

[54] **HYDRAULIC ENGINE STARTING SYSTEMS**

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60/404

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[58] Field of Search **60/325, 386, 413, 416,**
60/14 B, 14 R, 415; 123/179 F

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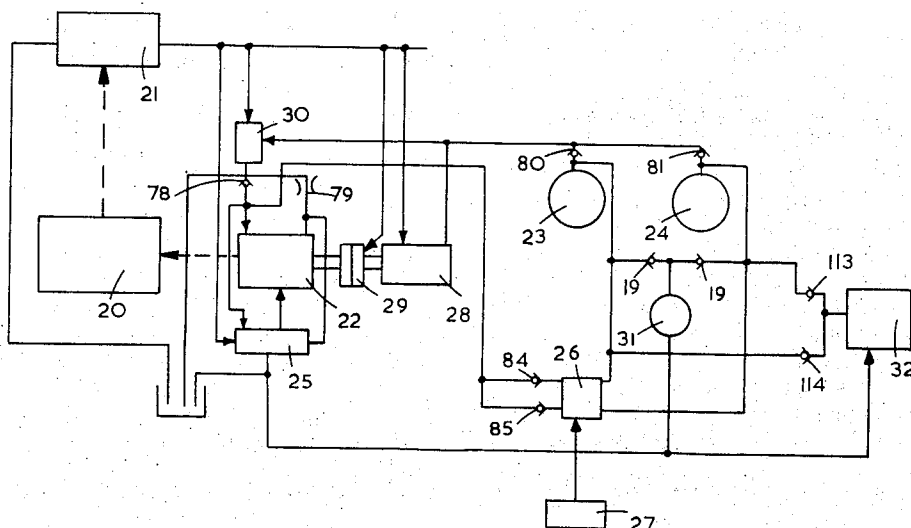
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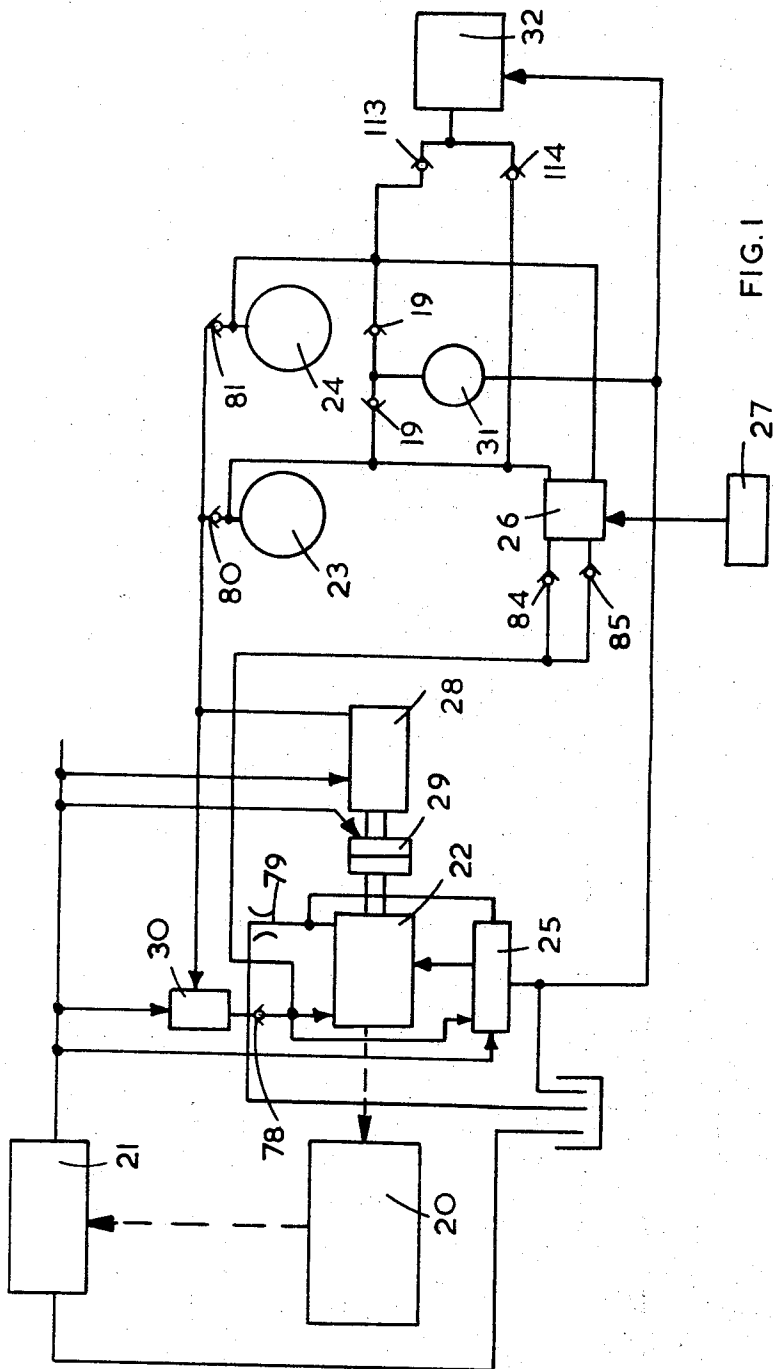
Primary Examiner—Edgar W. Geoghegan
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[57] **ABSTRACT**

