Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 1

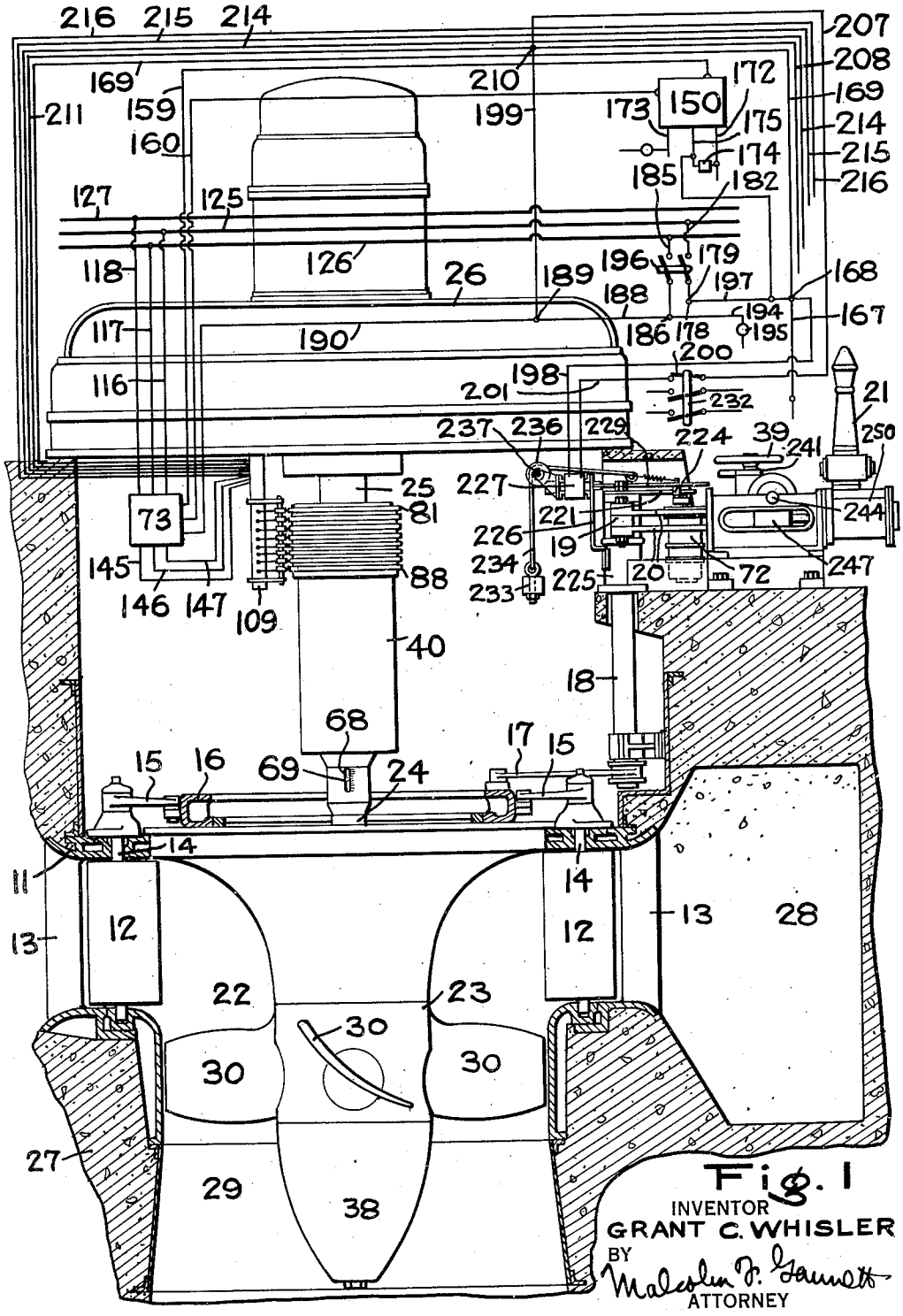


Fig. 1

INVENTOR
GRANT C. WHISLER
BY
Malcolm P. Garnett
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 2

