

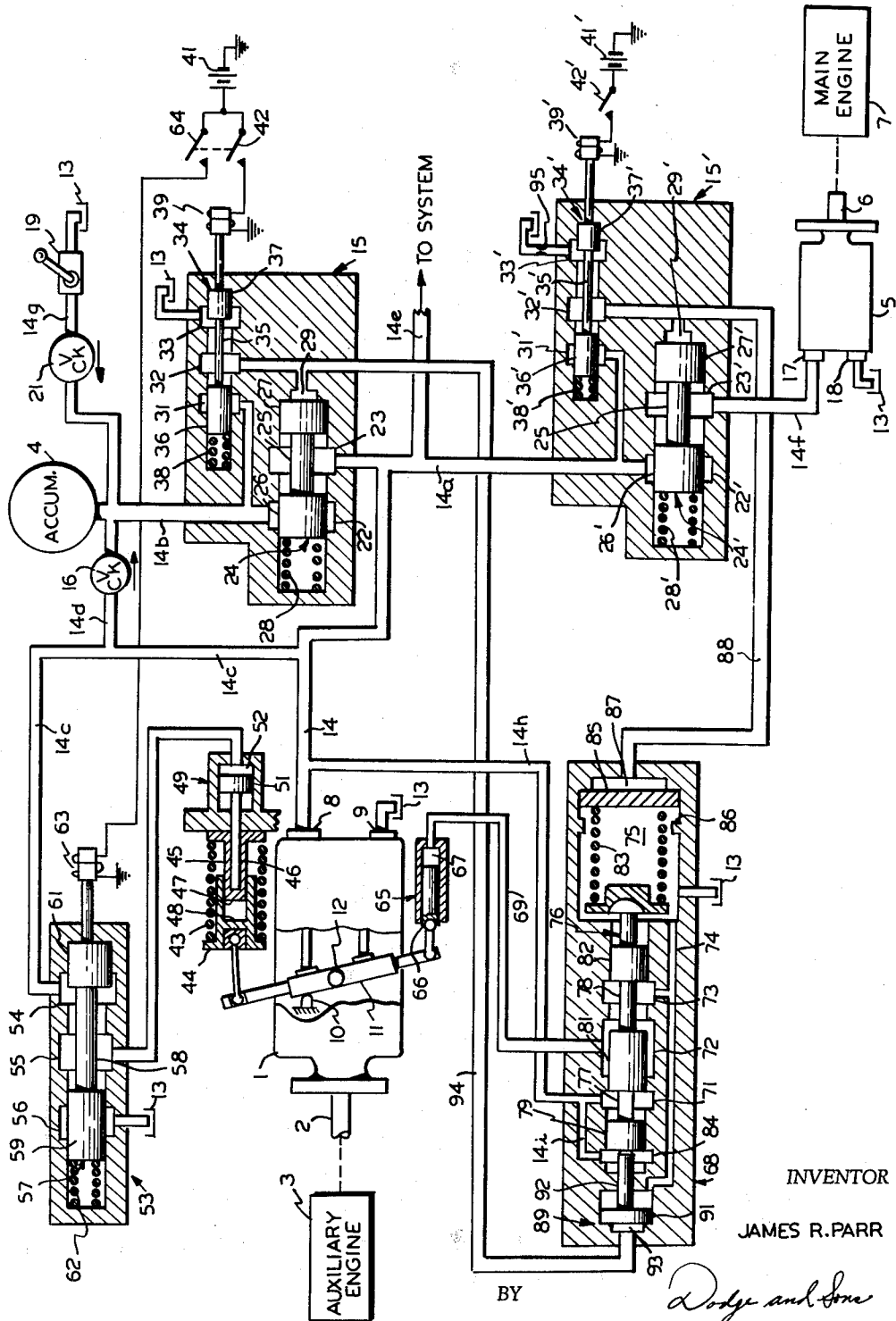
Aug. 31, 1965

J. R. PARR

3,203,165

HYDRAULIC DEVICE

Filed Aug. 10, 1962



1

3,203,165

HYDRAULIC DEVICE

James R. Parr, Watertown, N.Y., assignor to The New York Air Brake Company, a corporation of New Jersey

Filed Aug. 10, 1962, Ser. No. 216,191

4 Claims. (Cl. 60-18)

This invention relates to hydraulic pumps, and more particularly, to discharge pressure compensators for hydraulic motor-pump units used in engine starting systems.

