Nov. 7, 1933. C. B. TAYLOR 1,934,633

PRIME MOVER CONTROL SYSTEM

Filed March 23, 1932 3 Sheets-Sheet 1

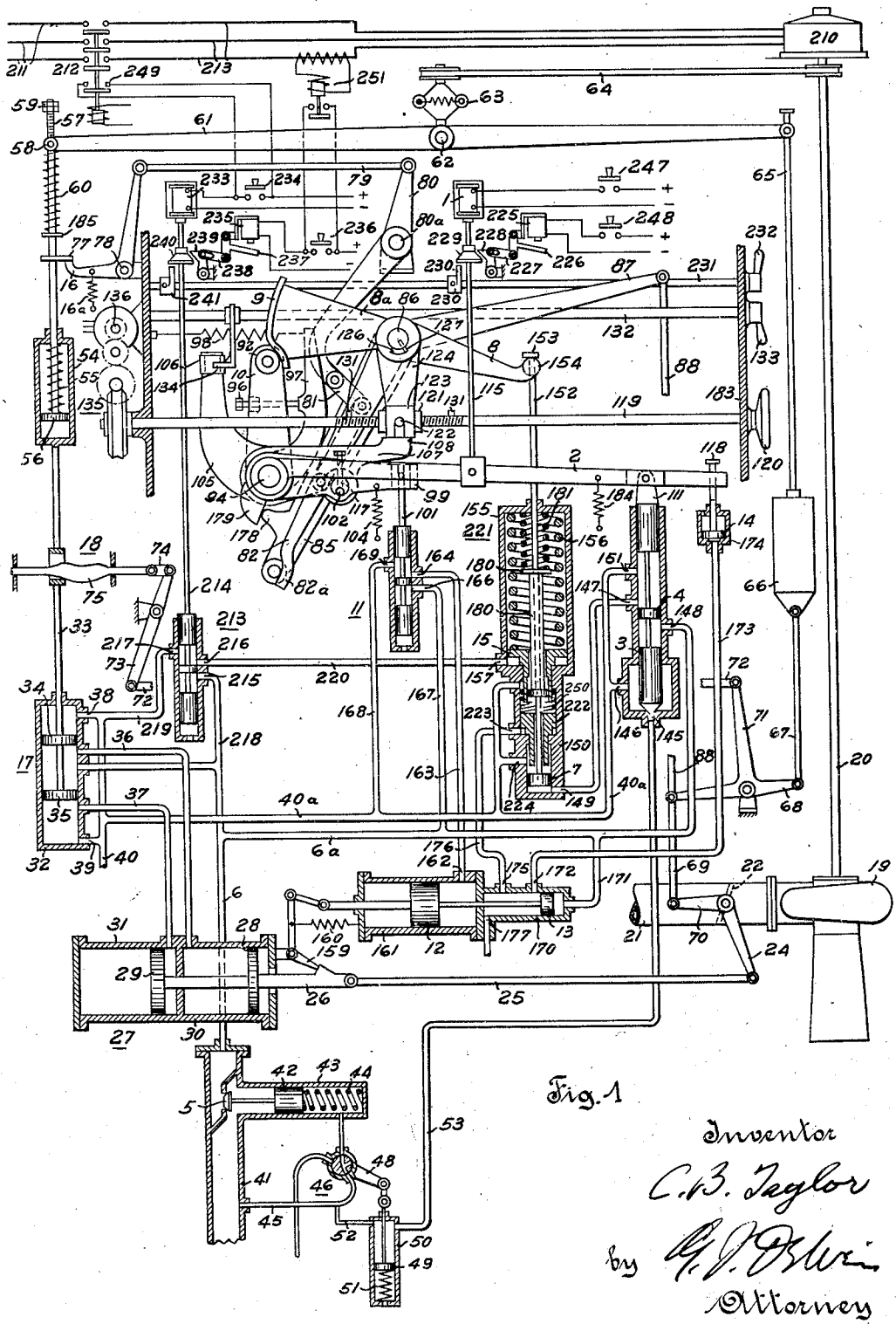

Fig. 1

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Nov. 7, 1933. C. B. TAYLOR 1,934,633