Fig. 2

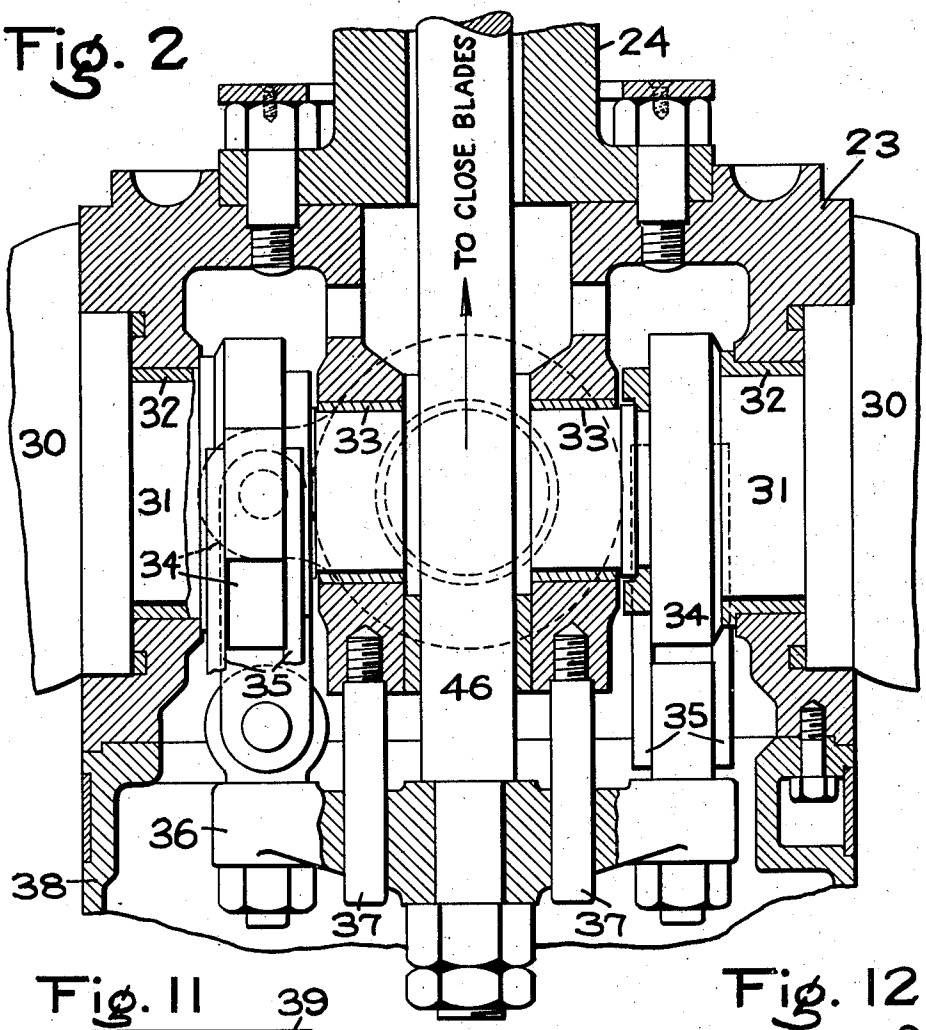


Fig. 11

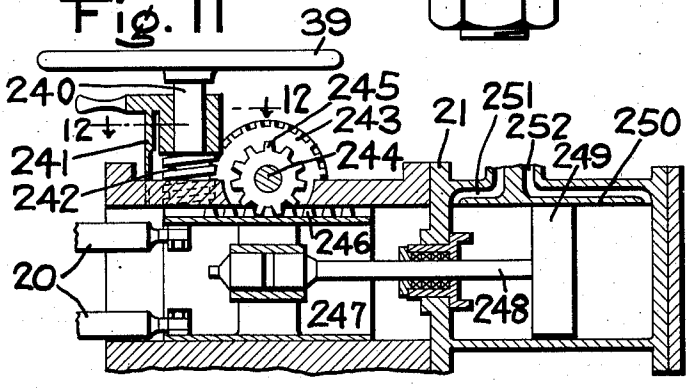
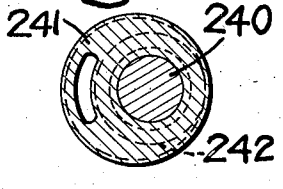


Fig. 12



INVENTOR
GRANT C. WHISLER
BY
Malcolm F. Gannett
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 3