The co-pending application of Melvin L. Kent and Mike Prewarski, Serial No. 111,721, filed May 22, 1961, now Pat. No. 3,116,595, discloses a hydraulic starting system including a motor-pump unit of the overcenter type and utilizing an accumulator as the source of motive fluid for the starting operation. The displacement control element of the motor-pump unit is urged toward one of its maximum displacement positions by a biasing means and is shifted toward the other of those positions by a fluid pressure control motor which is vented and pressurized by a control valve that responds to the pressure at the high pressure port of the unit. The biasing means, the control motor, and the control valve regulate the displacement of the unit during the motoring operation and also serve as a discharge pressure compensator during the pumping operation. With a system such as this, where the controls for the motor-pump unit perform two functions, the pressure level established by the compensator during the pumping operation is inherently limited to approximately the precharge pressure of the accumulator. Since it is desirable to use the unit to recharge the accumulator during the pumping cycle, and also to provide fluid under a higher pressure for auxiliary uses, the system includes means for selectively raising the pressure level to a higher value approximately equal to the fully charged pressure of the accumulator.

In some installations the motor-pump unit of the Kent and Prewarski application is used to start an auxiliary engine and then, when that engine is running and driving the unit as a pump, as a source of motive fluid for starting one or more main engines and for operating various hydraulically actuated devices. Sometimes the starting torque characteristics of the main engines are such that their starters must be operated at a higher pressure than either the auxiliary engine starter or the hydraulically actuated devices in order to keep their size within desirable limits. As a result, the compensator of the motor-pump unit must be set, and that unit continuously operated, at a pressure materially higher than that deemed most desirable for the remaining components of the system even though the demands of the main engine starters are of short duration. Obviously this is a disadvantage.

The object of this invention is to provide a discharge pressure compensator suitable for use on a motor-pump unit of the type described in the Kent and Prewarski application which affords three discharge pressure levels. According to the preferred embodiment of the invention, the compensator includes a control valve that is biased toward the supply position by a spring seated on a movable seat. As in the control valve described in the Kent and Prewarski application, the seat is moved from a low spring-load position to a high spring-load position by a fluid pressure motor in order to raise the level of the discharge pressure. The valve also includes a second fluid pressure motor that acts in opposition to the spring and which, when pressurized, overpowers the spring and in effect reduces the pressure at which the valve commences to pressurize the control motor and causes it to reduce displacement. With this type of compensator, the motor-

2

pump unit need supply fluid at the highest pressure level only when there is a demand for fluid at that pressure. At other times, fluid can be supplied at one of the lower pressure levels.

The invention also embraces a novel starting system incorporating the compensator just mentioned and including means for automatically energizing and de-energizing the two fluid pressure motors in the control valve. In the preferred form of this system, the motor-pump unit is connected with an auxiliary engine and is arranged to supply motive fluid to hydraulic starters connected with the main engines. Motive fluid is supplied to the motor-pump unit from the accumulator through a start valve that is so interconnected with the second fluid pressure motor in the control valve that the latter is pressurized when the start valve is opened and vented when the start valve is closed. In this way, the control valve is automatically adjusted to its lowest setting when the motor-pump unit is motoring and to its intermediate setting at other times. Motive fluid is supplied to each main engine starter from the motor-pump unit through a start valve that is so interconnected with the first fluid pressure motor in the control valve that the latter is pressurized and vented when the start valve is opened and closed, respectively. With this arrangement, the compensator is set to its highest level only when a main engine is being started. In the preferred form of this system, all of the start valves are of the pilot-operated type and their piloted motors are connected with the corresponding fluid pressure motors in the control valve. Thus, when the pilot valve pressurizes and vents the piloted motor to open and close, respectively, the start valve, it automatically pressurizes and vents the fluid pressure motor that adjusts the setting of the compensator.