PRIME MOVER CONTROL SYSTEM

Filed March 23, 1932 3 Sheets-Sheet 2

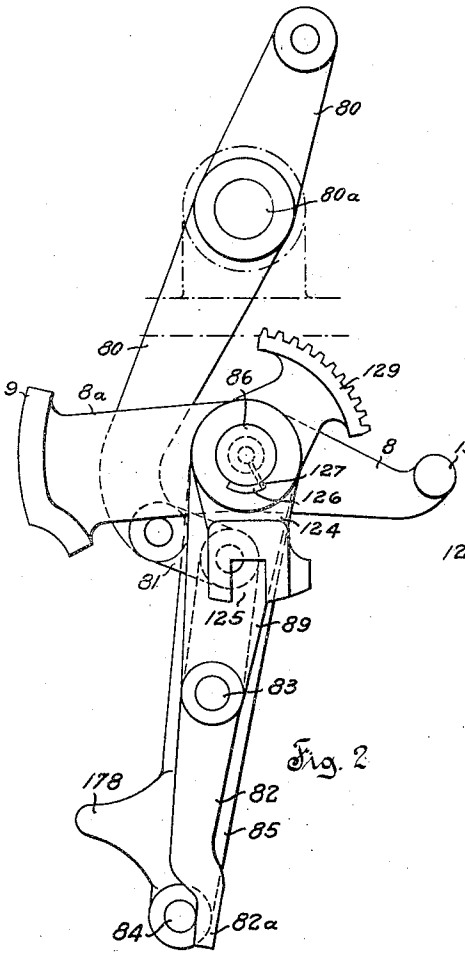

Fig. 2

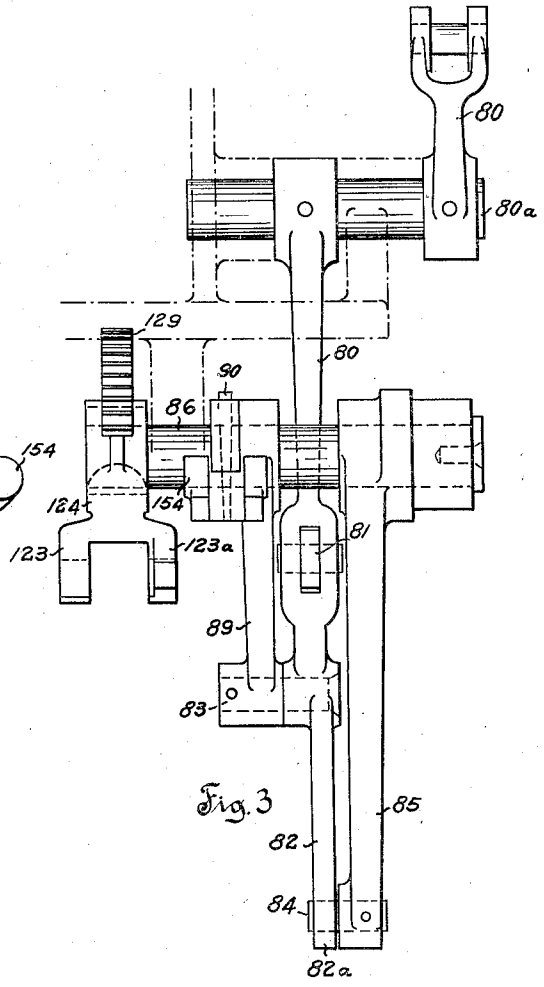

Fig. 3

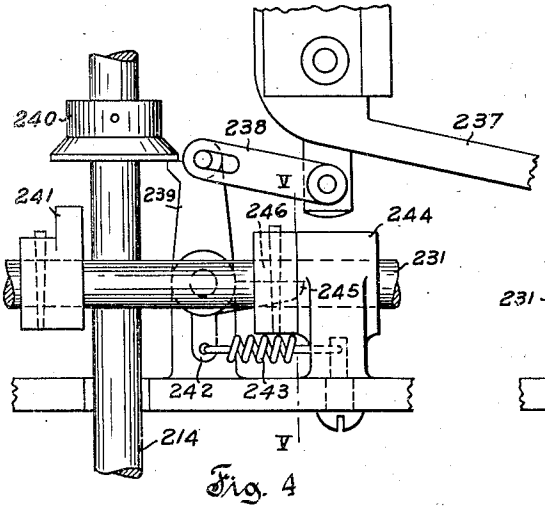

Fig. 4

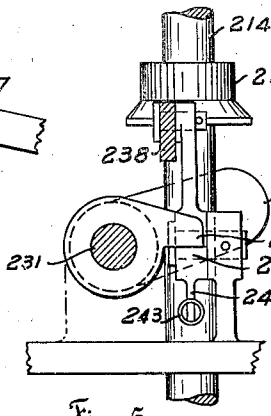

Fig. 5

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PRIME MOVER CONTROL SYSTEM

Filed March 23, 1932 3 Sheets-Sheet 3

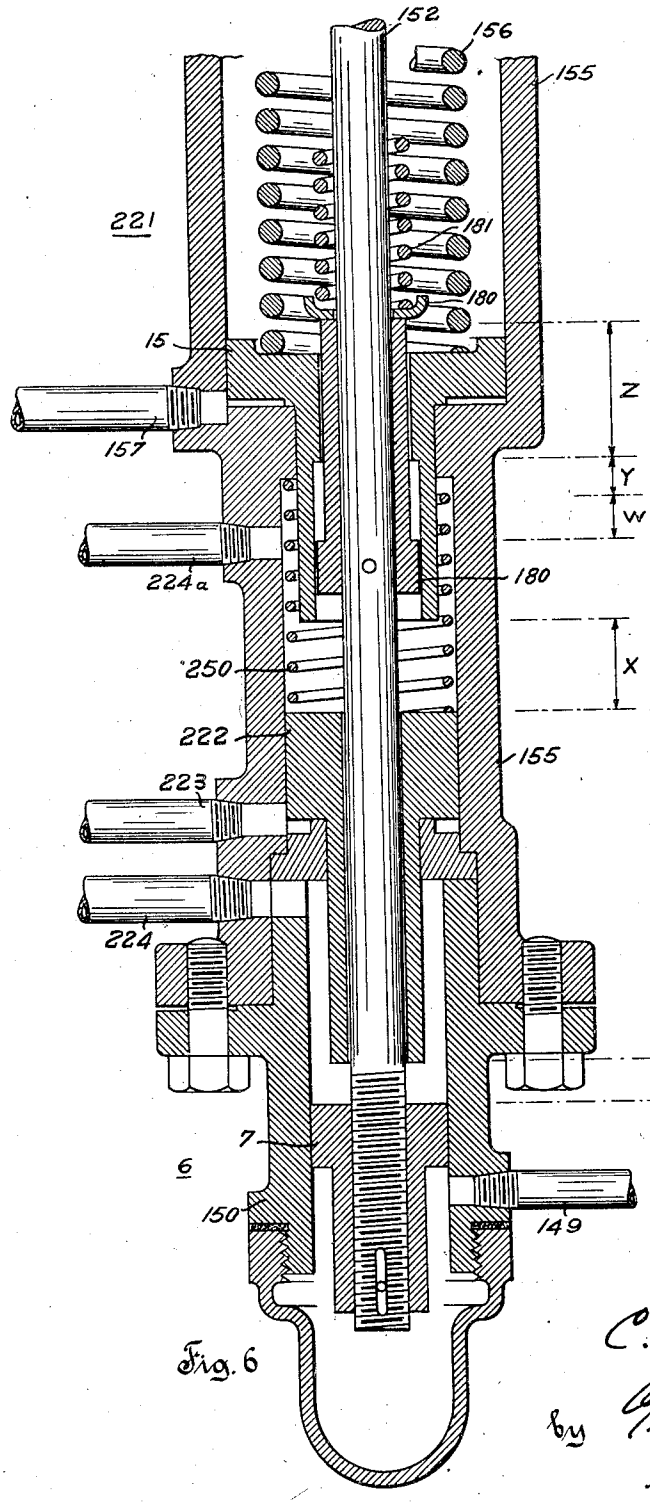

Fig. 6

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UNITED STATES PATENT OFFICE

1,934,633

PRIME MOVER CONTROL SYSTEM

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7 Claims. (Cl. 137—158)

This invention relates in general to prime mover control systems of the type shown in the Taylor et al. Patent No. 1,761,596, granted June 3, 1930, in which the prime mover is either automatically or manually started from rest, and relates, more particularly, to improvements on such systems whereby the gate for controlling the flow of operating fluid to the prime mover is caused to open during starting to a predetermined position corresponding substantially to normal speed without load and is subsequently permitted to open farther under the control of a speed governor.