An hydraulic engine starting system includes a motor which is used both for engine starting and for driving a pump for charging accumulators for storing liquid under pressure. For engine starting the motor is connected to one accumulator to receive liquid therefrom. For charging the accumulators the motor is connected to an hydraulic circuit powered by the engine and a clutch connects the motor to the pump. The clutch is operated by pressure in the circuit so that it is disengaged during engine starting. The motor has a constant flow servo-system which has means for varying the displacement of the motor according to whether the motor is receiving liquid from the accumulator or the circuit.

10 Claims, 13 Drawing Figures





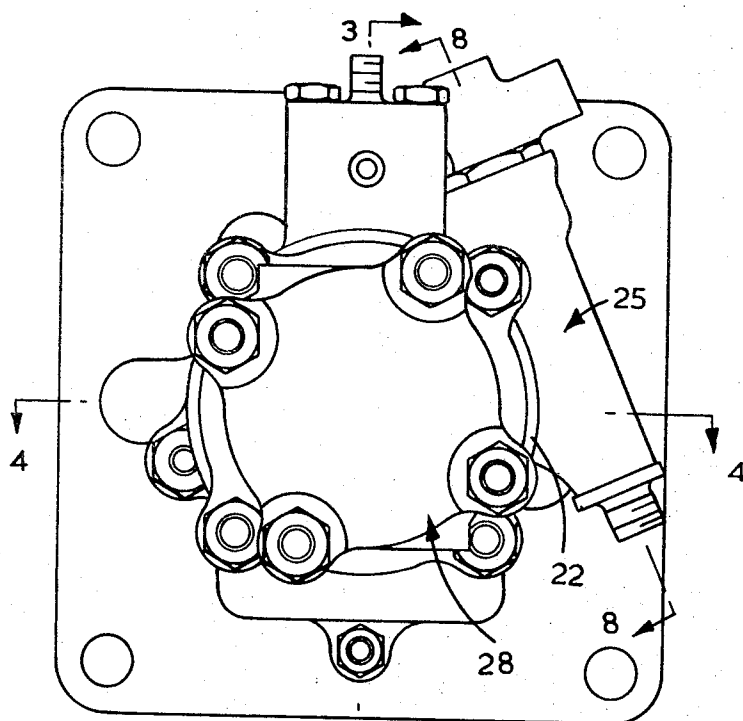