The preferred embodiment of the invention is described herein with reference to the accompanying drawing whose single figure is a schematic diagram of a typical engine starting system incorporating the invention.

As shown in the drawing, the starting system includes an overcenter motor-pump unit 1 of the type described in the Kent and Prewarski application mentioned above, whose drive shaft 2 is connected in driving and driven relation with auxiliary engine 3 and which is arranged to receive motive fluid from a gas-charged accumulator 4 and to deliver motive fluid to a starter motor 5 whose drive shaft 6 is connected in driving relation with main engine 7. Motor-pump unit 1 is of the rotary cylinder barrel, longitudinally reciprocating piston type and includes high and low pressure ports 8 and 9 and a cam plate 11 which is mounted for pivotal movement about the axis of trunnion 12. The low pressure port 9 of unit 1 is in continuous communication with reservoir 13 and the high pressure port 8 is connected with accumulator 4 along two parallel paths, one path including conduits 14, 14a and 14b and controlled by auxiliary starter valve 15, and the other path including conduit 14, 14c, 14d and 14b and containing a check valve 16. High pressure port 8 also is connected with a hydraulic system including the power operated devices (not shown) through conduits 14, 14a, 14e, and with the inlet port 17 of motor 5 through conduits 14, 14a and 14f. The last mentioned connection is controlled by main starter valve 15'. The discharge port 18 of motor 5 is in continuous communication with reservoir 13. The accumulator is charged initially by a hand pump 19 with which it is connected by conduit 14g containing a check valve 21.

Auxiliary starter valve 15 includes a main valve unit comprising inlet and outlet chambers 22 and 23 which are connected with conduits 14b and 14a, respectively, and a sliding valve plunger 24 formed with an annular groove 25 that defines two valve lands 26 and 27. Valve plunger

24 is biased to the illustrated position by a coil compression spring 28 and in this position land 26 interrupts communication between chambers 22 and 23. The valve plunger 24 is shifted to the left to the open position in which groove 25 interconnects chambers 22 and 23 by a piloted motor comprising working chamber 29 and a piston which is defined by the right end of the valve plunger. The working chamber 29 of the piloted motor is selectively vented and pressurized by a pilot valve comprising inlet, outlet and exhaust chambers 31, 32 and 33, which are connected, respectively, with conduit 14b, working chamber 29 and reservoir 13, and a sliding valve plunger 34 formed with an annular groove 35 that defines two valve lands 36 and 37. A coil compression spring 38 biases valve plunger 34 to the vent position in which land 36 blocks chamber 31 and groove 35 interconnects chambers 32 and 33. The plunger 34 is shifted to the left to the pressurizing position, in which land 37 blocks chamber 33 and groove 35 interconnects chambers 31 and 32, by a solenoid actuator 39. The coil of solenoid actuator 39 is connected in an electrical circuit with battery 41 and is selectively energized and de-energized by a switch 42.

Main starter valve 15' is identical to auxiliary starter valve 15 so its parts bear the same reference numerals with primes added for clarity.