One of the objects of this invention is to provide a prime mover control system in which the gate is caused to return to a predetermined position by manual control means or automatically upon occurrence of an abnormal condition on the prime mover or load device connected thereto, so that the prime mover can run at substantially normal speed at reduced load until the abnormal condition is removed.

Another object of this invention is to provide a prime mover control system in which starting, partial gate opening, and stopping is initiated by fluid pressure actuated devices controlled by valves which may be actuated either manually at a place near said devices or electromagnetically from a distance.

A further object of this invention is to provide a prime mover control system in which a load limiting device is utilized to return the gate to a position corresponding to no load idling speed in response to the tripping of a valve device, and to return the gate to fully closed position in response to the tripping of another valve device.

These and other objects and advantages are attained by this invention, various novel features of which will be apparent from the description and drawings herein and will be more particularly pointed out in the claims.

An illustrative example of the application of this invention is shown in the accompanying drawings, in which:

Figure 1 is a front elevation in diagrammatic form of a control system embodying the invention as it may be utilized in the control of a prime mover generator unit;

Figure 2 and Figure 3 are detailed views of certain lever assemblies used in the system shown in Figure 1, Figure 2 being a front elevation and Figure 3 a side elevation; and

Figure 4 and Figure 5 are detailed views of certain manually operable valve actuating and tripping mechanism shown in Figure 1, Figure 4 being a side view, and Figure 5 being a sectional view taken along V—V of Figure 4; and

Figure 6 is an enlarged view of an auxiliary servo-motor of the type shown in Figure 1.

Referring now to Figure 1 of the drawings, a prime mover 19 is here indicated as a hydraulic turbine having a shaft 20 adapted to drive a load device such, for example, as an electric generator 210. The turbine is supplied with operating fluid through a conduit 21 in which is interposed means for controlling the admission of operating fluid to the turbine, this means being here shown for the sake of simplicity as a gate 22, it being understood that the turbine may be controlled by other forms of gates including the usual guide vanes in the casing of a hydraulic turbine. The gate 22 is operable by servo-motor 27 through crank 24, connecting rod 25, and piston rod 26. Servo-motor 27 has, in this particular instance, two pistons 28 and 29 arranged in cylinders 30 and 31, respectively.

Servo-motor 27 is controlled by means of regulating valve 17 which is provided with a cylinder 32 in which are disposed two piston valves 34 and 35 which are movable in unison and are operable by means of a valve stem 33. The cylinder 32 has a pair of outlet ports to which pipes 36 and 37 are connected, respectively. Pipe 36 is connected to cylinder 30 and pipe 37 is connected to cylinder 31 of servo-motor 27. The regulating valve cylinder 32 is also provided with drain ports connected to drain pipe 40 by means of pipes 38 and 39.

Servo-motor 27 and other parts to be hereinafter described are supplied with fluid under pressure through a pressure supply pipe 41 which is fed from a pressure reservoir (not shown) of any desired form. The supply of pressure fluid is controlled by means of a shut-off valve 5 interposed in the pressure supply pipe 41. In the position shown, shut-off valve 5 is biased to its closed position by means of spring 44 in cylinder 43 when both sides of piston 42 are subjected to fluid pressure from pipe 41. The valve 46 is held in the position shown by lever 48 and servo-motor piston 49. A spring 51 is provided for biasing piston 49 to a position in which lever 48 cuts off fluid pressure from cylinder 43, however, in the position shown, piston 49 is under the influence of fluid pressure supplied from supply pipe 41 through pipe 45 and pipe 52 of small diameter, noting that pipe 53, which is connected to cylinder 50, is closed at its upper end by needle valve 3 to maintain pressure on piston 49 during the time the prime mover generator unit is shut down.

Returning now to regulating valve 17, the valve stem 33 of this valve is here shown as provided at the upper end thereof with a spring cage 54. A rod 57 extends into the spring cage 54 and is provided at its lower end with a collar 56. Between collar 56 and the upper end of cage 54 a compression spring 55 is interposed. Rod 57 extends slidably through a swivel connection 58 and is provided at its upper end with a threaded portion carrying adjustable nuts 59. Between the swivel connection 58 and a collar 185 on rod 57 a compression spring 60 is interposed. Swivel connection 58 is carried by a floating lever 61 having a floating pivot 62 which may be raised and lowered by means of governor fly balls 63, which are rotated in accordance with the speed of the prime mover 19 by any suitable means such as belt 64 driven from shaft 20. The other end of floating lever 61 is connected to piston rod 65 of compensating device 66 by means of any suitable swivel connection. The lower end of device 66 is pivotally connected to a rod 67 which in turn is connected to one end of relay lever 68. The other end of lever 68 is operatively connected to the gate 22 by means of a rod 69 and a lever 70.

Motion of the gate 22 is transmitted to a rate limiting device 18 by means of lever 70, rod 69, one end of lever 68, lever 71, connecting rod 72, lever 73, and link 74. The rate limiting device 18 comprises a cam member 75 which is adapted to pass through a slot or hole in valve stem 33 so as to limit the amplitude of movement of this valve stem. For a more complete understanding of this rate limiting device reference should be made to the patent of Arnold Pfau, No. 1,685,749, granted September 25, 1928.

