This invention relates to fluid pressure control systems in which a selectivel operator electric motor-driven pump with its motors are submerged, inaudited, or immersed in the fluid medium of the fluid pressure system. A further object of this invention is to provide a pump and driving mechanism therefor that may be operated for supplementing a system operated pressure developing unit under conditions where the normal flow is insufficient, and that may be operated or submitting or replacing a system operated pressure developing means at any time.

A further object of the invention is to provide an additional pressure developing means adapted for use in a rotation pressure system including a reservoir, control apparatus and a self operated pressure developing means, which additional pressure developing means may be operated while the structure is rotating to supplement the self operated means, and may be operated while the structure is not rotated to substitute or replace the self operated means.

According to the description, an electric motor is enclosed in a housing that is substantially fluid tight for openings through which fluid flows from the control apparatus may pass, pass through the motor housing around the rotor and windings and then exit to a switch or baffle. The motor drives a gear pump and has a fluid connection to the system and from the interior of the motor housing, the pump and motor as a unit being mounted in the rotatable reservoir so as to be immersed in the fluid medium thereof. The pump is always primed and the motor windings and bearings are cooled by the return flow from the system. Bush and slip rings provide means for selected operation of the motor-driven pump whether the structure be at rest or rotating.

Fig. 1 is a schematic showing laid out as a longitudinal section of a rotatable structure, in this instance an hydraulically controlled propeller, in which the instant invention is embodied.

Fig. 2 is a front elevation view of a motor-driven pump, as indicated by the arrow 2 of Fig. 4. Fig. 3 is a rear elevation view. Fig. 4 is an axial sectional view of the motor-driven pump substantially as indicated by the line and arrows 4—4 of Fig. 3.

Fig. 5 is a fragmentary showing in section substantially as indicated by the line and arrow 5—5 of Figs. 2 and 3. Fig. 6 is a transverse sectional view through the terminal board substantially as indicated by the line and arrow 6—6 of Fig. 2, and showing the manual and method of conveying electric current to the motor.

Fig. 7 is a transverse sectional view through the motor housing substantially as indicated by the line and arrow 7—7 of Fig. 4.

Figs. 8, 9 and 10 are fragmentary views illustrating the relation of a motor-driven pump and its rotatable mounting, substantially as indicated by the motors 10 and 16.

With reference to the drawings, and first referring to Fig. 1, a rotatable assembly or unit is shown in which a fluid pressure system is embodied that is primarily energized by a pump responding to rotation of the assembly for supplying a pressure line leading to control valves for controlling the application of fluid pressure to either side of a hydraulic fluid pressure motor upon the communication of control valves by the control means 10—16 automatically or manually controlled means.

In this instance the rotatable unit comprises an aircraft propeller 10 driven by a shaft 12 having bearing 14 in a gear casing or engine housing 16 as is the usual practice. The propeller unit comprises a hub 18 with pitch shiftable blades 20 having bearings 22 in sockets 24 radiating from the hub 18. Each blade is shifted in pitch by a rotatable cylinder 26 engaged thereto and to a blade gear 28 by a dowel or like device 30.

Within the cylinder 26 there is a piston 32 having a helically engaged engagement at 34 with the cylinder 26, and a helically engaged engagement at 36 with a spindle 38 radiating from the hub 18. The piston 32 divides the cylinder 26 into a decrease pitch chamber 40 and an increase pitch chamber 42. It is understood of course, that each fluid pressure servomotor comprises a rotatable cylinder with a piston 32, and that each blade 20 is provided with such servomotor and that all are interrelated by a master gear 44 meshing with all blade gears 28 so as to coordinate and correlate or equalize the blade movements in a pitch shifting sense. All of the pitch decrease chambers 40 are connected by passage 46 and joined to a common conduit 48 that opens at one end to a decrease pitch port 50 of a governor valve 52. All of the increase pitch chambers 42 are connected together by passages 54 and joined to a common conduit that opens at one end to an increase pitch port 58 of the governor valve 52. A pressure supply port 60 opens to the governor valve 52 between the ports 50 and 58 and leads by a conduit 62 to a chamber 64 of a pressure control valve 66 which chamber is also connected by passage 68 to a chamber 70 having a pinion 72 mounted for rotation by gear 74 carried by an adapter assembly 76.