The displacement of motor-pump unit 1 is controlled by cam plate 11 which is biased in the counterclockwise direction about the axis of trunnion 12 by a coil compression spring 43 which is seated on the outturned flanges of a pair of telescoping sleeves 44 and 45. Sleeve 45 is carried by a reciprocable piston rod 46 and is provided with a surface 47 which cooperates with the surface 48 on sleeve 44 to define a stop that prevents the cam plate 11 from moving in the clockwise direction from the zero displacement or neutral position during the pumping cycle. The cam stop is rendered effective, and the sleeve seat 45 is moved in a direction to increase the load in spring 43, by a piston motor 49 comprising a piston 51 and a working chamber 52. Working chamber 52 is selectively vented and pressurized by a selector valve 53 comprising inlet, outlet and exhaust chambers 54, 55 and 56 which are connected, respectively, with conduit 14c, working chamber 52 and reservoir 13, and a sliding valve plunger 57 formed with an annular groove 58 that defines two valve lands 59 and 61. Valve plunger 57 is biased to the illustrated pressurizing position by a coil compression spring 62 and in this position land 59 blocks exhaust chamber 56 and groove 58 interconnects chambers 54 and 55. A solenoid actuator 63 is provided for shifting valve plunger 57 to the left to the vent position in which land 61 blocks inlet chamber 54 and groove 58 interconnects chambers 55 and 56. The coil of solenoid actuator 63 is selectively energized and de-energized by an electrical circuit including battery 41 and a switch 64 which is opened and closed in unison with switch 42. The details of the cam plate biasing spring and stop assembly are more fully described in the Kent and Prewarski application mentioned previously so further description here is deemed unnecessary.

Cam plate 11 of motor-pump unit 1 is moved in the clockwise direction about the axis of trunnion 12 against the bias of spring 43 by a control motor 65 including piston 66 and working chamber 67. Fluid is supplied to and exhausted from working chamber 67 under the control of a pressure responsive control valve 68 with which it is connected by conduit 69. Control valve 68 includes an inlet chamber 71 which is connected with the high pressure port 8 of motor-pump unit 1 through conduits 14h and 14, an outlet chamber 72 which is connected with conduit 69, an exhaust chamber 73 which is connected with reservoir 13 through passage 74 and spring chamber 75, and a sliding valve plunger 76 formed with two annular grooves 77 and 78 that define three valve lands 79, 81 and 82. Valve plunger 76 is biased to the left

toward the illustrated vent position, in which land 81 isolates inlet chamber 71 from outlet chamber 72 and groove 78 interconnects outlet chamber 72 and exhaust chamber 73, by a coil compression spring 83. The valve plunger 76 is shifted to the right, first to a lap position in which land 81 isolates outlet chamber 72 from chambers 71 and 73, and then to a supply position in which groove 77 interconnects chambers 71 and 72 and land 81 isolates chamber 72 from exhaust chamber 73, by the fluid pressure in chamber 84 which acts upon the left end of the valve plunger. This chamber 84 is in continuous communication with the high pressure port 8 of unit 1 through conduits 14i and 14h.

The pressure in chamber 84 required to shift valve plunger 76 to the lap position against the bias of spring 83 is termed the reference pressure, and the control valve 68 includes two devices for raising and lowering this reference pressure. The first device, which is used to raise the reference pressure above the normal valve, comprises a movable spring seat 85 for spring 83 which is shiftable between the illustrated low spring-load position and a high spring-load position in which it abuts stop 86, and a piston motor including the right end of seat 85 and working chamber 87. A conduit 88 interconnects working chambers 87 and 29' and, therefore, these working chambers are vented and pressurized simultaneously by the pilot valve of main starter valve 15'. Control valve 68 is adjusted to establish its lowest reference pressure by a piston motor 89 comprising a piston 91 whose rod 92 abuts the left end of valve plunger 76, and a working chamber 93 which is connected with the working chamber 29 of starter valve 16 by a conduit 94. Therefore, motor 89 and working chamber 29 are vented and pressurized simultaneously by the pilot valve of auxiliary starter valve 15.

Like motor-pump unit 1, starter motor 5 is also of the rotary cylinder barrel, longitudinally reciprocating piston type. Preferably motor 5 is a variable displacement unit, but for simplicity, its controls are not illustrated. The copending application of Melvin L. Kent and Edward V. Manning, Serial No. 119,170, filed June 23, 1961 discloses a suitable design for this motor.

It might be mentioned here that in those cases when there are a plurality of main engines 7 that are to be started, each main engine is provided with a starter motor 5 and a starter valve 15'. The inlet chambers 22' of the starter valves are connected in parallel with conduit 14a and a conduit 88 is provided between the piloted motor of each starter valve and the working chamber 87 of the control valve. Since the main engines in these cases are started in sequence, it is necessary to provide a restriction 95 in the vent conduit leading to the exhaust chamber 33' of each starter valve in order to develop a back pressure sufficient to shift the main valve plunger 24' in each starter valve to its open position and to shift the seat 85 to its high spring-load position.