Valve stem 33 is provided with a collar 77 adapted to be engaged by a load limiting finger 16 which is pivoted at 78. The load limiting finger 16 is biased in a counter-clockwise direction by spring 16*a*, however, counter-clockwise rotation of finger 16 is limited by mechanism now to be described. One end of finger 16 is connected to a lever 80 by means of link 79. Lever 80 is provided with a pivot 80*a* and is connected at its lower end to a link 81 which in turn is pivotally connected to one end of a floating lever 82.

Referring now to Figure 2 and Figure 3 which more clearly show the details of the above lever mechanism, floating lever 82 is pivoted near its middle to a floating pivot 83 which is carried by lever 89. Floating lever 82 is provided with a lower portion 82*a* adapted to engage a pin 84 carried by a relay lever 85. Relay lever 85 is freely rotatable about a shaft 86 and is pivotally connected at its upper end 87 to a rod 88 which is moved in accordance with the position of the gate 22 by means of lever 70. It is thus seen that protuberance 178 on lever 85 is moved in accordance with the position of the gate 22.

The floating pivot 83 which carries lever 82 is attached to the lower end of a lever 89 which is rigidly fastened to shaft 86 by means of pin 90 (noting Figure 3). The lever 89 is provided with integral extensions 8 and 8*a*. Lever assembly 8—8*a*—89 is adapted to be rotated in a counter-clockwise direction by auxiliary servomotor 221 by means of rod 152, and the extension 8*a* is provided with a cam surface 9 adapted to actuate roller member 92 on lever 10. Lever 10 is rigidly attached to shaft 94 and lever 99 is also fastened to shaft 94 so as to move in unison with lever 10. Stem 101 of valve 11 is pivotally connected to the end of lever 99 so that valve 11 is actuated by movement of cam surface 9 relative to roller 92. For a more detailed description of the levers carried by shaft 94 reference may be made to the patent to C. B. Taylor et al, No. 1,761,596, issued June 3, 1930. For an understanding of the present invention it is sufficient to state that a lever 97 is rotatable about shaft 94 and is provided with a lug portion 179 adapted to engage protuberance 178 on lever 85. Lever 97 is biased in a counter-clockwise direction by adjustable spring 98 and is adapted to move into abutment with an adjustable screw 96 carried by lever 10. A lever 105 having an arm 107 is also rotatable about shaft 94 and is provided at one end with a roller 106 which is adapted to be actuated by manual starting cam 134. Cam member 134 is adapted to be rotated in a counter-clockwise direction as viewed from the right hand side of the page by means of shaft 132 and manual starting lever 133 in order to manually actuate lever 105 and valve 11. Arm 107 of lever 105 extends horizontally to the right of shaft 94 and is provided with an interlocking abutment portion 108 which is adapted to engage sleeve member 121 for a purpose to be hereinafter described. Lever 99, and consequently the shaft 94 and lever 10, are biased in a clockwise direction by means of an adjustable spring 104 suitably fastened to a stationary part of casing 183. Between portion 107 of lever 105 and lever 99 there is a lost motion connection which comprises an axially extending pin 102 which is carried by lever 99 and extends into a slot or hole in arm 107 of lever 105 and is also adapted to engage set screw 117 carried by lever 2.

The shaft 94 also carries a lever 2 which is freely rotatable about this shaft. Lever 2 is adapted to be actuated in a counter-clockwise direction by means of an electromagnet 1, which is provided with an operating rod 115. Lever 2 is biased in a clockwise direction by means of a spring 184 which is suitably attached to a portion of casing 183. Valves 3 and 4 are connected to lever 2 by means of valve stem 111. Valve 4 is for the purpose of connecting outlet port 147 either to drain port 151 as shown in Figure 1 or to pressure inlet port 148 upon actuation thereof. Needle valve 3 serves to close port 145 in the position shown and to connect this port to drain port 146 upon actuation thereof. Lever 2 is also provided with an adjustable screw 117 which is adapted to engage pin 102 under certain conditions, for a purpose hereinafter set forth. Lever 2 also carries an adjustable screw 118 adapted to engage piston 14.

For predetermining the maximum gate opening permissible during operation of the turbine, the following load limiting mechanism is provided. A shaft 119 is rotatable by means of a hand wheel 120 and carries a threaded nut 121 thereon. A pin 122 extends laterally through nut 121 and is adapted to engage the transverse slot 125 (see Figure 2) in the bifurcations 123 and 123*a* in the end of lever 124 (see Figure 3). Lever 124 is loosely mounted on a shaft 86 and is provided with a wide keyway 126 having sides which are adapted to engage a key 127 in shaft 86. Lever 124 is also shown as being provided with a toothed projection 129 on the hub thereof forming a driving means for a load limiting indicator which may be geared thereto. The in-

dicator has not been shown in view of the fact that it would cover up and confuse the remaining mechanism. The shaft 119 is provided with two stops 131 on either side of the nut 121 so as to limit the amount of travel of this nut. It will be noted that if the shaft is rotated so as to move the nut 121 toward the left as viewed in Figure 1, the right hand side of keyway 126 will eventually engage the key 127 and move the levers 8 and 89 in a clockwise direction. This movement of lever 89 will cause floating pivot 83 to move to the left thereby causing floating lever 82 to tilt in a counter-clockwise direction about pin 84. The pin 84 is for the time being fixed inasmuch as it remains stationary as long as the gate 22 remains stationary due to the connection between lever 85 and the gate previously described. As the floating lever 82 tilts in counter-clockwise direction it causes lever 80 to swing in a clockwise direction thereby moving load limiting finger 16 in a clockwise direction. If the turbine is running, this movement of finger 16 is in such a direction as to cause regulating valve 17 to actuate the servo-motor 27 toward gate closed position. As the gate moves toward closed position the pin 84 moves clockwise so that floating lever 82 tends to tilt clockwise and, therefore, control finger 16 will no longer be effective to cause gate closing movement when the regulating valve 17 has assumed a neutral position. It will, therefore, be clear that if nut 121 is moved sufficiently toward the left the gate 22 will be completely closed. On the other hand, if the nut is moved toward the right the control finger 16 will be moved in a counter-clockwise direction under the influence of spring 16*a* thereby freeing the collar 77 for movement to any position within the control range of valve stem 33. In other words, if the nut 121 is moved as far to the right as stop 131 will permit, the gate may be opened to its full extent by the fly balls 63 if the load so requires movement to this extent. The shaft 119 may be rotated from a remote control point by means of servomotor mechanism 135. This mechanism includes a reversible motor having a shaft 136 adapted to rotate shaft 119 through gearing.