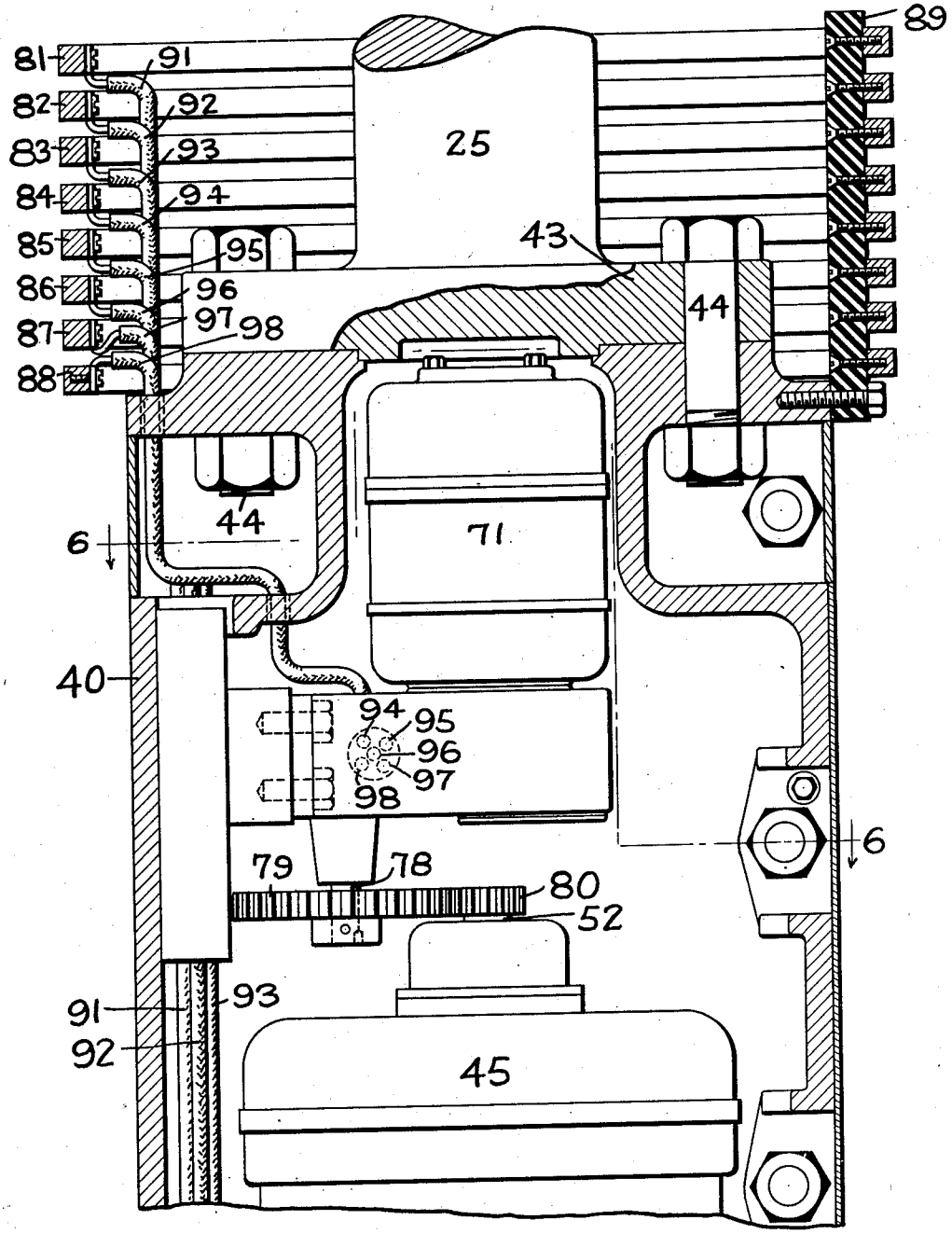


Fig. 3

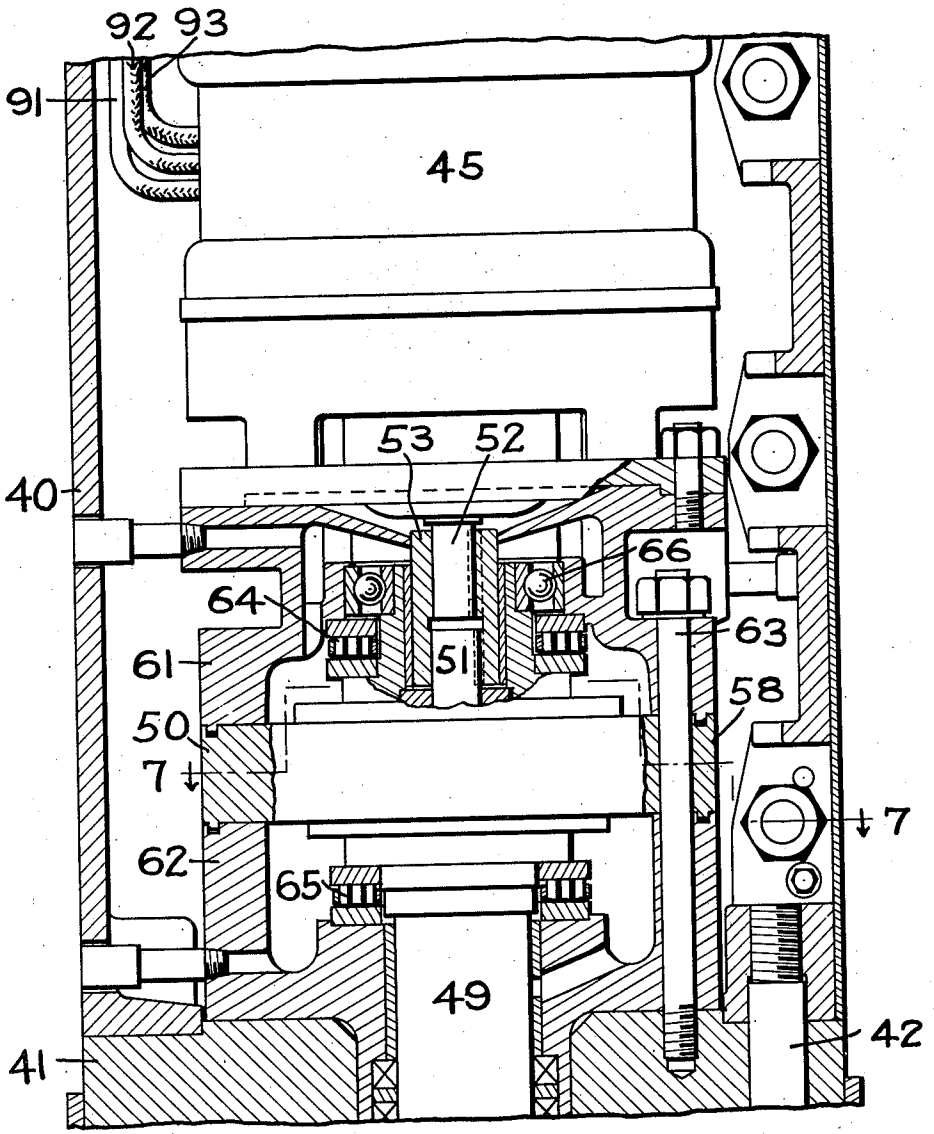
INVENTOR
GRANT C. WHISLER
BY Malcolm F. Gannett
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 4