Operation

At the commencement of a starting cycle, the components of the system assume their illustrated positions so that motor-pump unit 1 is isolated from accumulator 4 by starter valve 15 and motor 5 is isolated from motor-pump unit 1 by starter valve 15'. Initially, accumulator 4 is charged with hydraulic fluid by hand pump 19. For purposes of discussion, it will be assumed that the pre-charge pressure of accumulator 4 is 1500 p.s.i., that the fully charged pressure of the accumulator is 3000 p.s.i., and that the three reference pressures of control valve 68 are 1500 p.s.i., 3000 p.s.i., and 4000 p.s.i.

In order to start auxiliary engine 3, the operator closes switch 42 to thereby energize solenoid actuator 39 and cause it to shift pilot valve plunger 34 to the left to its pressurizing position in which groove 35 interconnects chambers 31 and 32. Fluid from the accumulator 4 may now flow to the working chamber 29 of the piloted motor

along a path comprising conduit 14b, chamber 31, plunger groove 35, and chamber 32 where it is effective to shift main valve plunger 24 to the left to its open position in which groove 25 interconnects chambers 22 and 23. Simultaneously several other events take place. First, closure of switch 42 also effects closure of switch 64 so that solenoid actuator 63 is energized and shifts the valve plunger 57 of selector valve 53 to the left to the vent position in which motor 49 is vented to reservoir 13 through chambers 55 and 56 and plunger groove 58. Second, fluid under pressure is delivered through conduit 94 to working chamber 93 in control valve 68 where it acts upon piston 91 and causes it to shift valve plunger 76 to the right to its supply position. This action sets control valve 68 to its lowest reference pressure of 1500 p.s.i. Since the valve plunger 24 of auxiliary starter valve 15 is open, fluid under pressure is now delivered to working chamber 67 of control motor 65 through conduits 14b, 14a, 14, 14h, chamber 71, plunger groove 77, chamber 72 and conduit 69. As a result, the control motor 65 moves cam plate 11 in the clockwise direction to its maximum displacement position on the motoring side of neutral.

The fluid supplied to motor-pump unit 1 from accumulator 4 through conduits 14b, 14a, 14 and high pressure port 8 causes the motor-pump unit 1 to develop torque and accelerate engine 3. As engine 3 accelerates, the pressure in chamber 84 acting upon the left end of valve plunger 76 are sufficient to hold the valve plunger in the supply position at pressures above 1500 p.s.i., working chamber 67 remains pressurized and control motor 65 holds cam plate 11 in the maximum displacement position for the entire starting cycle. The parts of the system are so proportioned that the engine will reach ignition speed before accumulator pressure begins to approach 1500 p.s.i. and will reach or even exceed starter cut-out speed (i.e., the speed at which the engine is capable of developing sufficient power to accelerate itself) by the time accumulator pressure reaches 1500 p.s.i. Therefore, when the accumulator pressure decreases to 1500 p.s.i., and the accumulator is fully discharged, engine 3 will be running and accelerating at a rate greater than that of motor-pump unit 1. Consequently, at this time, system pressure will decrease momentarily below 1500 p.s.i. and spring 83 will shift valve plunger 76 to the vent position and exhaust working chamber 67 to reservoir 13 along a path which comprises conduit 69, chamber 72, plunger groove 78, chamber 73, passage 74 and spring chamber 75. As a result, spring 43 moves cam plate 11 in the counter-clockwise direction a slight distance beyond the zero displacement or neutral position so that motor-pump unit 1 commences to discharge fluid under pressure from high pressure port 8. This pumping action of motor-pump unit 1 restores system pressure to 1500 p.s.i. and, when the displacement of motor-pump unit 1 equals the rate of leakage from the system, valve plunger 76 will move to the right to the lap position and hydraulically lock control motor 65. Motor-pump unit 1 is now serving as a pressure compensated pump that establishes a maximum system pressure of 1500 p.s.i. Since this pressure is relatively low and the displacement of motor-pump unit 1 is quite small, the load on engine 3 is small and it may accelerate rapidly to the speed at which it develops sufficient power to start main engine 7.