An auxiliary servo-motor 221 of improved construction is provided with a cylinder 150 in which a piston 7 is adapted to slide, noting that Fig. 6 shows in detail a preferred form of this servo-motor. Piston rod 152 is adjustably attached to piston 7 and is provided at its upper end with a collar 153 which is adapted to engage the upper side of the bifurcations 154 (see Figures 2 and 3) of the lever 8. Piston rod 152 is biased downwardly by a spring 181 acting at its lower end against a sleeve or collar 180 which is suitably attached to said rod. The upper portion 155 of servo-motor 221 is provided with a bore in which piston 15 is adapted to slide and also a bore of smaller diameter which is adapted to receive an auxiliary piston 222 which has a central bore through which piston rod 152 may slidably move. Piston 222 is biased downwardly by spring 250 and is provided with an annular depending sleeve portion which constitutes a temporary abutment for piston 7 when piston 7 moves through distance W. The upward stroke X of piston 222 is temporarily limited by the annular depending sleeve portion of piston 15 against which piston 222 is adapted to abut when piston 15 remains in the position shown. The annular depending sleeve portion of piston 15 is provided with an inner step or abutment adapted to limit the upward stroke W plus Y of collar 180 and piston rod 152 when only pistons 7 and 222 are energized. Piston 15 is biased downwardly by heavy spring 156. The depending sleeve portion of piston 15 is adapted to slide through a bore in cylinder 155 so as to form a pressure chamber which is provided with an inlet port 157.

The actuation of piston 7 is controlled by an electromagnetically actuated valve 4 which is adapted to connect inlet port 149 either with pressure conduit 6*a* or drain pipe 40*a*. Valve 4 is actuated by means of electromagnet 1, the energization of which, from any suitable source, is controlled by means of push button 247. Upon energization of electromagnet 1, collar 229 on valve stem 115 will move past latch 228 which will thereupon latch valve stem 115 in its upper position in a manner similar to that illustrated in Figs. 4 and 5. Valve stem 115 may be caused to return to its lowermost position by means of tripping mechanism which comprises a latch 228, a link 227, and an armature 226, of electromagnet 225 upon energization of this electromagnet by means of push button 248. The actuation of piston 222 is controlled by valve 13 which in the position shown in Fig. 1, connects inlet port 223 with drain port 177 through port 175 and pipe 176. When valve 13 moves to the left as viewed in Fig. 1, the under side of piston 222 will be supplied with fluid under pressure from pipe 171, through port 175, through pipe 176, and port 223. A drain port 224 serves to remove any oil that might leak past pistons 7 and 222. The actuation of piston 15 is controlled by an auxiliary valve 213 which is actuated by electromagnet 233. Electromagnet 233 is adapted to be energized from any suitable source of current by means of push button 234, or by means of switch 249 which is adapted to momentarily shunt the contacts of push button 234 a suitable time after the circuit breaker 212 has closed. Operating rod 214 of electromagnet 233 is adapted to be latched in its uppermost position by latch 239, which is biased in a clockwise direction by means of spring 243, noting Figs. 4 and 5. Latch 239 may be tripped upon actuation of push button 236 or closure of contacts in parallel therewith upon occurrence of any predetermined abnormal condition such as overload for example, noting overload relay 251. Energization of electromagnet 235 causes armature 237 to move link 238 and latch 239 to thereby permit valve stem 214 to return to its initial position. Valve stem 214 and operating rod 115 may be simultaneously actuated to their upper positions by manual means comprising cams 241 and 230 on shaft 231 which is journaled in casing 183 and is actuated by means of a hand lever 232. Valve stem 214 and operating rod 115 may also be manually tripped simultaneously by mechanism shown in Figs. 4 and 5 in which an unlatching lever 246 is adapted to engage arm 245 of latch 239 upon manual rotation of shaft 231 in a direction opposite to the direction which causes cams 241 and 230 to raise the valve stem 214 and operating rod 115, respectively. It is to be noted that Figure 4 shows how latch member 239 may be biased in a counter-clockwise direction by means of a spring 243 acting upon a depending lever portion of this latch member. It is also to be noted that slotted link 238 permits collar 240 to be raised past latch 239 without causing movement of armaure 237.

Means are provided for shutting off fluid pressure from all control apparatus in order to pre-

vent leakage of fluid. This mechanism comprises shut-off valve 5 which is biased to its closed position by spring 44 when both sides of piston 42 are subjected to fluid pressure. When the right hand side of piston 42 is connected to the drain by valve 46 pressure on the left hand side of piston 42 will compress spring 44 thereby opening valve 5. Valve 46 is held in the position shown in Figure 1 by means of piston 49 during the time needle valve 3 is closed.

A pivoted latch 159 is adapted to be biased toward latched position by means of tension spring 160 for the purpose of holding gate 22 in its closed position while fluid is shut off by valve 5. In order to permit opening of the gate 22 automatic means are provided for releasing the latch 159 including a piston 12 operated in a cylinder 161. The cylinder 161 is provided with an admission port 162 conected by means of a pipe 163 to a port 164 of valve 11. The valve 11 is also provided with a port 166 which is connected by pipe 167 to pressure line 6*a*. Valve 11 is also provided with a drain port 169 connected by a pipe 168 to the drain 40*a*. Lifting of valve 11 cuts off communication with drain port 169 and connects ports 164 and 166 so that fluid pressure may be admitted to cylinder 161 to raise latch 159.