The governor valve 52 provides a bore 78 within which is movable a valve plunger 80 that has lands 82 and 84 cooperable with the ports 50 and 58 respectively for controlling the flow of fluid pressure from the source port 60 to either side of the servo motor piston 32. A lever 86 is articulated to the plunger 80 and is urged into engagement with a movable fulcrum 88 by a spring 90, the governor valve 52 being so mounted that the bore 78 is radially disposed with respect to the axis of rotation O and is responsive to centrifugal force in opposition to the force of spring 90 to vary the radial position of valve plunger 80 in the bore 78, an equilibrium position being reached when the lands 82 and 84 cover the ports 50 and 58. The point at which equilibrium will be reached is effected by a control ring 92 operable to move the fulcrum 88 to different positions along the length of the lever 86.

Screw shafts 94 threading into the control ring 92 have journals in the gear housing 74 and terminate with pinions 96 engageable with a circular rack 98 whose oscillation is controlled by a manual lever 100.

The pressure regulator valve 66 includes a plunger 102 providing a pressure piston 104 movable in a chamber 106 communicating by passage 108 with the control means 10—16 connected with the increase pitch chambers 42 of the servomotors and with the increase pitch port 58 of the governor valve. The piston 104 is therefore exposed on one side to the pressure existing in chamber 106 and on the other side to the pressure existing in the chamber 64 and is so constituted as to operate in the metering sense to varyingly close an exhaust port 110 for relief of excessive pressure in the pump line 62. This valve is responsive to centrifugal force and is assisted in radial outward movement by means of a spring 112 so that the potential of pressure maintained in the pump line 62 will be relatively low upon on-speed operation, but will immediately be stepped up according to pressure demand when the governor valve directs fluid pressure to either control port.

The foregoing defines a rotatable structure embodying a self energizing fluid pressure system with control means adapted to direct fluid pressure to either side of the servomotor to control blade movement as called for by either the manual means 10—16 or by changing the fulcrum 88 to call for some specific speed setting, or by call of the hydraulic fluid pressure motor upon the communication of control valves by the control means 10—16 automatically or manually controlled means.
tor, or rather the reservoir 118, is closed off by the adapter assembly 76 through the use of proper seals, though not so shown. The adapter assembly is retained against rotation by lugs 120, and the adapter by means of lugs and alignment means 120 provided by the adapter assembly 76 and gear casing 16. By that means, when the propeller rotates, which is accomplished by the shaft 12 of the rotor, rotates with respect to the adapter assembly such that the pump gear 72 rolls around the gear 
74, and so that a shoe 122 of the fulcrum carriage slides in a groove of the monitor ring 92. The cover 116 of the monitor also rotates with respect to the adapter assembly and with respect to the gear casing.

That construction provides for automatic development of pressure potential whenever the propeller is rotating, but does not provide any source of pressure while the propeller is not rotating. In some constructions, and particularly in that for the present propellers, there is a need for a pressure potential at times when the propeller is not rotating, and sometimes it is desirable to supplement the flow of fluid in the system while the propeller is rotating. That need is particularly desirable when blade pitch changes of considerable magnitude are desired or are called for. Some of those needs might arise at the conclusion of feathering, or at the change into or out of negative pitch, or to changes of great magnitude within the governing range of the propeller operation. A motor driven pump 130 is therefore provided with control means so that it may be operated at any time with a waveform bearing the propeller is rotating or not. In this embodiment as shown in Fig. 1 a pump 132 is driven by a motor 134 and shaft 136 energized by the leads 138, 140 and 142 forming a cable 144.