FIG. 2

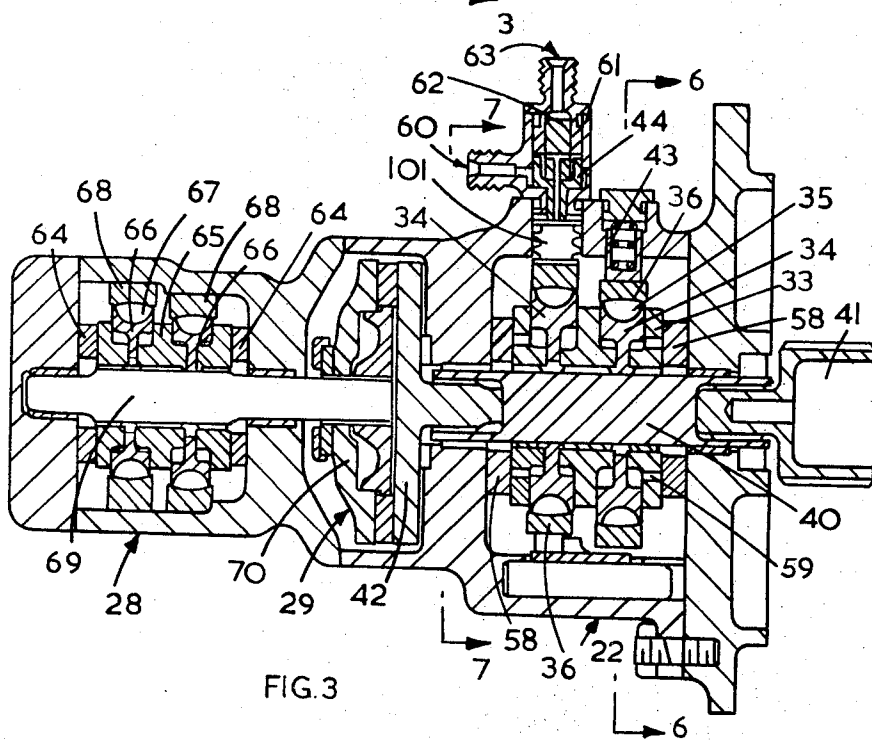
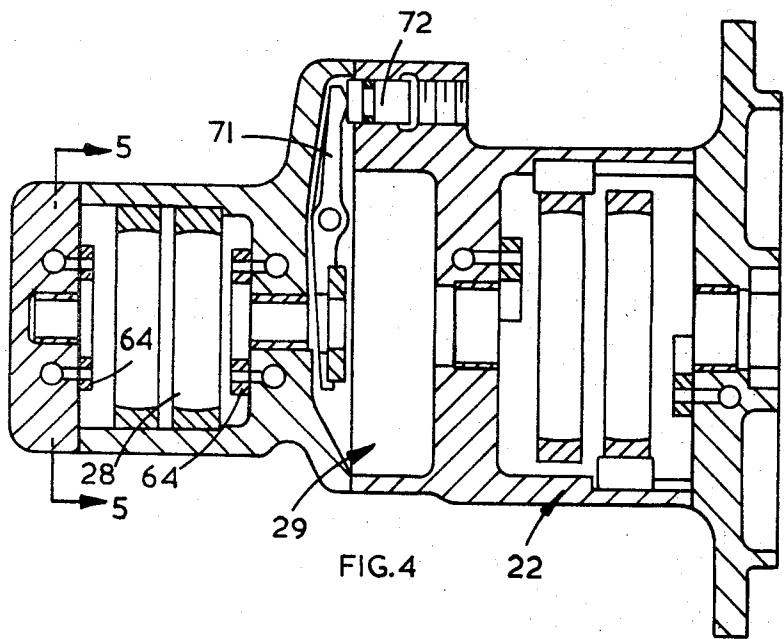
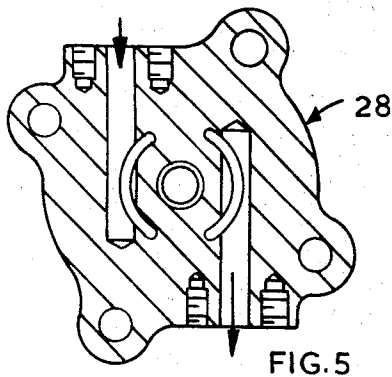
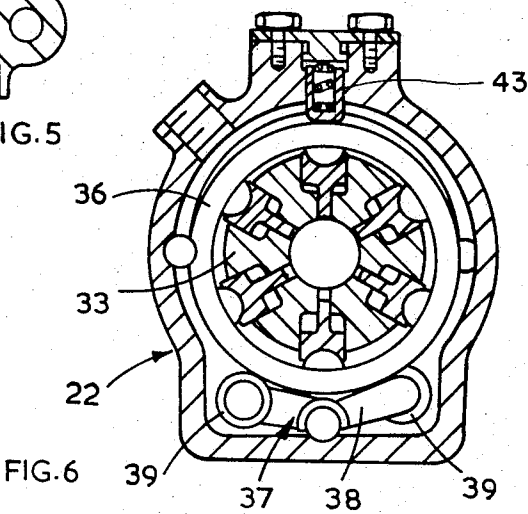
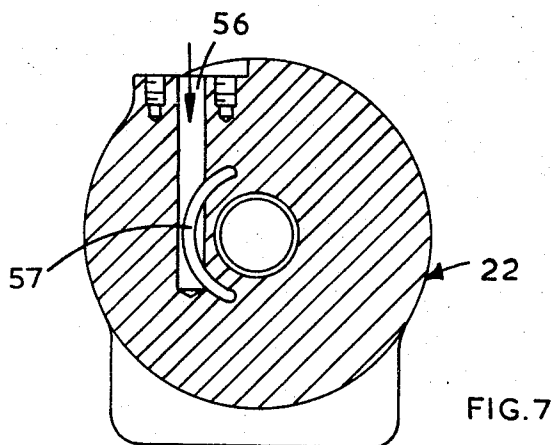
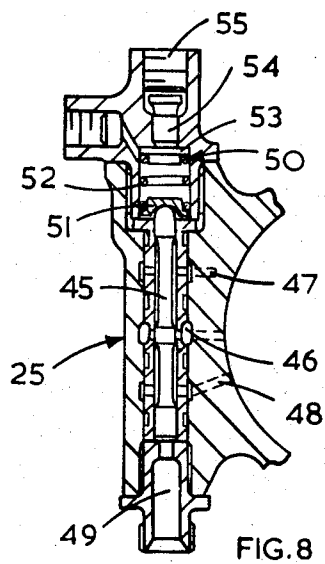
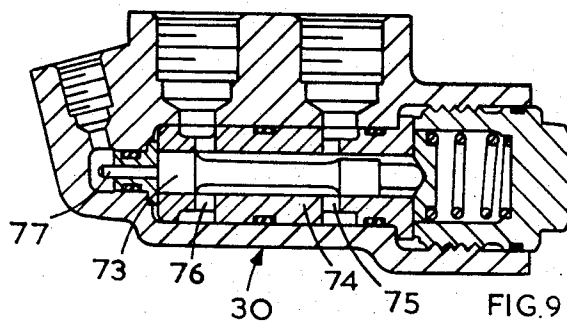
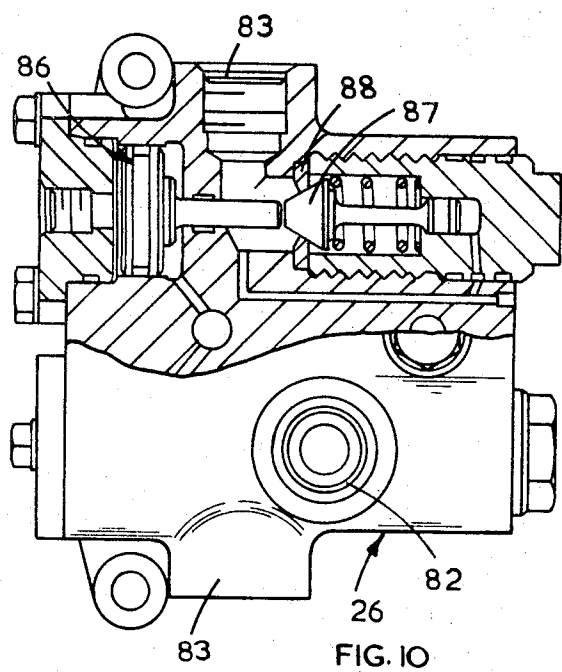
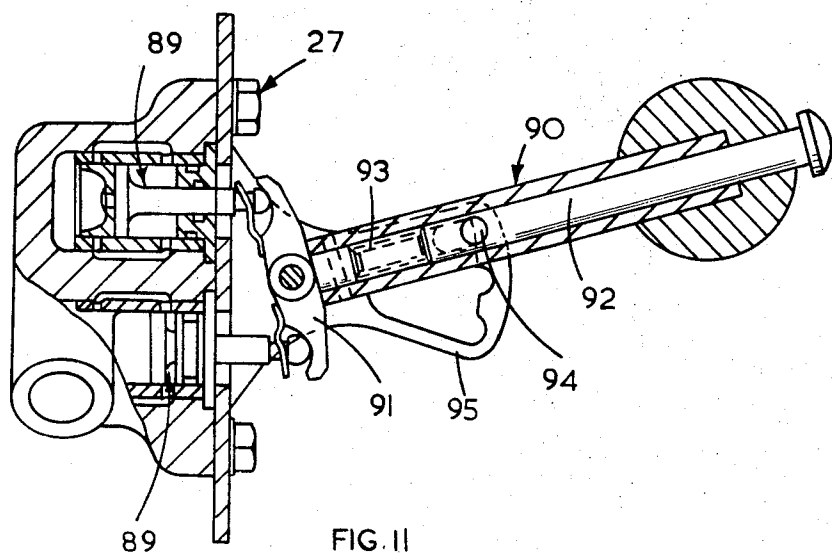