Fig. 4



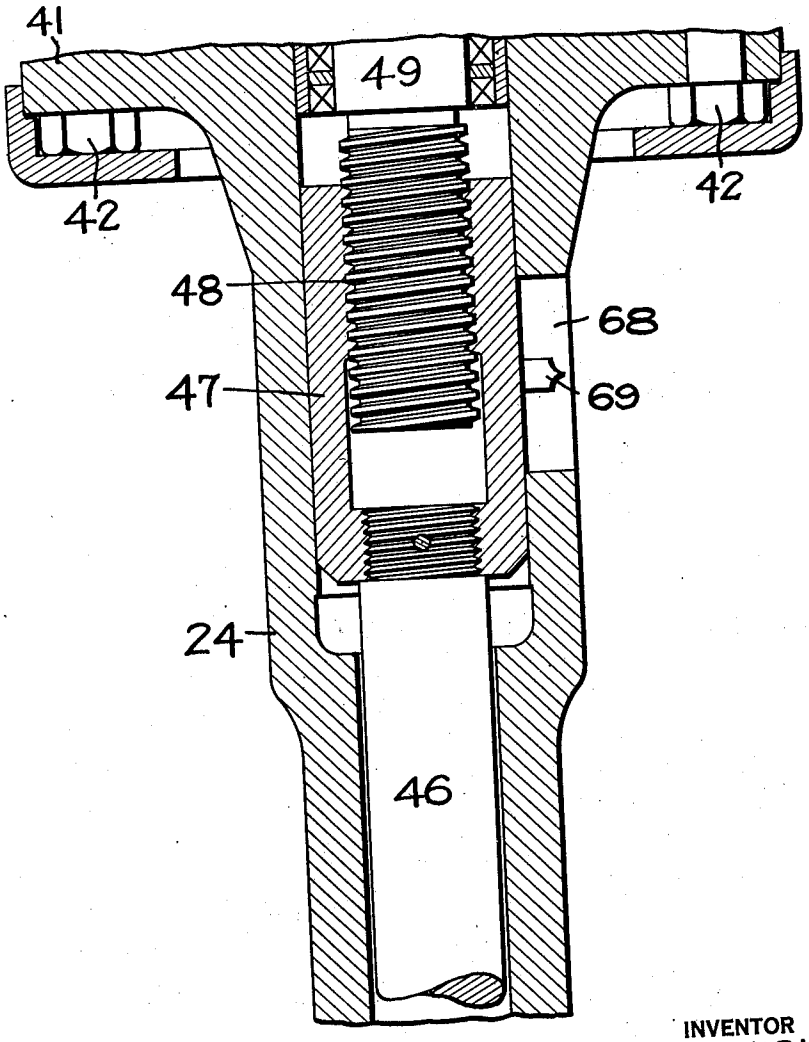
INVENTOR
GRANT C. WHISLER
BY
Malcolm S. Gardner
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 5

Fig. 5



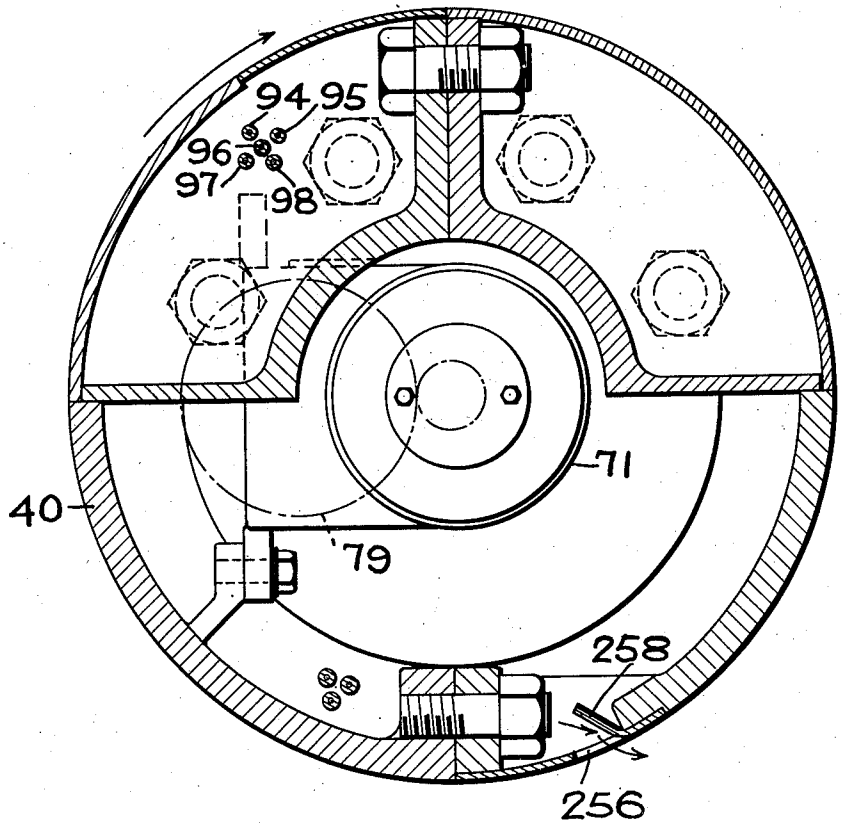
INVENTOR
GRANT C. WHISLER
BY
Malcolm F. Gannett
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 6