Operating in unison with piston 12 is a piston valve 13 operating in a cylinder 170. The cylinder 170 is connected by means of a pipe 171 to the pressure line 6*a*. The cylinder 170 is also provided with a port 172 connected by a pipe 173 to a cylinder 174 in which a plunger piston 14 is adapted to move. The cylinder 170 is also provided with another port 175 connected by pipe 176 to the port 223 in cylinder 150 of auxiliary servo-motor 221. The ports 172 and 175 are so located that when the latch 159 is in latched position the valve 13 prevents the flow of pressure fluid from pipe 171 to ports 172 and 175. Cylinder 170 is also provided with a drain port 177 so that in the position shown in Figure 1, both ports 172 and 175 are connected to this drain port. Communication between the drain port 177 and ports 172 and 175 is successively cut off when the piston valve 13 moves toward the left, as viewed in Figure 1.

The operation of the system is as follows. With the prime mover 19 at rest all apparatus is in the positions shown in Figure 1. For example, fly balls 73 are in their innermost position so that the floating pivot 62 is in its lowest position. Consequently spring 60 is compressed and the rod 57 tends to move in a downward direction, however, downward motion is prevented by the load limiting finger 16. The reason finger 16 cannot swing in a counter-clockwise direction under the influence of spring 16*a* and spring 60 is that the counter-clockwise tendency of lever 80 to move floating lever 82 and pivot 83 thereon in a clockwise direction about the relatively fixed pivot 84 is prevented due to the fact that the lever 8—8*a*—89 cannot move in a counter-clockwise direction because the spring 181 is pulling down on a lever 8 through rod 152.

By means of the apparatus hereinbefore described a prime mover generator unit may be started in any one of four different ways. In automatically starting the apparatus from a remote point when it is desired to cause the gate 22 to open to a predetermined position corresponding substantially to normal speed of said unit without load, push button 247 may be momentarily actuated to energize electromagnet 1 thereby lifting lever 2 and latching the same in its raised position by means of latch 228. Upward movement of needle valve 3 connects pipe 53 with drain pipe 40*a* thereby permitting spring 51 to force piston 49 upward to actuate valve 46. Actuation of valve 46 connects the right hand side of piston 42 to drain 47 thereby causing piston 42 to move to the right under the influence of fluid pressure on the left hand side of this piston. This actuation of piston 42 opens valve 5 thereby admitting fluid pressure to pipe 6 and 6*a*. With valve 17 in the position shown the admission of fluid pressure to pipe 6 by valve 5 causes fluid under pressure to flow through valve 17, out pipe 36, into cylinder 30, thereby causing piston 28 to move to the right to firmly set gate 22 in fully closed position and also to relieve the back pressure of the notch 158 on latch 159. The initial movement of lever 2 also lifts valve 4 to such a position that fluid under pressure from pipe 6*a* flows through inlet port 148, outlet port 147, through port 149, to the under side of piston 7 thereby causing piston 7 to move upwardly a distance W against the influence of spring 181, noting that piston 222 which is biased by spring 250 constitutes a temporary abutment for piston 7. Piston 7 and piston rod 152 in moving upward permit lever 8—8*a*—89 to rotate in a clockwise direction under the influence of springs 16*a* and 60 acting through load limiting finger 16, link 79, lever 80, link 81, pivot point 83, and lever 82 which is in engagement with pin 84. The above described movement of lever 8*a* causes cam 9 to move lever 10 in a clockwise direction to an extent determined by the curvature of the cam thereby lifting valve 11. Lifting of valve 11 causes pressure under fluid to flow from pipe 6*a* through inlet port 166, out through outlet port 164, through pipe 163, to inlet port 162, of the gate unlatching servo-motor thereby causing piston 12 to move to the left to disengage latch 159 from stop 158.

A predetermined movement of latch piston 12 causes valve 13 to admit fluid under pressure through port 172 to cylinder 174 thereby causing piston 14 to rise. Piston 14 does not rise sufficiently to touch screw 118, noting that the purpose of this movement of piston 14 will be later described in connection with the stopping cycle of the system. When the latch 159 has been fully released the valve 13 is in a position which permits fluid under pressure to flow from pipe 171, out port 175, through pipe 176, to inlet port 157, of auxiliary servo-motor 221 thereby causing piston 222 to move upwardly a distance X into engagement with the sleeve portion of valve 15. This movement of piston 222 permits rod 152 to rise an additional amount Y thereby permitting load limiting finger 16 to swing an additional amount under the influence of springs 16*a* and 60 so as to partially free the collar 77 for downward movement under the influence of spring 60. Downward movement of valve stem 33 causes fluid under pressure to flow into servo-motor cylinder 31, thereby causing servo-motor 27 to open the gate 22 to start the prime mover. The opening movement of gate 22 is relayed through lever 70, link 88, lever 85, pin 84, lever 82, which is pivoted at 83, link 81, lever 80, link 79, to load limiting finger 16 to move valve 17 to a neutral position when the gates have been moved to a position corresponding to normal speed with only friction load. The gate limiting action of load limiting finger 16 causes the speed of the generator 210 to change at a very slow rate as

normal speed is approached so that synchronization with the power line 211 may be readily accomplished.

Upon closure of circuit breaker 212, by any suitable well known synchronizing apparatus, contacts 249 will be momentarily closed preferably a definite time after the closure of circuit breaker 212, thereby energizing electromagnet 233, noting that contacts 249 close only during the closing movement of circuit breaker 212.

The energization of electromagnet 233 lifts auxiliary valve 213, thereby causing fluid under pressure to flow from pipe 218 through ports 215 and 216, through pipe 220 and port 151 to the under side of piston 15, which thereupon rises and permits piston rod 152 to rise an additional amount Z. This additional movement of piston 152 permits lever assembly 8—8*a*—89 to rotate clockwise an additional amount thereby permitting load limiting finger 16 to swing completely free of collar 77. In this connection it is to be noted that the amount of clockwise movement of load limiting finger 16 will be determined by the relative position of a keyway 126 and key 127 associated with the present load limiting mechanism. Thus the maximum permissible gate opening may be set for any desired fraction, usually expressed in tenths, of the full gate opening.