FIG. 3







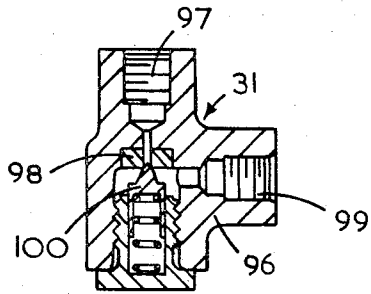


FIG. 12

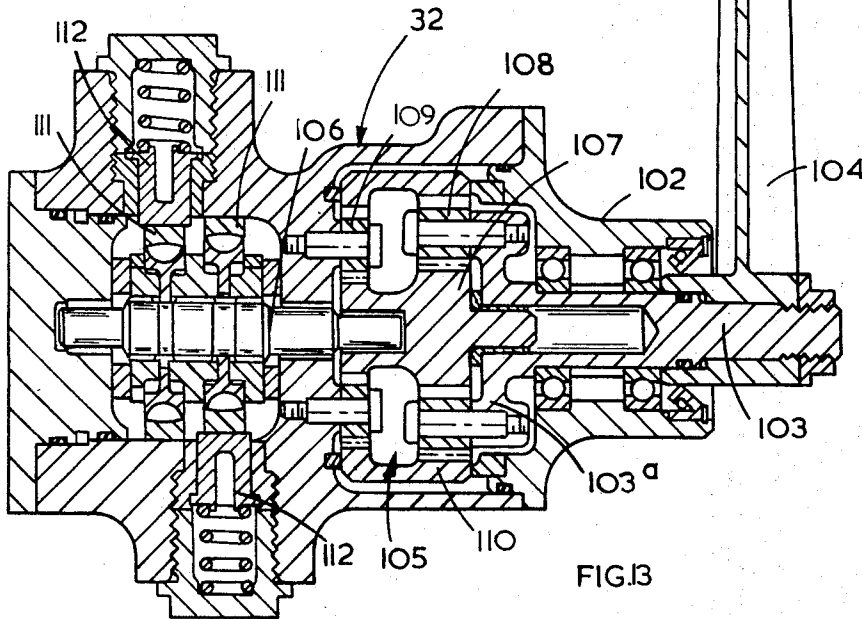


FIG. 13

HYDRAULIC ENGINE STARTING SYSTEMS

This invention relates to an hydraulic engine starting system. An engine starting system in accordance with the invention comprises an accumulator, a pump for charging the accumulator and connected thereto by a non-return valve, drive means for driving said pump, an engine starting motor and valve means controlling the connection of said engine starting motor to said accumulator so that on actuation of said valve means liquid is discharged from the accumulator into the motor.

The drive means may comprise a clutch which is engaged when charging of the accumulator is required.

The clutch is preferably fluid pressure actuated and is connected to an hydraulic circuit associated with the engine such that hydraulic pressure is normally present in said circuit when the engine is running, said clutch being opened when the pressure in said circuit is below a predetermined value.

According to a further feature of the invention the pump driving motor is the same motor as that which is driven by the accumulator, valve means being provided for connecting the accumulator to the motor and to prevent discharge of liquid from the accumulator into said hydraulic circuit.

According to a further feature of the invention the motor has a constant flow servo-control for varying the displacement of the motor, said servo-control comprising means for producing a signal pressure varying with the rate of liquid flow through the motor, and a pressure sensitive displacement control device for decreasing the displacement of the motor as the flow rate increases.

Preferably, where the motor is, as above described, used both for driving the accumulator-charging pump and for engine starting, said pressure sensitive displacement control device includes biasing means sensitive to the pressure in said hydraulic circuit so as to decrease the displacement of the motor for a given flow rate when pressure is present in said hydraulic circuit. In addition, means may be provided for changing the maximum displacement of the motor, so as to increase the displacement when the clutch is engaged.

According to a further feature of the invention the displacement control device of the motor includes temperature sensitive means controlling the position of a maximum displacement stop in the motor, whereby the maximum displacement of the motor is decreased when the ambient temperature rises.

According to yet another feature of the invention the system includes an auxiliary pump for charging the accumulator said pump having automatic displacement control means for reducing the pump displacement as the pump output pressure rises.

An example of the invention is illustrated in the accompanying drawings, in which:

FIG. 1 is a diagram of the complete engine starting system.

FIG. 2 is an end view of an hydraulic pump and motor assembly included in the system.

FIGS. 3 and 4 are sections taken on lines 3—3 and 4—4 in FIG. 2,

FIG. 5 is a section taken on line 5—5 in FIG. 4,

FIGS. 6 and 7 are sections taken on lines 6—6 and 7—7 in FIG. 3,

FIG. 8 is a section taken on line 8—8 in FIG. 2,

FIG. 9 is a section showing a shut-off valve included in the system,

FIG. 10 shows a selector valve included in the system,

FIG. 11 shows a pilot valve device for the selector valve,

FIG. 12 shows a relief valve which is included in the system, and

FIG. 13 is a section through a manual auxiliary pump used in the system.

The system is required to start a small gas turbine engine which may be employed in an aircraft to start the main engines and to operate various auxiliary systems while the main engines are not in use. This engine 20 or the main engines of the aircraft are arranged to drive an hydraulic circuit 21 so that pressure is not present in said circuit whenever the main engine is running. For starting the engine 20 there is provided an hydraulic starter motor 22 which is driven to turn the engine by liquid discharged from either of the accumulators 23 or 24. The motor 22 is a double row radial piston machine with a servo-control 25 for varying the stroke thereof. For discharging the accumulators through the motor there is provided a selector valve 26 which is controlled by a pilot valve 27. For charging the accumulators a pump 28 is provided which can be coupled by a clutch 29 to the motor 22. The clutch 29 is hydraulically operated and is engaged only when pressure is present in the hydraulic circuit 21. During charging the motor is driven by liquid under pressure from the circuit 21 and a shut-off valve 30 sensitive to the pressure at the outlet of the pump 28 is provided for cutting off the supply of liquid to the motor 22 from the circuit 21, when the pump outlet pressure reaches a desired value. A relief valve 31 is provided to allow the accumulators to discharge a small amount of liquid into the aircraft reservoir in the event of the system temperature rising after the accumulators have been fully charged. For emergency purposes there is a manual auxiliary pump 32 which can be used to charge the accumulators 23, 24.