Fig. 6



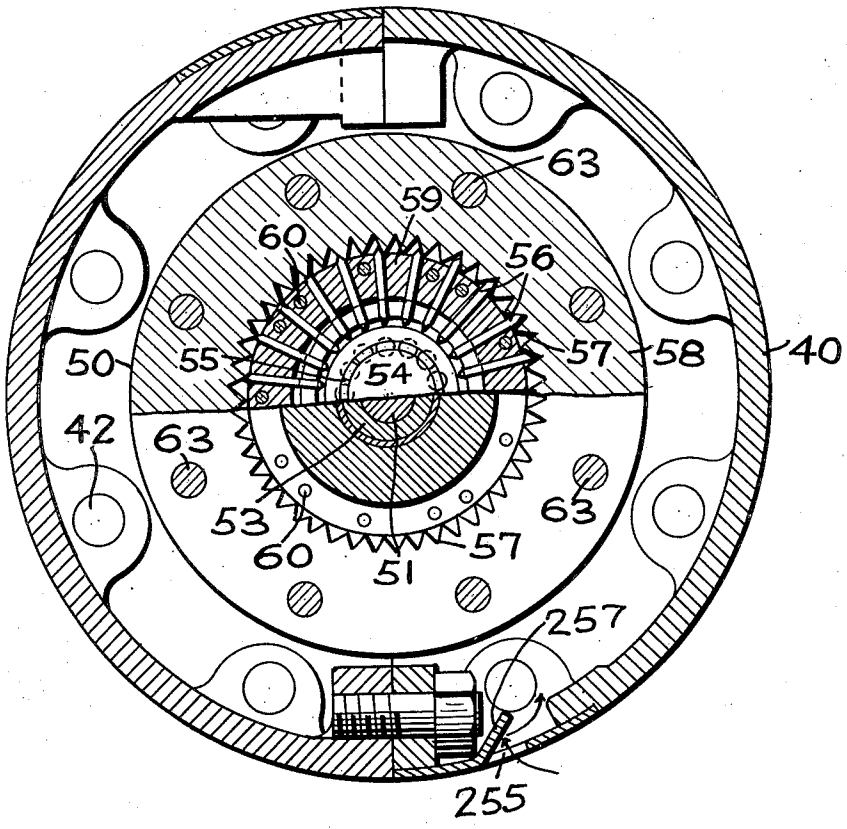
INVENTOR
GRANT C. WHISLER
BY
Malcolm F. Gannett
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 7

Fig. 7



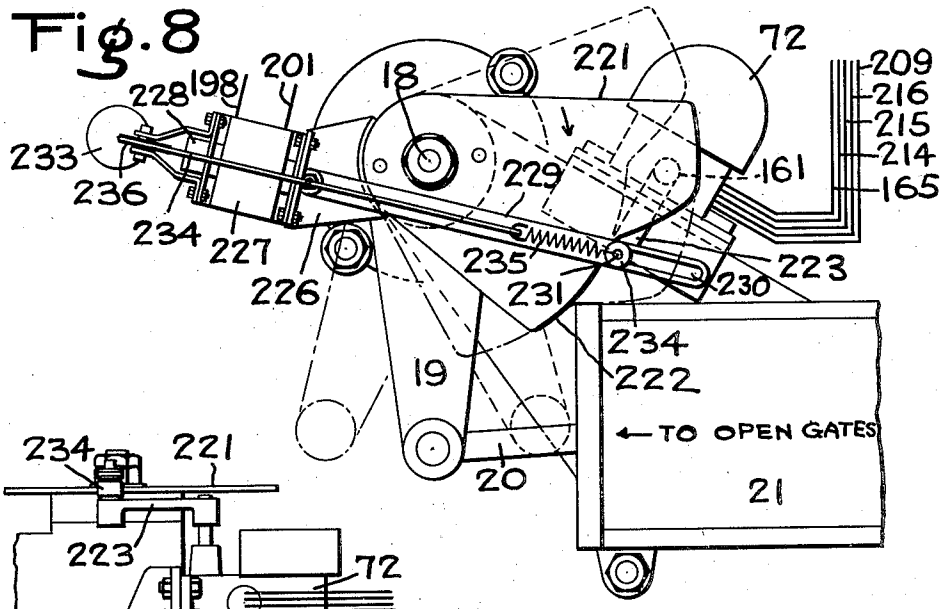
INVENTOR
GRANT C. WHISLER
BY Malcolm F. Garnett
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 8