The downward movement of stem 33 is preferably limited by cam 75 which serves to control the rate of acceleration of the prime mover in accordance with the position of the gate. As the gate opens, the pin 84 on lever 85 will move in a clockwise direction thus tilting floating lever 82 about pivot point 83 which at this time is fixed due to the engagement of key 127 and with keyway 126 and this movement is thus relayed to load limiting finger 16 which thus limits the maximum opening of gate 22. As the load on the generator 210 changes the servo-motor 27 also comes under the control of fly balls 63 in the usual manner.

The prime mover generator may be automatically started in a second manner from a remote point upon simultaneous actuation of both push buttons 234 and 247. The actuation of lever 2 initiates the same cycle of movements as hereinbefore described noting that as soon as fluid pressure is admitted to pipe 218, piston 15 will be caused to raise by reason of fluid under pressure passing from pipe 218 through ports 215 and 216, through pipe 220 and through port 157. Due to the fact that piston 15 raises before piston 222, it will be apparent that when piston 222 is actuated by fluid under pressure from outlet port 175, it will raise through its full stroke without being limited by the sleeve portion of piston 15. Piston 7 will initially move through distance W to cause valve 11 to actuate the gate unlatching servo-motor to thereby actuate piston 222 as hereinbefore described. Piston 7 will thereupon follow piston 222 to its final position through distance W plus Y plus Z without stopping at the intermediate position hereinbefore described. It is thus seen that by simultaneously energizing electromagnets 1 and 233 the prime mover generator may be rapidly started from rest and caused to accelerate to such a speed at which the fly ball governor will take control of the gate without limiting the rate at which the generator approaches synchronous speed. This method of starting is particularly advantageous where there has been a failure of voltage on line 211 so that it is unnecessary to synchronize generator 210 with the frequency of the line before closing circuit breaker 212, however, it is to be understood that even if voltage conditions on line 211 are normal, the above second method of starting the prime mover may be used, noting that synchronization will not be impossible with this method of starting. It is to be noted that the actuation of only auxiliary valve 213 by electromagnet 233 does not cause any operation because during rest there is no fluid pressure on pipes 6 and 218.

Referring now to a third method of starting the prime mover, the hereinbefore described second method of starting may be manually accomplished by rotating hand lever 232 so that cams 230 and 241 simultaneously raise valve stem 214 and operating rod 115 noting that the sequence of operations will be precisely the same as described in connection with the simultaneous energization of electromagnets 1 and 233.

The prime mover generator may be started from rest in a fourth manner by first manually operating hand wheel 120 toward the full gate position so that interlocking portion 103 of lever arm 107 is free to move upward. Lever 133 may then be manually moved in such a direction that cam 134 will rotate lever 105—107 in a clockwise direction so as to cause the bottom portion of the slot in lever arm 107 to raise pin 102 of lever 99 into engagement with set screw 117 thereby causing lever 2 to rotate in a clockwise direction. The clockwise rotation of lever 107 in raising pin 102 also causes lever 99 to rotate a predetermined amount in a clockwise direction thereby performing the same function with respect to valve 11 as previously done by cam surface 9 and roller 92 on lever 10.

The prime mover generator may be shut down in any of four different ways. For example, when it is desired to reduce the load on generator 10 to substantially zero without stopping the prime mover, push button 236 may be actuated to trip latch 239 and thereby cause valve 213 to return to its initial position, wherein port 157 is connected to drain pipe 40, through pipe 220, and ports 216 and 217. Heavy spring 156 thereupon causes piston 15 to return to its initial position thereby moving piston rod 152 downward through a distance Z, noting that spring 156 is sufficiently strong to overpower piston 7 which is still energized. The downward movement of piston rod 152 causes lever assembly 8—8*a*—89 to rotate clockwise thereby causing upward movement of load limiting finger 16 by reason of motion through link 79, lever 80, link 81, floating lever 82, which is pivoted to lever arm 89. The upward movement of load limiting finger 16 causes servo-motor 27 to move gate 20 to a position corresponding to normal speed with friction load only.

The same above described operations will occur when a temporary abnormal condition in generator 210, such as overload, causes relay contacts 251 to close, however, it is to be understood that the contacts of push button 236 may be shunted upon occurrence of conditions other than overload, for example, excessive bearing temperature, low pressure on the fluid which operates the prime mover 19, or under load on generator 210.

If it is desired to move the gate to its fully closed position after the gate has been moved to its partially closed position, push button 248 may be actuated to cause the tripping of latch 228

thereby permitting lever arm 2 to move toward its initial position into engagement with the stop on piston 14. This downward movement of lever arm 2 is sufficient to permit valve 4 to connect the lower side of piston 7 to drain pipe 40a through port 147 and port 148, thereby permitting spring 181 to return piston rod 152 to the position shown in Figure 1, however, it is to be noted that the downward movement of lever 2 is not sufficient to close needle valve 3 because piston 14 is still energized. Downward movement of piston rod 152 causes lever assembly 8—8a—89 to rotate in a clockwise direction to the position shown in Figure 1. The lever 10, however, does not rotate clockwise under the influence of spring 104 at this time for the reason that lever 97, which is biased by the stronger spring 98, holds the lever 10 out of notch 91 of cam 9 so that valve 11 does not close at this time. The lever 97 is caused to move against lever 10 by reason of the fact that the protuberance 178 on lever 85 is not in engagement with the lug portion 179 of lever 97 when the gate 22 is in its open position. The final downward movement of piston rod 152 also causes load limiting finger 16 to move upwardly by reason of motion through link 79, lever 80, link 81, and floating lever 82 which is pivoted to lever arm 89. This upward movement of load limiting finger 16 raises valve stem 33 so that fluid under pressure is caused to flow from pipe 6 through pipe 36 to cylinder 30 thereby causing gate 22 to move to its closed position. When the gate has moved to its fully closed position the protuberance 178 has moved the lug portion 179 of lever 97 sufficiently in a clockwise direction to thereby permit lever 10 to move in same direction under the influence of spring 104 to cause roller 92 to enter notch 91. The valve 11 is thus returned to the position shown in Figure 1 thereby connecting port 162 of the gate latching servo-motor to drain pipe 40a through pipe 163 and ports 164 and 169. The spring 160 consequently moves the latch 159 along with piston 12 and piston 13. The initial movement of latch 159 toward latched position causes valve 13 to connect the under side of piston 222 with drain port 177 through port 223 and pipe 176. Piston 222 thereupon moves to the position shown in Figure 6 under the influence of spring 250, noting that the downward movement of piston 15 has already partially returned piston 222 toward its initial position. When latch 159 is in its fully engaged position, the piston valve 13 connects the under side of piston 14 with drain port 177 through pipe 173 and port 172 thereby permitting lever arm 2 to return to the initial position shown in Figure 1. This additional downward movement of lever 2 causes needle valve 3 to close thereby causing pressure to build up in cylinder 50 so as to cause piston 49 to return valve 46 to the position shown in Figure 1. Movement of valve 46 to the initial position causes shut off valve 5 to return to the initial closed position shown in Figure 1. Obviously the energization of tripping electromagnet 225 may be controlled by any well known protective devices responsive to such abnormal conditions as field failure or short circuited windings, to thereby completely shut down the prime mover generator unit.

