway 65a. As the piston again moves outwardly, telescoping within its guide fitting 63, its valving portion 62a passes over and outward of the inlet A cutting off its connection to the high pressure fluid through the port P and causing the pump to again discharge in its normal low pressure circulating flow-path through the passage C, the passage B and through the conduit 21 back to the sump S. If during this recharging process, the pressure developed on the high pressure side of the system should exceed 1750 p. s. i., the relief valve 20 opens and the excess fluid is returned through the line 19 to the suction or low pressure side of the pump 17 comprising its sump S and the suction portion of the line 16.

It will, accordingly, be seen that the improved accumulator and its make-up by-pass valve 18 form an essential portion of a hydraulic actuating system which is charged from a compressed air receiver and is automatically maintained in operating condition with the desired actuating pressures by means of a continuously running hydraulic pump which delivers hydraulic fluid at a rate in a preferred embodiment, of approximately 1 gal. per minute with the requirement of but relatively low power input. This is accomplished by the improved accumulator which is made up of three telescoping chambers, namely, an outer high pressure chamber K, an intermediate or compressed air charging chamber G and an inner or low pressure sump chamber S, with a supplementary atmospheric chamber M disposed between chambers G and S. The system is also such that the working fluid on the high pressure side of the accumulator is automatically returned through the servo control valve following actuation of the servomotor and when the pressure or volume of fluid on the high pressure side is reduced to a predetermined extent, it is automatically replenished from the return sump of the accumulator through the continuously running pump 17 as determined by the positioning of the actuating elements 69—70 of the by-pass valve 18 which

reflects the condition of the several telescoping chambers in the accumulator 10.

The improved accumulator is also in effect an air driven automatic reciprocating hydraulic pump which is automatically controlled and provided with make-up fluid by the small continuously running circulating pump. The improved system compares favorably with the more conventional electric motor pump system and the one shot accumulator system and is admirably adapted to withstand high acceleration forces such as particularly met with in rocket and missile operations. It may be operated as described by energy stored in the form of compressed gas, which may either be air, nitrogen, carbon dioxide, etc., and this gas may be stored at a high pressure and furnished to the unit at the reduced pressure held constant by the pressure regulator. Whereas the constant pressure air will normally deliver constant pressure hydraulic fluid or oil, the present system is not limited to constant operation but through the use of differential area pistons, the energy of low pressure air is converted into much higher pressure hydraulic oil. The described system is particularly adapted for high output hydraulic systems for installation in a minimum of space and in such systems the present accumulator is ideal for supplying hydraulic oil at variable volumes. The improved accumulator overcomes many of the disadvantages of the conventional accumulator in that the supply is not limited by size, and also in that the working pressure does not drop as the oil is used or lost, and in effect the improved accumulator provides the more desirable characteristics of a self-replenishing accumulator operating at constant pressure. When an electric motor-pump system is designed to approach the requirements of constant pressure and self-replenishment, it must be designed to accommodate the maximum delivery specifications of the pump, and if the pump output is to be exceeded even momentarily, an accumulator must be incorporated. As the periods of high flow become longer and the flow much greater than the pump output, a duty cycle must be defined which limits the periods during which oil is taken from the accumulator and the periods during which the pump restores the accumulator charge. Similarly when the demands of the system are below the pump output, fluid must be unloaded or by-passed and this results in a waste of stored energy. Design parameters of maximum and minimum use are extremely difficult to establish for such hydraulic systems, particularly where the system is used for surface control in missile flight. To provide an electric pump system to allow for these variable conditions, results in considerable bulk and weight.

The presently disclosed system meets these variable requirements satisfactorily and eliminates the drawbacks and shortcomings of the conventional hydraulic systems used heretofore in applying a charge of air to one side of the system pressurizing the operating oil on the other side, whereas the present device acts as a piston type accumulator and the stored energy is used only as fast as required by the oil demands. However, high flow requirements can be filled automatically, instantaneously and completely, and load variations are followed without the objectionable replenishing and unloading or by-passing cycles inherent in prior motor systems, which were also very susceptible to leakages and pressure losses under the severe conditions met with in missile operation. The improved system is relatively free from oil flow pulsations, obviating the need of surge chambers and automatically and rapidly compensates for system oil volume variations caused by external leakage, differential volumes of the actuators and the fact that high pressure oil may leak through the amplifier unit into the sump during idle periods. The system is extremely compact and the energy storage, used as a regulating feature, in the form of compressed gas is especially convenient to the configuration of guided missiles. Where tanks are included as part of the structure, weight saving can be shown over bulky,

weighty batteries which must be supported upon additional structure. It further has the advantages of having its rate of delivering energy not closely limited by the size of the unit, it has the advantage of no electrical interference, it may be used in explosive atmospheres and it does not require cooling. Any two fluids may be used, either liquid or gas, and the pressure ratios can be controlled by the piston area ratios. Constant output pressure can be achieved by holding inlet pressure constant and the rates will be governed by output consumption. Applications other than the specific hydraulic system outlined, will become obvious to those skilled in the art after reading and understanding the foregoing description. For example, it may be advantageously used as a fuel transfer or booster pump particularly in view of its being explosion-proof and self-cooled. When used as such a pump, compressed air may be supplied from a convenient remote location or ram air flow from the speed of the airplane or missile might be utilized as well as the circulating engine oil for the working fluid.