Fig. 8



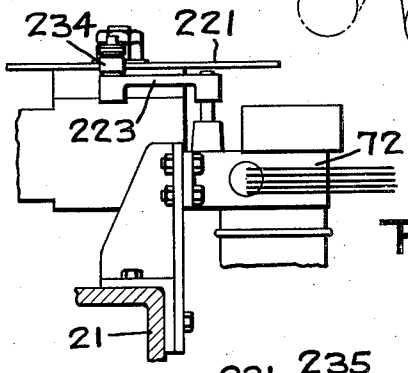


Fig. 10

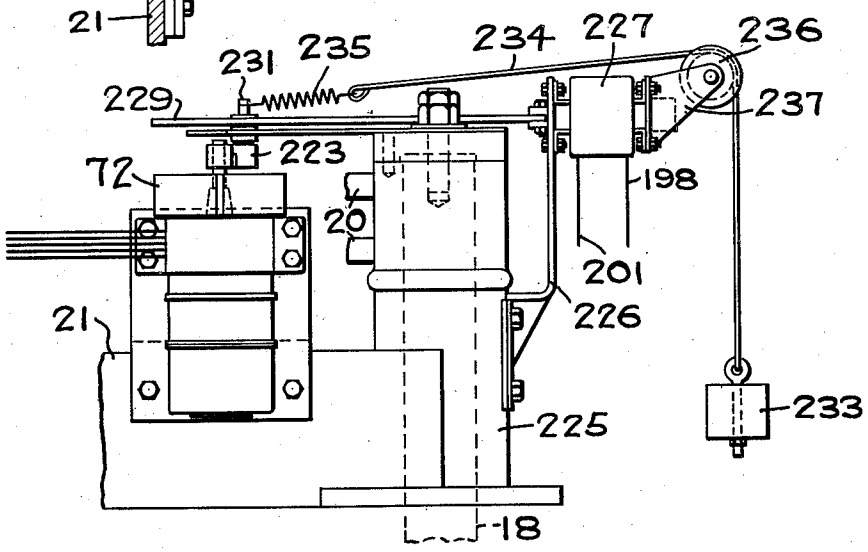


Fig. 9

INVENTOR
GRANT C. WHISLER
BY
Malcolm F. Gannett
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 9

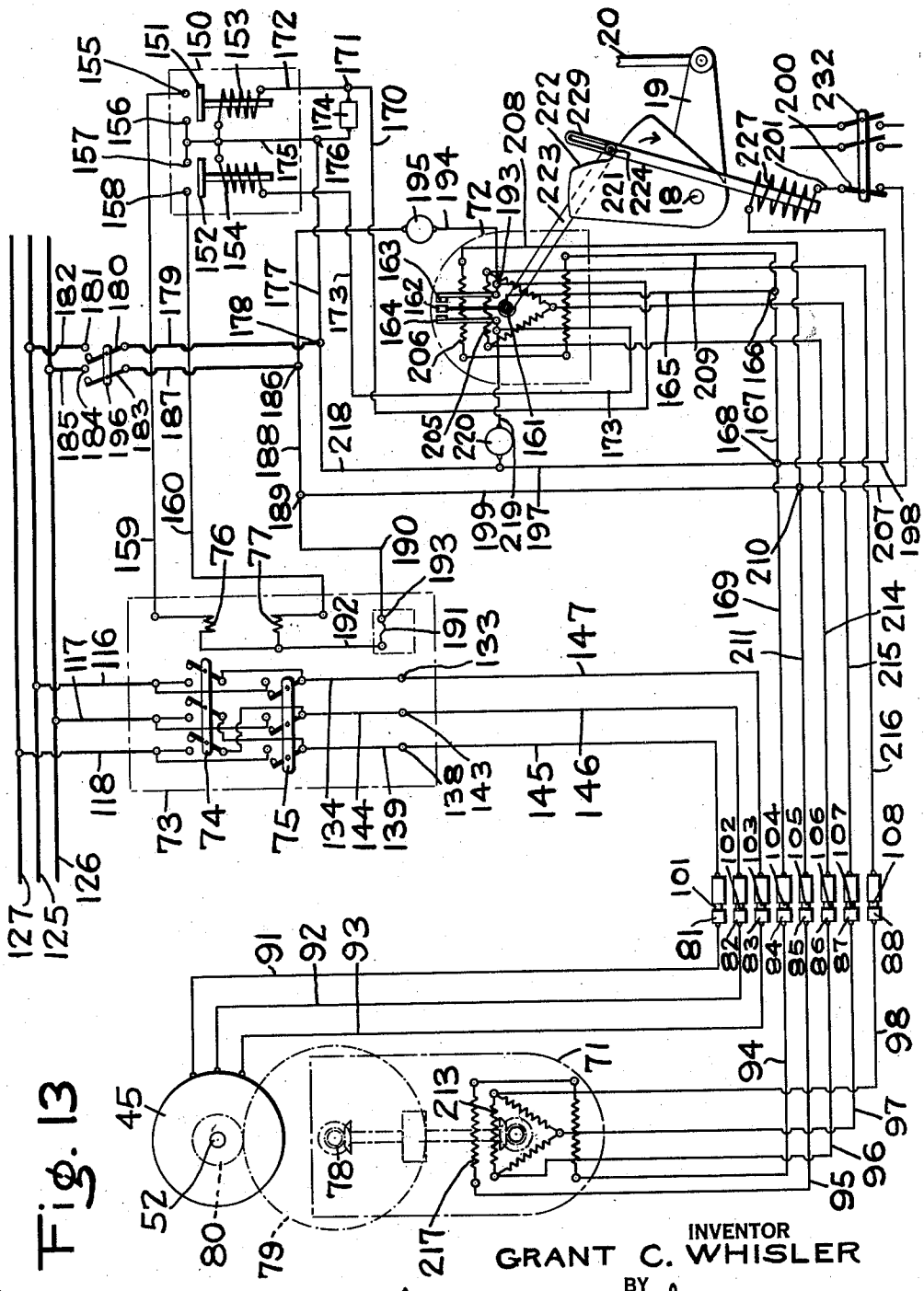


Fig. 13

INVENTOR
GRANT C. WHISLER
BY
Malcolm F. Hamlett
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938 11 Sheets-Sheet 10