When it is desired to shut down the motor generator without stopping at the intermediate position corresponding to normal speed with the load, both push buttons 236 and 248 may be simultaneously energized, thus permitting piston rod 152 to immediately return to its lowermost position. The cycle of operations thereafter is substantially the same as that above described except that, inasmuch as piston 15 is deenergized, piston rod 152 will not remain in the intermediate position.

The same results as are obtained by simultaneously actuating push buttons 236 and 248 may be secured by operating hand lever 232 in such a direction that levers, such as 246 shown in Figure 5, manually trip latches 240 and 229 to cause valve stem 105 and operating rod 115 to move downwardly.

It is also to be noted that if the prime mover generator has been started by means of hand lever 133 shut down operations may be also initiated by returning hand lever 133 to its initial position thereby causing the apparatus to operate in a manner which will be obvious from the above description.

It should be understood that it is not desired to limit the invention to the exact details of construction shown and described, and obvious modifications may occur to persons skilled in the art.

It is claimed and desired to secure by Letters Patent:

1. In a control system for a prime mover having a gate for controlling the admission of operating fluid to said prime mover, a servo-motor for actuating said gate, means comprising a plurality of remotely controlled electromagnetically actuated valves for initiating upon actuation thereof the starting of said prime mover, means for causing one of said valves to return to its initial position and for thereby causing said gate to return to a predetermined position corresponding to no load speed, and means for causing another of said valves to be returned to its initial position and for thereby causing said gate to return to its completely closed position.

2. In a control system for a prime mover, a gate for controlling the admission of operating fluid to said prime mover, a servo-motor for actuating said gate, a valve for controlling said servo-motor, a load limiting device actuated in accordance with the movement of said gate for limiting the movement of said valve so as to predetermine the maximum permissible opening of said gate, an auxiliary servo-motor having a plurality of pistons, means for selectively actuating said pistons and for thereby selectively moving said load limiting device to gate closed position, to friction load gate position, and to a predetermined position corresponding to maximum permissible gate opening.

3. In a control system for a prime mover, a gate for controlling the admission of operating fluid to said prime mover, a servo-motor for actuating said gate, a valve for controlling said servo-motor, a load limiting device adapted to limit the gate opening movement of said valve, an auxiliary servo-motor having more than two pistons arranged when actuated to vary the position of said load limiting device, means for causing one of said pistons to return to its initial position and for thereby causing said load limiting device to limit the opening of said gate to a position corresponding to normal speed of said prime mover without load, and means for causing another of said pistons to return to its initial position and for thereby causing said load limiting device to reduce the opening of said gate to zero.

4. In a control system for a prime mover having a speed governor and a gate controlled thereby for controlling the admission of operating

fluid to said prime mover, said governor comprising a valve controlled servo-motor for actuating said gate, a load limiting device associated with the valve of said servo-motor for limiting the opening movement of said gate, an auxiliary servo-motor for actuating said load limiting device, remotely controlled means for initiating the actuation of said auxiliary servo-motor, and means whereby said load limiting device is caused to move said gate to a partially open position corresponding to normal speed of said prime mover without load upon actuation of said remotely controlled means.

5. In a control system for a prime mover having a speed governor and a gate controlled thereby for controlling the admission of operating fluid to said prime mover, said governor comprising a valve controlled servo-motor for actuating said gate, a load limiting device associated with the valve of said servo-motor for limiting the opening movement of said gate, an auxiliary servo-motor for actuating said load limiting device, control means for causing said load limiting device to first move to a position permitting said gates to open to a position corresponding to normal speed without load and then move to a position permitting said gates to move between predetermined limits under the control of said governor.

6. In a control system for a prime mover having a governor controlled gate for controlling the admission of operating fluid thereto, means for limiting the opening of said gate to various preselected positions, means comprising a first electromagnetically actuated valve for causing upon actuation of said valve a movement of said load limiting device permitting said governor controlled gate to open to a predetermined first position corresponding to normal speed without substantial load, and means comprising a second electromagnetically actuated valve for causing upon actuation of said valve a movement of said load limiting device permitting said governor controlled gate to open to a predetermined second position corresponding to one of said preselected positions.

7. In a control system for a prime mover having a governor controlled gate for controlling the admission of operating fluid thereto, means for limiting the opening of said gate to various preselected positions, means comprising a first electromagnetically actuated valve for causing upon actuation of said valve a movement of said load limiting device permitting said governor controlled gate to open to a predetermined first position corresponding to normal speed without substantial load, means comprising a second electromagnetically actuated valve for causing upon actuation of said valve a movement of said load limiting device permitting said governor controlled gate to open to a predetermined second position corresponding to one of said preselected positions, and manual means operable to simultaneously actuate said first and second valves to thereby cause said first mentioned means to move directly to said predetermined second position.

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