Turning now to FIGS. 2 to 8, the pump and motor assembly is shown in detail therein, although in FIG. 4 the entire rotating assembly has been omitted for simplicity.

As mentioned above, the motor is of the double row radial piston type that is to say it includes a rotor 33 which has a plurality of radial bores therein in two axially spaced rows and pistons 34 slidable in these bores. Each piston carries a slipper 35 which runs on a circular cam track 36. As can be seen from FIGS. 3 and 6, each of the two cam tracks 38 is pivotally mounted and a mechanism 37 is provided for coupling together the two cam tracks 36 to ensure that their eccentricities are equal and opposite. This mechanism 37 consists of a pivoted frame 38 and a pair of rollers 39 which respectively engage the two cam tracks externally. Thus, movement of either cam track 36 towards the mechanism 37 will cause the associated roller to be displaced thereby tilting the frame 38 and transmitting such movement to the other cam track. The rotor 33 is carried on a shaft 40 which projects at one end from the motor casing, and is provided with a coupling device 41 whereby it can be coupled via means not shown to the engine shaft. The opposite end of the shaft 40 has a clutch input member 42 secured thereto.

The motor servo-mechanism includes a piston 43 slidable within a bore in the motor casing and spring-loaded into engagement with one of the cam tracks 36 to urge the cam track 36 to a maximum stroke position, determined by a second plunger 44. The pressure applied to the plunger 43 is controlled by the servo-valve 25 shown in FIG. 8. This valve has a spool 45 which controls the connection of a port 46 (connected to the space behind the plunger 43) either to a high pressure inlet port 47 or to a low pressure drain port 48. The position of the spool 45 is determined by a signal pressure applied to an inlet 49 of the valve 25 to act on one end of the spool, a spring-loading device 50 acting on the other end of the spool. This device comprises a cup member 51 engaging the end of the spool, a spring 52 engaging the cup member 51 and a disc 53 engaged by the other end of the spring 52 and itself engaged on its opposite side by a plunger 54. The plunger 54 is acted upon by pressure in a port 55 which is connected directly to the hydraulic circuit 21.

The motor 22 has a conventional porting system shown, somewhat diagrammatically, in FIG. 7. The motor casing is formed with inlets 56 which communicate with crescent shaped ports 57 in the casing, and aligned crescent shaped ports in a pair of port plates 58 on opposite sides of the rotor 33. These port plates are of crescent shaped configuration arranged so that throughout one half of each revolution of the rotor, each of the passages 59 connecting the bores in the rotor to the porting faces of the rotor communicates with the interior of the housing and throughout the other half of the revolution each passage 59 communicates with the arcuate port 57.

The position of plunger 44 is determined by the pressure in circuit 21 and the pressure which is being applied to the motor inlet 56. The pressure in circuit 21 is applied to one side of the plunger 44 via a drilling 60 in a body 61 in which the plunger 44 is slidable. A second plunger 62 of smaller diameter than the plunger 44 is also slidable in the body 61, and has the motor inlet pressure applied to it via a drilling 63.

The pump 28 is of the fixed displacement double row radial piston type and acts to pump liquid from the hydraulic circuit 21 to the accumulators 23, 24. Thus there is high pressure at both its inlet ports and its outlet ports so that complete annular port plates 64 are required, these engage opposite sides of the rotor 65 of the pump in radial bores in which the pistons 66 are slidable. Slippers 67 on the pistons engage fixed cam tracks 68. The pump shaft 69 is connected to the output member 70 of the clutch 29. This output member 70 is movable by a lever 71 (see FIG. 4) engaged by a plunger 72 to which the pressure from hydraulic circuit 21 is applied to engage the clutch.