Other forms and modifications of the present invention, both in respect to the general system and its components, which occur to those skilled in the art after reading the foregoing description, are intended to come within the scope and spirit of the present invention, as more particularly set forth in the appended claims.

We claim:

1. An accumulator device comprising a casing having an outer annular high pressure chamber and an inner low pressure chamber co-axially disposed internally of said outer annular chamber, a primary piston having opposed first and second faces reciprocable within said outer chamber, a secondary piston of lesser diameter than said primary piston reciprocable within said inner chamber, said primary piston having a major portion of a first face exposed to the atmosphere and the remaining portion of said first face exposed to the interior of said outer chamber, and port means extending through said casing for admitting charging fluid at a pressure intermediate the pressures within said outer and inner chambers to an interior space disposed between the second face of said primary piston and said secondary piston whereby a higher pressure is applied by said charging fluid acting against the entire second face of said primary piston to the fluid in said outer annular chamber and a lower pressure is applied to the fluid within said inner chamber.

2. An accumulator of the type called for by claim 1 characterized by said inner low pressure chamber having ports arranged to deliver fluid to and receive fluid from a circulating pump means and automatic means initiated by loss of fluid from said outer high pressure chamber and predetermined movement of said primary piston to cause delivery of said pump means to be diverted to said outer high pressure chamber.

3. An accumulator device comprising a fixed casing having an outer annular chamber and an inner cylindrical chamber, said casing having an opening in an end adjacent said annular chamber, an offset primary piston reciprocable within said outer chamber and having an offset portion projecting through said end opening of said casing whereby differential areas of a first face of said primary piston are exposed to the atmosphere and to said outer chamber, said inner chamber defined by an internal cylindrical wall internally of and of lesser diameter than said outer chamber and an internal transverse wall having an opening therein, a secondary piston reciprocable within said inner cylindrical chamber and having a reduced diameter portion extending from a first face through the opening in said internal transverse wall forming a differential area piston, and port means extending through said casing for admitting charging fluid at a pressure intermediate those within said inner and outer chambers to an interior space between said primary and secondary pistons in contact with said second face of said primary piston and the reduced diameter portion of said secondary

piston whereby due to the differential areas of said pistons a higher working pressure is developed within the fluid in said outer annular chamber by the first face of said primary piston and a lower pressure fluid is maintained within said inner cylindrical chamber by the second face of said secondary piston.

4. An accumulator device comprising a fixed casing having first and second chambers formed therein, said first chamber adapted to have a relatively higher pressure developed therein as compared to a lower pressure within said second chamber, a primary piston reciprocable within said first chamber, a secondary piston reciprocable within said second chamber, said pistons having differential areas on their working faces and port means extending through said casing for admitting charging fluid at a pressure intermediate the higher and lower pressures of said first and second chambers to an interior space between the opposed faces of said primary and secondary pistons whereby a pressure working fluid higher than said intermediate pressure is developed on the opposite face of said primary piston and a control pressure lesser than said intermediate pressure is developed on the opposite face of said secondary piston.

5. In an accumulator system, a fixed casing having a high pressure cylindrical chamber, a primary piston reciprocable within said high pressure chamber, said casing having a low pressure cylindrical chamber, a secondary piston reciprocable within said low pressure chamber, the adjacent faces of said pistons defining with said casing an intermediate chamber, and a port through said fixed casing for admitting charging fluid to said intermediate chamber, said primary and secondary pistons having differential areas exposed to said charging fluid and to said high and low pressure chambers arranged in such manner that said charging fluid causes said primary piston to develop working pressures in said high pressure chamber in excess thereof and said secondary piston maintains pressure in said low pressure chamber of lesser magnitude than said charging pressure.

6. In an accumulator system, a fixed casing having a high pressure cylindrical chamber, a primary piston reciprocable within said high pressure chamber, said casing having a low pressure cylindrical chamber, a secondary piston reciprocable within said low pressure chamber, the adjacent faces of said pistons defining with said casing an intermediate chamber, a port through said fixed casing for admitting charging fluid to said intermediate chamber, said primary and secondary pistons having differential areas exposed to said charging fluid and to said high and low pressure chambers arranged in such manner that said charging fluid causes said primary piston to develop working pressures in said high pressure chamber in excess thereof and said secondary piston maintains pressure in said low pressure chamber of lesser magnitude than said charging pressure and automatic means including a continuously operating circulating pump in circuit with said low pressure chamber for automatically supplying make-up fluid to said high pressure chamber.