The motor is enclosed in a housing 145 from which a port 146 opens to the pump 132 whose delivery passage 148 connects with a check valve 150 opening into the pressure source line 62. The valve 150 is so constituted that fluid under pressure may flow from passage 148 into conduit 62, but that fluid in the conduit 62 may not flow into the passage 148. A pump control valve 152 connects between the pump 132 and the pressure line 62. The valve unit 152 provides a bore 156 which opens by port 158 into the low pressure side of the relief valve 150 and also opens by port 160 into the pressure line 148 communicating with the pump 132. Slidable within bore 156 there is a plunger 162 urged radially inward by a spring 164 and having a piston face 166 always with the relief valve 150 and also opens by port 160 into the pressure line 148 communicating with the pump 132. The motor housing 145 also has an opening 174 into a scavenge or baffle 176 surrounding the motor housing and exhausting at 178 into the reservoir 118. The scavenge 170 also collects drain or return flow fluid medium from the blade servomotors by way of the governor valve 52. Each end of the bore 78 is open by ports 180 or 182 that lead to a passage 184 connecting with the sump 178 as shown in Fig. 1. Drain of fluid from either chamber 40 or 42 of the servomotor follows passage 46, or 54, conduit 48 or 56, through port 50 or 58 and 180 or 182 then through 184 to 174, which also collects return fluid from the pump control valve 152 if the output of pump 132 is not connected with the system trunk line 62. By returning all drain from the servomotors and the control valves to the sump 178 there is collected a mass of cool fluid which goes through the openings 172 of the motor housing, between the motor parts and out the opening 174 to the closed end of the sump from where it empties into the reservoir 118 at 178. The pump 132 is therefore always provided because it is from the interior of the motor housing, and the windings and bearings of the motor driving the pump are adequately cooled by the return of the fluid from the blade servomotors.

The described construction of the motor driven pump is illustrated by Figs. 2 to 7 inclusive of the drawings, to which reference is now made. Motor end frame 186 provides a secured mounting. The jacket of the armature shaft 136 that supports armature laminations 196 fitted with conductors 198 axially disposed within the stator laminations 200 carrying field windings 202. The other end of the armature shaft 136 has bearing in a bushing 204 secured in one end of the motor housing 145. The motor housing 145 is of cup form. The armature ring 206 surrounds a flange 208 of the end frame 190, a seal 210 being disposed between them. The stator of the motor is thus enclosed within a sealed chamber provided by the end frame 190 and the housing 145.

A space plate 212, and a mounting plate 214 are clamped against the flat face of the end frame 190 by bolts 216 where they are localed by pins 218. The end 212 is appropriately apertured to receive a pair of gears 228, 230 constituting the pump 132.

Along a tangent to the contacting pitch lines of the gears a channel 222 is formed in the space plate 212 to connect pump intake port 146 with a pump outlet port 224. As shown in Fig. 5 the pump intake port 146 is formed by aligned holes in the end member 119 and the space plate 214 and is disposed in one end of the channel 222. The pump outlet port 224 is formed by a bore through the plate 214 communicating with the other end of channel 222. As shown in Figs. 3 and 4 the passages 172 connecting the sump 170 with the interior of the motor housing are formed by a plurality of drill ways through the motor housing 145 and the mounting plate 214. As shown in Fig. 4 the pump gear 232 has axial extensions 226 and 228 having journal bearings in the mounting plate 214 and member 119 respectively. The gear 232 has a similar bearing and support. The axial extension 228 of the pump gear 220 protrudes from the mounting plate 190 to be concentric with the shaft 192 and has driven engagement with the motor shaft 136.