At this point in the cycle the operator opens switches 42 and 64, thereby de-energizing solenoid actuators 39 and 63. Spring 38 now shifts pilot valve plunger 34 back to the illustrated vent position in which working chambers 29 and 93 are connected to reservoir 13, and spring 28 shifts main valve plunger 24 to its closed position. Since motor 89 is now vented, spring 83 shifts control valve plunger 76 to its vent position against the opposing force developed by the fluid pressure in cham-

ber 84, and spring 43 moves cam plate 11 to its maximum displacement position on the pumping side of neutral, i.e., spring 43 moves cam plate 11 into engagement with stop 10. Simultaneously, spring 62 of selector valve 53 moves plunger 57 to its pressurizing position and fluid under pressure is transmitted from conduit 14 to working chamber 52 through conduit 14c, chamber 54, plunger groove 58 and chamber 55. As explained in the Kent and Prewarski application mentioned above, piston 51 now moves spring seat sleeve 45 to its high spring-load position and renders the stop defined by surfaces 47 and 48 effective to prevent cam plate 11 from being moved in the clockwise direction beyond the neutral position.

The fluid discharged by motor-pump unit 1 now passes through conduits 14, 14c, 14d and 14b to accumulator 4, and, since control valve 68 is now set to establish a reference pressure of 3000 p.s.i., the accumulator 4 is recharged to 3000 p.s.i. When the accumulator 4 is fully charged, and assuming there is no other demand for hydraulic fluid, system pressure tends to rise above 3000 p.s.i. and valve plunger 76 shifts to its supply position. Control motor 65, therefore, becomes effective to move cam plate 11 toward the zero displacement position against the opposing bias of spring 43. Inasmuch as these systems always have some leakage, the cam plate 11 will come to rest, and control motor 65 will be hydraulically locked, when the system pressure is restored to 3000 p.s.i. and the displacement of motor-pump unit 1 equals the rate of leakage.

In order to start main engine 7, the operator closes switch 42' to energize solenoid actuator 39' and shift pilot valve plunger 34' to its pressurizing position. Fluid under pressure discharged by motor-pump unit 1 may now flow to working chamber 29' through conduits 14 and 14a, chamber 31', plunger groove 35', and chamber 32' where it is effective to shift main valve plunger 24' to the left and open a flow path from conduit 14a to inlet port 17 of motor 5 that includes chamber 22', plunger groove 25', chamber 23' and conduit 14f. Opening of this flow path imposes a demand on motor-pump unit 1 and produces a momentary drop in system pressure below 3000 p.s.i. Therefore, valve plunger 76 shifts to its vent position and spring 43 moves cam plate 11 toward its maximum displacement position on the pumping side of neutral.

Simultaneously, with the opening of main starter valve 15', fluid under pressure is transmitted to working chamber 87 through conduit 88 where it is effective to shift spring seat 85 to the left into engagement with stop 86. This shift of the spring seat increases the preload in spring 83 and, therefore, raises the reference pressure of valve 68 to 4000 p.s.i. Starter motor 5 now commences to accelerate engine 7 to cut-out speed.

After engine 7 has been started and reaches starter cut-out speed, switch 42' is opened to de-energize solenoid actuator 39' and allow spring 38' to move pilot valve plunger 34' to its illustrated vent position. Working chambers 29' and 87 are now exhausted to reservoir 13 through chamber 32', plunger groove 35' and chamber 33', thereby allowing spring 28' to close the main starter valve and allowing spring 83 to move seat 85 back to its low spring load position. Since this action reduces the reference pressure of control valve 68 to 3000 p.s.i., the fluid pressure in chamber 84 immediately moves valve plunger 76 to its supply position (assuming that the system is imposing no demand on motor-pump unit 1 at this time). Control motor 65, therefore, moves cam plate 11 in the clockwise direction to a reduced displacement position in which the displacement of motor-pump unit 1 equals the rate of leakage and system pressure is maintained at 3000 p.s.i.