Turning now to FIG. 9, the shut-off valve includes a spring-loaded spool 73 slidable in a sleeve 74 formed with a pair of ports 75, 76. The spring-loading of the spool urges the spool to a position such that these two ports are inter-connected. A plunger 77 acts on one end of the spool to urge it against this spring loading when hydraulic pressure is applied thereto. This plunger 77 is subjected to the pressure at the outlet of the pump 28. It will be noted from FIG. 1 that the shut-off valve 30 controls the connection of the hydraulic circuit 21 to the motor inlet 56. A non-return valve 78 which prevents return flow of liquid from the motor to the hydraulic circuit, is provided between the valve 30

and the motor 22. A flow restrictor 79 is connected in a line connecting the outlet of the motor 22 to drain, and the inlet 49 of the servo-valve 25 is connected between this restrictor and the motor outlet.

The pump outlet is connected via a pair of non-return valves 80, 81 to the two accumulators 23, 24 and these accumulators are in turn connected to a pair of inlet ports 82 of the selector valve 26. The outlet ports 83 of the valve 26 are connected via a pair of non-return valves 84, 85 to the inlet 56 of the motor 22. The valve 26 which is shown in FIG. 10, includes two slave cylinder units 86, which operate to lift a frusto-conical closure member 87 out of sealing engagement with a seat 88 in a passage interconnecting the inlet 82 with the associated outlet 83 of the valve 26. The pilot device for operating the valve 26 includes a pair of master cylinder units 89, connected respectively in closed circuits with the two slave cylinder units 86. A manually operable lever 90 is provided for operating the two master cylinder units 89 by means of a rocker arm 91. A detent mechanism is provided for locking the lever 90 in any one of three positions corresponding to positions of the valve 26, in which one of the closure members 87 is closed and the other open, in which both of the closure members 87 are closed, and in which said one of the closure members is open and the other is closed. As shown in FIG. 11, this detent mechanism includes a rod 92 slidable in a bore in the lever 90, a spring 93 acting on the rod 92 to urge it outwardly, a pin 94 extending transversely from the rod 92 to a slot in the wall of the lever 90 and engageable in notches in a plate 95 on which the rocker arm 91 and lever 90 are pivotally mounted. It is necessary to depress the rod 92 into the lever 90 to free the pin 94 from the notch in which it is engaged before the lever 90 can be moved to a new position. The relief valve 31 shown in FIG. 12 has a body 96 with an inlet port 97 connected via a pair of non-return valves 19 to the two accumulators 23 and 24 respectively. A seat 98 in a passage through the housing separates the inlet 97 from the outlet 99. A spring loaded closure 100 engages the seat 98, but moves away from it when the pressure at inlet 97 rises sufficiently high to overcome the spring loading of the closure 100.

The system thus far described operates as follows:

During the charging of the accumulators pressured liquid from the circuit 21 is supplied to the motor inlet 56 and pressure is applied to the plunger 72 to engage the clutch 29 so that the motor 22 can drive the pump 28. Also the plunger 44 which forms the maximum stroke stop for the motor 22 is urged out of the position shown to a slightly withdrawn position, since the pressure in hydraulic circuit 21 being applied to both of the inlets 60 and 63, and the provision of differential areas on opposite sides of the plunger 62 causes withdrawing movement thereof, shut-off valve 30 being open at this stage and the selector valve 26 being shut. The speed at which the motor 22 drives the pump 28 is determined by the servo 25 in combination with the restrictor 79. The pressure applied to the inlet 49 of the servo will depend upon the rate at which liquid is leaving the motor 22. Thus the valve spool 45 will occupy a position such that the force applied to it by the spring 51, exactly balances the force applied to it as a result of the pressure applied at inlet 49. The effect of the pressure from circuit 21 on the plunger 54 is to displace the latter downwardly as viewed in FIG. 8 thereby increasing

the spring loading on the spool 45. Any increase in the pressure applied at inlet 49 will cause the spool 45 to move upwardly as shown in FIG. 8, opening the port 46 to the port 48, and thereby lowering the pressure applied to plunger 43 of the motor and causing de-stroking of the motor. Similarly, a fall in pressure in the inlet 49 causes the spool 45 to move downwardly as seen in FIG. 8 opening the port 46 to the port 47. This has the effect of increasing the pressure applied to the plunger 43 and increasing the stroke of the motor although the maximum stroke is still controlled by the stop provided by the plunger 44. As the accumulators 23 and 24 become fully charged, the pressure at the outlet of the pump 28 rises to a value such that the force applied by the plunger 77 of the shut-off valve 30 to the spool 73 thereof can overcome the spring loading of the spool and thereby disconnect the motor inlet from the circuit 21. The motor 22 thus stops rotating and no further charging of the accumulators occurs. In fact, the valve 30 will take up a slightly open position such that sufficient liquid passes to the motor 22 to replace any system losses, compensate for any temperature reduction and maintain the pressure in the pump outlet at the same level as that in the accumulators. Thus, should the temperature fall whilst the engine 20 is running the accumulators 23, 24 will be kept topped up. Should the temperature rise after the accumulators 23 and 24 are fully charged, the relief valve 31 will open to allow sufficient liquid to leak out to keep the pressure in the accumulators at an acceptable level. When it is required to start the engine 20 the pilot device 27 is operated, so that one of the slave cylinders 86 displaces the associated closure member 87 from its seat 88. Liquid is then discharged from one of the accumulators 23 or 24, via the selector valve to the motor and to the servo valve 25. At this time it will be appreciated that the very much higher pressure stored in the accumulators is applied to the inlet 63 (whilst inlet 60 is at low pressure) so as to move the plunger 44 to the position shown, and thereby reduce the maximum permitted motor displacement somewhat. Since there is now no pressure on the inlet 55 of the valve 25, the plunger 54 returns to the position shown in FIG. 8, thereby decreasing the spring force on the spool 45 somewhat. The result of this is that the spool 45 will be in equilibrium at a somewhat lower speed than when the accumulators are being charged. The clutch, of course, is also disengaged because of the absence of pressure in the hydraulic circuit 21.