Mounted on the outside of the motor housing 145 the scavenge 170 covers the opening 174 and extends about three-quarters of the way around the motor housing 145 and is mounted to the housing 145 by bolts 176 to the open end 178. The other end of the scavenge 170 is closed by a head member 230 so that fluid exit from the opening 174 must follow the contour of the scavenge 170 before it can enter into the reservoir at 178. The cable 144 by which electrical energy is put into the control unit 132 is substantially as shown in Figs. 4, 5, 6 and 7 where the cable 144 extends from the cable 142 and exposes the leads 138, 140 and 142 for passage through the opening 174 to the motor windings 202, and supports them at the other end on a terminal board 222 which is carried by brackets 234 provided by the mounting plate 214. The terminal board and terminal construction are shown in detail in Fig. 6 where a non-conducting body 240 is provided with terminals 236, 240, and 242 to which the leads 138, 140 and 142 are electrically connected. The non-conducting plate 244 covers the terminal junctures and is supported by the brackets 234 by means of rivets 246 or the like.

The motor-driven pump 130 as so constituted forms a sealed motor and pump unit adapted for mounting in the regulator of the regulator with the propeller by means of bearing bolts or other screw devices through apertured lugs or ears 248 of the mounting plate 214 and threading them into the body of the regulator plate 119. Fig. 4 and 5 show the unit mounted in that fashion where it will be observed that the regulator plate 114 provides a large recess or well for the pump 170 over which the motor driven pump is mounted. A circumferencing groove receives a seal ring 250 which is under compression when the motor unit is mounted on the regulator plate, thus preventing flow from the sump 170 except through the passage 172, through the motor housing, through the aperture 174 and around the scavenge 170 to exit 176. The drain back or return flow of fluid from the system enters the well 170 by means of a port 252 as a terminus of the drain passages 168 or 184. When the motor driven pump is first mounted the electric leads of the cable 144 are joined to brushes 254, 256, and 258 insulatingly supported in the motor housing 145. The brushes engage electric slip rings 260, 262 and 264 insulatingly supported by a plate 266 stationary with respect to the gearing 16. Conductors 268, 270 and 272 connect the slip rings 260, 262, and 264 to the switch 274 adapted to control the application of electrical energy from a power source over the line cable 276, the electrical potential being in the order of 200 volts, three phase, 400 C. P. S. The switch 274 may be a gung switch operated by a solenoid 278 through closure of a
5 manual switch 280 leading to a current source of suitable characteristics. Reference is now made to Figs. 8, 9 and 10, for features of mounting and operation of the motor-driven pump, the several views being disposed to show the relation of the motor, pump, mounted on an annular plate 114, revolves about the rotor 300 center O,D. When the pump unit is mounted on a pump bearing 222, it will be noticed that the channel 222 extends substantially radial of the plate 114 as it rotates about the center O,300. In Fig. 5, the channel 222 connects by port 246 with the interior of the motor housing at one end, and at the other end connects the port 222 in a pad 284 embedded in the plate 114 and opening into a channel 148 through port 286. In Figs. 8, 9 and 10 the output passage 148 and the drain-back passage 184 by which the pump 170 is supplied from the fluid acting line, free from air because they are embodied in the body of the plate 114.

When the propeller is conditioned for operation, the regulator is filled about half full for the fluid medium by which the control is to be effected. If Figs. 8, 9 and 10 can be regarded as a complete regulator, then the fluid medium will be substantially at the level D — D, and under static conditions the pressure will be in any position below that line which will be wholly immersed in the fluid medium. If it be assumed that a condition of great depression of fluid pressure has taken place, and the regulator is not rotating, there is still an ample supply of fluid in the motor housing to prime it if its use is desired while the propeller is at rest. The minimum level of fluid in the motor housing in cases of Figs. 8, 9 and 10 is indicated by the lines marked by the letters S—L. If the propeller is rotating, then the fluid in the regulator will lay along the outer periphery of the reservoir some 56 feet indicated by the curved line indicated by the letters R-S in Figs. 8, 9 and 10. The outlet from the scroll 176 is immersed to such extent that fluid is always available for the pump which, in addition to the fact that with each rotating cycle of the propeller pump and forced into the system through the passage 148, there is an equal volume leaving the system by either the control valve 152, or the governor valve 52, the drain back from which is led by the passages 168 and 184 to the sump 170. The return fluid reaching the sump 170 must flow through the motor housing before it can reach the pump 122 to return to the system, or return to the reservoir, and therefore aids in cooling the bearings and windings of the motor.