Motor-pump unit 1 is now available to supply the various demands connected with conduit 14e and it will be understood that in handling these demands, as

well as those of starter motor 5, the compensator including control valve 63, control motor 65 and spring 43 will vary the angular position of cam plate 11, and consequently, the displacement of motor-pump unit 1, in inverse relation to system pressure so that that pressure is maintained substantially constant at the selected reference pressure.

It might be mentioned here that in some cases, for example when the ambient temperature is relatively high, the torque demand of engine 3 may be such that the entire capacity of accumulator 4 is not required during the starting cycle of this engine. In these cases, engine 3 will reach starter cut-out speed when accumulator pressure is still considerably above (for example, several hundred p.s.i. above) the lowest reference pressure of 1500 p.s.i. Under these conditions the operator may interrupt motoring operation of motor-pump unit 1 by opening switch 42. This action results in closure of the auxiliary starter valve 15, in shifting of selector valve 53 to its pressurizing position, and in adjustment of control valve 68 to its intermediate reference pressure of 3000 p.s.i. Therefore, valve plunger 76 of the control valve 68 moves to the vent position and spring 43 pivots cam plate 11 in the counterclockwise direction to a small displacement position on the pumping side of neutral. Motor-pump unit 1 now operates as a pump compensated to 3000 p.s.i. in the manner previously described. In the alternative, the operator may allow motor-pump unit 1 to accelerate engine 3 to a speed materially higher than starter cut-out speed and permit the controls to shift cam plate 11 in the counterclockwise direction automatically as in the case first described. However, in this event, the motor-pump unit 1 must be designed to withstand the overspeed condition.

As stated previously, the drawing and description relate only to the preferred embodiment of the invention. Since changes can be made in the structure of this embodiment without departing from the inventive concept, the following claims should provide the sole measure of the scope of the invention.

What I claim is:

1. A hydraulic system for accelerating an engine comprising

- (a) a hydraulic motor connected with the engine for driving same and having inlet and discharge ports;
- (b) an auxiliary engine;
- (c) a hydraulic motor-pump unit of the overcenter type connected with the auxiliary engine and having high and low pressure ports and a displacement control element shiftable between first and second maximum displacement positions on opposite sides of a neutral zero displacement position;
- (d) an accumulator;
- (e) a first conduit connecting the accumulator with the high pressure port of the motor-pump unit;
- (f) means biasing the displacement control element toward the first maximum displacement position;
- (g) a fluid pressure control motor connected with the displacement control element for moving it toward the second maximum displacement position;
- (h) a second conduit connecting the high pressure port of the motor-pump unit with the inlet port of the hydraulic motor;
- (i) first and second starter valves controlling flow through the first and second conduits, respectively, each valve being shiftable between open and closed positions;
- (j) a control valve having an inlet passage connected with the high pressure port of the motor-pump unit, an outlet passage connected with the control motor, and an exhaust passage and including a movable valve member shiftable between first and second positions in which, respectively, the outlet passage is connected with the exhaust passage and the inlet passage and having an intermediate lap position in which the out-

let passage is isolated from both the exhaust passage and the inlet passage;

- (k) a spring biasing the valve member toward the first position;
- (l) a movable spring seat for the spring shiftable between low spring load and high spring load positions;
- (m) means responsive to the pressure in the inlet passage for urging the valve member toward the second position;
- (n) a first actuating motor acting in opposition to the spring;
- (o) a second actuating motor connected with the movable spring seat and arranged to move the seat toward the high spring load position;
- (p) reservoir means connected with the low pressure port of the motor-pump unit, the discharge port of the hydraulic motor, and the exhaust passage of the control valve;
- (q) means for selectively energizing and de-energizing the first actuating motor; and
- (r) means for selectively energizing and de-energizing the second actuating motor.