It will be noted that a sealed capsule 101 is interposed between the plunger 44 and the cam ring 36. This capsule makes the maximum stroke stop position variable with ambient temperature. As the ambient temperature rises the maximum permitted stroke of the pump is reduced. This provision is made since less torque is required to turn over the engine 20 in warm conditions than in cold conditions.

For charging the accumulators 23 and 24 when no pressure is available in the hydraulic circuit 21, there is provided a manual auxiliary pump 32 which is shown in section in FIG. 13. This pump includes a body 102 with an input shaft 103 journaled into it, a handle 104 on the input shaft 103 and an epicyclic gear-train 105 connecting the input shaft 103 to a pump shaft 106. The epicyclic gear train consists of a planet pinion carrier 103a integral with the input shaft 103, a compound sun gear 107 secured to the pump shaft 106, a larger

toothed portion of the compound sun gear being meshed with pinions 108 on the carrier 103a, further pinions 109 rotatably mounted on the body and meshing with the smaller toothed portion of the compound sun gear 107 and also meshing with a smaller toothed portion of a compound annular gear 110, the larger part of which meshes with the pinion 108. Once again the pump is of the double row radial piston type and in this case the two cam rings 111 are urged by spring loaded plungers 112 to their maximum stroke position, and are de-stroked as the pressure within the piston bores rises urging the cam rings to concentric positions and thus moving the plungers 112 against the spring loading. The manual pump is connected to the two accumulators via non-return valves 113 and 114.

We claim:

1. An hydraulic engine starting system comprising an accumulator, a pump for charging the accumulator, and connected thereto by a non-return valve, a clutch for drivingly connecting said pump to a prime mover when charging of the accumulator is required, an engine starting motor and valve means controlling the connection of said engine starting motor to said accumulator so that on actuation of said valve means liquid is discharged from the accumulator into the motor, said clutch being fluid-pressure actuated and being connected to an hydraulic circuit associated with the engine such that hydraulic pressure is normally present in said circuit when the engine is running, said clutch being disengaged when the pressure in said circuit is below a predetermined value.
2. A system as claimed in claim 1 in which said clutch is connected to said motor so that the pump is driven by the motor when the clutch is engaged.
3. A system as claimed in claim 2 in which the motor has a constant flow servo-control for varying the displacement of the motor, said servo-control comprising means for producing a signal pressure varying with the rate of flow of liquid through the motor, and a pressure sensitive displacement control device for decreasing the displacement of the motor as the flow rate increases.
4. A system as claimed in claim 3 wherein, said pressure sensitive displacement control device includes biasing means sensitive to the pressure in said hydraulic circuit so as to decrease the displacement of the motor for a given flow rate when pressure is present in said hydraulic circuit.
5. A system as claimed in claim 4 in which means are provided for increasing the maximum displacement of the motor when the clutch is engaged.
6. A system as claimed in claim 3 in which there is provided temperature sensitive means controlling the position of a maximum displacement stop in the motor whereby maximum displacement of the motor is decreased as the ambient temperature rises.
7. A system as claimed in claim 1 in which there are a pair of accumulators connected by non-return valves to the outlet of the pump and a selector valve for selectively connecting said accumulators to the motor.
8. A system as claimed in claim 7 in which the selector valve is pilot operated.
9. A system as claimed in claim 1 further comprising an auxiliary pump for charging the accumulator, said auxiliary pump having automatic displacement control means for reducing the auxiliary pump displacement as the auxiliary pump output pressure rises.
10. A system as claimed in claim 9 in which the auxiliary pump is of the radial piston type including a cam ring spring-loaded to a position of maximum eccentricity and movable in a direction to decrease its eccentricity by the loads applied thereto by the pistons.

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