The embodiment of the present invention as herein disclosed, constitutes a preferred form, it is to be understood that other forms might be adopted. What is claimed is as follows:

1. A fluid pressure control system for a rotatable aircraft propeller including a plurality of blades, the combination comprising, a reservoir containing a fluid pressure medium, a propeller having a plurality of blades mounted for rotation about their longitudinal axes to alter the pitch thereof, fluid servo-motors operatively connected to said blades for changing the pitch thereof, means within the reservoir and operable upon rotation of the propeller for creating from said fluid pressure medium a source of fluid pressure, means rotatable with the propeller for direct application of said fluid pressure to the servo-motors for effecting the rotation of said blades, an electric motor-driven pump mounted in the reservoir and immersed in the fluid medium thereof, a housing enclosing the electric motor and opening to the reservoir, a sump chamber collecting the exhausted fluid medium from the fluid servo-motors, an outlet from the sump into the motor housing whereby the return flow of fluid medium from the fluid servo-motors to the reservoir must pass through the outlet for the pump connected with the motor housing, source of fluid pressure control means for connecting the pump outlet with the source of fluid pressure, and means controlling the operation of said electric motor.

2. In a fluid pressure system for the control of blade pitch in an aircraft propeller by direct application of fluid pressure to and from blade actuating servo-motors, the combination comprising, a rotatable propeller having a plurality of blades mounted for rotation about their longitudinal axes to different pitch positions, fluid pressure operated servo-motors operatively connected to said blades for adjusting the pitch position thereof, a reservoir rotatable with the propeller and containing a quantity of fluid medium, means within the reservoir for continuously placing a portion of said fluid medium under pressure during rotation of the propeller center O,300, so directed to and returned from the blade actuating servo-motors and the reservoir and immersed in the fluid medium thereof, a housing enclosing the electric motor and pump driven thereby mounted in the interior of said motor housing, a circumferential passage leading from the interior of the motor housing and opening to the said reservoir whereby return flow from the blade actuating servo-motors to the reservoir operates to cool the electric motor, means connecting the outlet of said pump to the fluid pressure system, and means tending to adjust the operation of said electric motor and pump whether the propeller be rotating or not rotating.

3. A fluid pressure system for the control of blade pitch of an aircraft propeller operable in constant speed, feathering and negative pitch regime by application of fluid pressure to said return flow from double acting servo-motors, comprising in combination, a rotatable propeller having a plurality of blades mounted for rotation about their longitudinal axes to different pitch positions, double acting fluid pressure operated servo-motors operatively connected to said blades for changing the pitch position thereof, a reservoir rotatable with the propeller and containing a quantity of fluid medium to be applied to the servo-motors, means within the reservoir and operable during propeller rotation for placing a portion of said fluid medium under pressure, a valve for applying the fluid medium under pressure to either side of the double acting servo-motors for controlling the return flow of fluid medium from the said motors, means operable manually upon the valve unit for selecting the direction of application of fluid medium to and return flow from said servo-motors, an electric motor the housing of which is immers ed in the fluid medium thereof, passage means for conducting the return flow of fluid medium from the servo-motors to the interior of the electric motor, means connecting the outlet of said pump with the interior of the motor and the outlet thereof with the system, and manually operable means for controlling the actuation of said electric motor and pump.

4. The combination set forth in claim 3, wherein a pressure actuated valve controls the connection of said pump output with said system and responds to the fluid medium under pressure produced by said motors within the reservoir for disconnecting the output of the motor driven pump from the system.