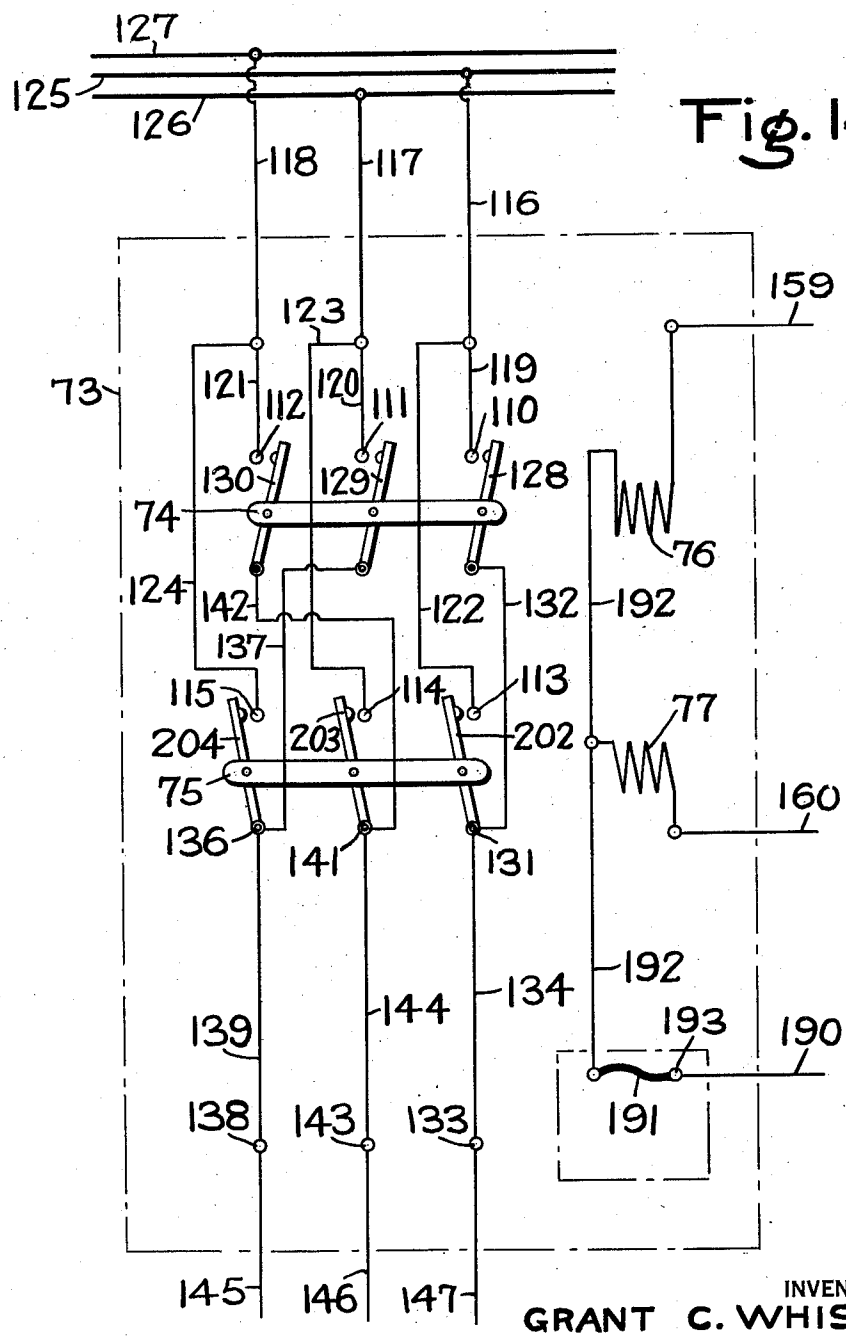


Fig. 14

INVENTOR
GRANT C. WHISLER
BY Malcolm F. Gannett
ATTORNEY

Oct. 11, 1938. G. C. WHISLER 2,132,504

HYDRAULIC MACHINE

Filed Feb. 17, 1938. 11 Sheets-Sheet 11

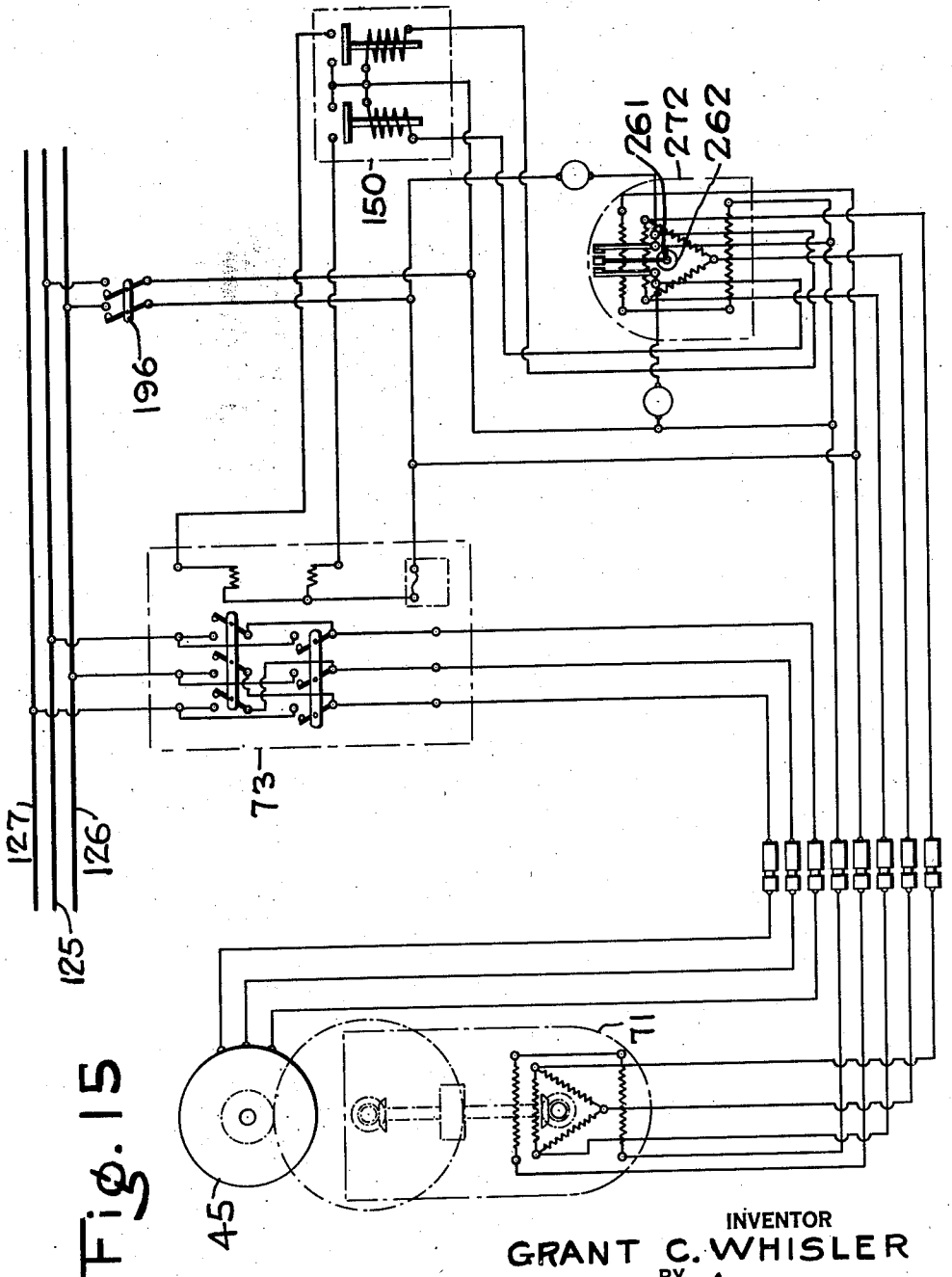


Fig. 15

INVENTOR
GRANT C. WHISLER
BY
Malcolm F. Gannett
ATTORNEY

Patented Oct. 11, 1938 2,132,504

UNITED STATES PATENT OFFICE

2,132,504

HYDRAULIC MACHINE

Grant C. Whisler, York, Pa., assignor to S. Morgan Smith Company, York, Pa., a corporation of Pennsylvania

Application February 17, 1938, Serial No. 191,095

41 Claims. (Cl. 253—143)

This invention relates to improvements in hydraulic machines and more particularly to hydraulic turbines of the type wherein the blades of the runner are adjustable to vary their angle and the area of the water opening through the runner to correspond with the angle and opening of the wicket gates or guide vanes which control the admission of water to the runner.

An object of the invention is to provide an improved adjustable blade hydraulic turbine having a control mechanism in which means are provided by which the operating mechanism for the runner blades is electrically actuated under the control of the wicket gate controlling means, so that when the wicket gates are adjusted, the relative position of the runner blades will also be correspondingly adjusted and thereby maintain a definite relationship between the angle or position of the wicket gates and the angle or position of the runner blades at all times.

Another object of the invention is to provide an improved hydraulic turbine of the above type in which the runner blade adjusting mechanism is operated by an electric motor which is, during the normal operation of the turbine, under the control of self-synchronous electrical devices associated with the wicket gate controlling mechanism.