7. In an accumulator system, a fixed casing having a high pressure cylindrical chamber, a primary piston reciprocable within said high pressure chamber, said casing having a low pressure cylindrical chamber, a secondary piston reciprocable within said low pressure chamber, the adjacent faces of said pistons defining with said casing an intermediate chamber, a port through said fixed casing for admitting charging fluid to said intermediate chamber, said primary and secondary pistons having differential areas exposed to said charging fluid and to said high and low pressure chambers arranged in such manner that said charging fluid causes said primary piston to develop working pressures in said high pressure chamber in excess thereof and said secondary piston maintains pressure in said low pressure chamber of lesser magnitude than said charging pressure and automatic means including a continuously operating circulating pump in circuit with said

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low pressure chamber and a by-pass valve in circuit with said high and low pressure chambers initiated by movement of said primary piston within said casing for automatically supplying make-up fluid to said high pressure chamber.

8. In a hydraulic actuating system, a servomotor, a servo control valve, fluid conduits connecting said servomotor with said control valve, an accumulator having a fixed casing, said fixed casing having a first cylindrical chamber and a primary piston reciprocable within said first chamber, said casing having a second cylindrical chamber, and a secondary piston reciprocable within said second chamber, a third chamber formed by said casing and the adjacent faces of said primary and secondary pistons, a port through said fixed casing for admitting charging fluid to said third chamber, said primary and secondary pistons having differential areas arranged in such manner that said charging fluid causes said primary piston to develop high pressure working pressures in said first chamber and said secondary piston maintains pressure in said second chamber of lesser magnitude than said charging pressure, and high pressure fluid conduits connecting said first chamber with said servomotor and with said servo control valve.

9. In a hydraulic actuating system, a servomotor, a servo control valve, fluid conduits connecting said servomotor with said control valve, an accumulator, having a fixed casing, said fixed casing having a first cylindrical chamber and a primary piston reciprocable within said first chamber, said casing having a second cylindrical chamber and a secondary piston reciprocable within said second chamber, a third chamber formed by said casing and the adjacent faces of said primary and secondary pistons, a port through said fixed casing for admitting charging fluid to said third chamber, said primary and secondary pistons having differential areas exposed to said charging fluid arranged in such manner that said charging fluid causes said primary piston to develop high pressure working pressures in said first chamber and said secondary piston maintains pressure in said second chamber of lesser magnitude than said charging pressure, high pressure fluid conduits connecting said first chamber with said servomotor and with said servo control valve, and automatic means including a circulating pump for automatically supplying make-up fluid to said first chamber on the high pressure side of said primary piston.

10. In a hydraulic actuating system, a servomotor, a servo control valve, fluid conduits connecting said servomotor with said control valve, an accumulator having a fixed casing, said fixed casing having a first cylindrical

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chamber and a primary piston reciprocable within said first chamber, said casing having a second cylindrical chamber and a secondary piston reciprocable within said second chamber, a third chamber formed by said casing and the adjacent faces of said primary and secondary pistons, a port through said fixed casing for admitting charging fluid to said third chamber, said primary and secondary pistons having differential areas arranged in such manner that said charging fluid causes said primary piston to develop high pressure working pressures in said first chamber and said secondary piston maintains pressure in said second chamber of lesser magnitude than said charging pressure, high pressure fluid conduits connecting said first chamber with said servomotor and with said servo control valve, a return conduit from said servomotor to said control valve and said accumulator, automatic means including a continuously operating circulating pump and a by-pass valve initiated by movement of said primary piston within said casing for automatically supplying make-up fluid to said first chamber on the high pressure side of said primary piston.

11. An accumulator device for receiving charging power from a compressed gas and supplying fluid power to a motor, comprising a high pressure fluid chamber having a primary piston reciprocable therein for varying the capacity of said high pressure chamber, a low pressure fluid chamber having a secondary piston reciprocable therein for varying the capacity of said low pressure chamber, an intermediate chamber formed between and open to opposed faces of said primary and secondary pistons adapted to be supplied with a compressed gas at a predetermined pressure, said opposed faces of said primary and secondary pistons having differential areas exposed to said compressed gas and the opposite faces of said pistons having differential areas exposed to the fluid in said respective chambers whereby said primary piston develops high pressure fluid in said first chamber for supplying fluid power to said motor and said secondary piston develops low pressure fluid in said second chamber, pump means normally circulating fluid at low pressure through said second chamber, and by-pass valve means initiated by loss of fluid from said high pressure supply to said motor for automatically replenishing said fluid by supplying liquid at high pressure from said pump means to said first chamber.

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