5. The combination set forth in claim 3 wherein the manual means operable upon the valve unit for adjusting a propeller operation in either the feathering or negative pitch regime, and a pressure responsive valve subject to the diminution of fluid under pressure by the rotating propeller is used for connecting the output of the motor driven pump with the system near the end of propeller operation in the feathering regime, and means including said pressure responsive valve subject to the diminution of fluid under pressure by the rotating propeller and means for connecting the output of the motor driven pump with the fluid medium under pressure by means of said responsive valve when feathering, unfeathering and negative pitch operation of the propeller.

6. In a fluid pressure system having a rotatable propeller partially filled with a fluid medium, an electric motor driven pump adapted to be immersed in the fluid medium of the reservoir and operable to deliver the fluid medium under pressure to the system, a housing enclosing the motor and having an opening to the reservoir, means connecting the return flow from the system to the motor housing for cooling of the motor, passage means for connecting the pump inlet with the interior of the motor housing, and means connecting the outlet of the reservoir to the pump inlet so that the pump is always primed by the fluid medium within the motor housing.

7. The combination set forth in claim 6 wherein a circular scroll extends from the opening of the motor housing more than half way around the motor housing, the
end of said scroll adjacent the motor housing opening being closed and the other end of said scroll being open, said scroll being so located that a predetermined level of fluid medium for priming the pump is maintained in said motor housing irrespective of the angular position of the rotatable reservoir.

8. In a fluid pressure system, a rotatable structure constituting a reservoir which is partially filled with fluid medium, said rotatable structure including a plate member and a cover member, means constituting a sump chamber in said plate member, an electric motor having a housing attached to said plate member, said housing having an opening communicating with said sump chamber and through which exhaust of fluid from the sump chamber must flow, a pump driven by said electric motor, said pump having an intake communicating with the interior of said motor housing and an outlet connected with the system, passage means connecting the return flow from the system to said sump chamber, and means constituting an outlet passage from said motor housing communicating with said reservoir, said outlet passage being so located that irrespective of the angular position of said rotatable structure, a predetermined level of fluid medium for priming the pump is maintained in the motor housing.

9. In a fluid pressure system, the combination including, a first source of fluid pressure, a system supply passage, a second source of fluid pressure comprising an electric motor driven pump, a sump chamber from which said pump draws fluid, first passage means directing fluid flow from said sump chamber to said pump through said motor whereby cooling of said motor is effected, and second passage means connecting the output of said pump to said system supply passage including a check valve, one side of which is exposed to the pressure of said system passage and the other side of which is exposed to the pressure output of said pump, and a pressure relief valve having an inlet port connected with the output of said pump, an outlet port connected to said sump chamber, and a plunger having a surface exposed to the pressure in said system passage whereby communication between said second passage means and said system supply passage is blocked and the output of said pump is diverted to said sump chamber when the pressure in said system supply passage is above a predetermined potential.

References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,347,732</td>
<td>Cooper</td>
<td>July 27, 1920</td>
</tr>
<tr>
<td>2,229,058</td>
<td>Dicks</td>
<td>Jan. 21, 1941</td>
</tr>
<tr>
<td>2,291,953</td>
<td>Dicks</td>
<td>Aug. 4, 1942</td>
</tr>
<tr>
<td>2,356,243</td>
<td>Huber</td>
<td>Aug. 22, 1944</td>
</tr>
<tr>
<td>2,356,306</td>
<td>Davis</td>
<td>Aug. 22, 1944</td>
</tr>
<tr>
<td>2,556,435</td>
<td>Mochri et al.</td>
<td>June 12, 1951</td>
</tr>
<tr>
<td>2,611,440</td>
<td>Haworth et al.</td>
<td>Sept. 23, 1952</td>
</tr>
</tbody>
</table>