2. A hydraulic starting system as defined in claim 1 wherein

- (a) the first and second actuating motors are fluid pressure motors; and
- (b) the means for selectively energizing and de-energizing the actuating motors each comprises means for selectively pressurizing and venting the associated motor.

3. A hydraulic starting system as defined in claim 1 wherein

- (a) the first and second actuating motors are fluid pressure motors;
- (b) the means for selectively energizing and de-energizing the first actuating motor comprises valve means operated in unison with the first starter valve for connecting the first actuating motor with the first conduit and the reservoir means when the first starter valve is in the open and closed position, respectively; and
- (c) the means for selectively energizing and de-energizing the second actuating motor comprises second valve means operated in unison with the second starter valve for connecting the second actuating motor with the second conduit and the reservoir means when the second starter valve is in the open and closed positions, respectively.

4. A hydraulic starting system for an engine comprising

- (a) a hydraulic motor connected with the engine for driving same and having inlet and discharge ports;
- (b) an auxiliary engine;
- (c) a hydraulic motor-pump unit of the overcenter type connected with the auxiliary engine and having high and low pressure ports and a displacement control element shiftable between first and second maximum displacement positions on opposite sides of a neutral zero displacement position;
- (d) an accumulator;
- (e) a first conduit connecting the accumulator with the high pressure port of the motor-pump unit;
- (f) means biasing the displacement control element toward the first maximum displacement position;
- (g) a fluid pressure control motor connected with the displacement control element for moving it toward the second maximum displacement position;
- (h) a second conduit connecting the high pressure port of the motor-pump unit with the inlet port of the hydraulic motor;
- (i) first and second starter valves controlling flow through the first and second conduits, respectively, each valve being biased to a closed position and including a fluid pressure piloted motor for shifting it to an open position;

9

- (j) a first pilot valve having an inlet passage connected with the accumulator, an outlet passage connected with the piloted motor associated with the first starter valve, an exhaust passage, and a movable member having first and second positions in which, respectively, the outlet passage is connected with the exhaust and inlet passages; 5
- (k) a second pilot valve having an inlet passage connected with the high pressure port of the motor-pump unit, an outlet passage connected with the piloted motor associated with the second starter valve, an exhaust passage, and a movable member having first and second positions in which, respectively, the outlet passage is connected with the exhaust and inlet passages; 10
- (l) a control valve having an inlet passage connected with the high pressure port of the motor-pump unit, an outlet passage connected with the control motor, and an exhaust passage, and including a movable valve member shiftable between first and second positions in which, respectively, the outlet passage is connected with the exhaust passage and the inlet passage and having an intermediate lap position in which the outlet passage is isolated from both the exhaust passage and the inlet passage; 15
- (m) a spring biasing the valve member of the control valve toward the first position; 20
- (n) a movable spring seat for the spring shiftable between low spring load and high spring load positions; 25

10

- (o) means responsive to the pressure at the high pressure port of the motor-pump unit for urging the valve member of the control valve toward the second position; 4
- (p) a first fluid pressure actuating motor connected with the outlet passage of the first pilot valve and acting in opposition to the spring of the control valve;
- (q) a second fluid pressure actuating motor connected with the outlet passage of the second pilot valve and arranged to urge the movable spring seat toward the high spring-load position; and
- (r) reservoir means connected with the low pressure port of the motor-pump unit, the discharge port of the hydraulic motor, and the exhaust passages of the control valve and the first and second pilot valves.

References Cited by the Examiner

UNITED STATES PATENTS

2,258,160	10/41	Nardone	60—18
2,747,515	5/56	Montelius	103—161
2,838,908	6/58	Forster	60—18
2,913,005	11/59	Grant et al.	137—620
2,919,716	1/60	Boyer	137—620
3,051,092	8/62	Lambeck	103—161

JULIUS E. WEST, *Primary Examiner*.ROBERT R. BUNEVICH, *Examiner*.