Another object of the invention is to provide an improved electrical system for controlling the operation of adjustable blade hydraulic turbines which can be installed in existing turbine settings of the fixed blade or propeller type, without changes in the generator equipment or turbine setting.

Another object of the invention is to provide an improved control system for adjustable blade hydraulic turbines which is adapted to be combined with a standard turbine governor mechanism without the necessity of changing the governor or increasing the cost thereof.

Another object of the invention is to provide an improved control system for hydraulic machines of the type having adjustable runner blades and movable wicket gates and governor mechanism for varying the positions of the runner blades and the wicket gates in accordance with variations in load so that the runner blades are correspondingly positioned with respect to the wicket gates during operation of the hydraulic machine, wherein means are provided by which the runner blades can be moved independently of any movement of the governor from closed position when the hydraulic machine is idle and set at a desired position preparatory to starting up the machine and the governor can be manually actuated to shift the position of the wicket gates from closed position to a position corresponding with the runner blades as the runner attains speed.

Another object of the invention is to provide an improved hydraulic machine of the character mentioned, which is simple in construction, and reliable and exact in function under all conditions of service.

The invention also comprises certain new and useful improvements in the construction, arrangement and combination of the several parts of which it is composed, as will be hereinafter more fully described and claimed.

In the accompanying drawings:

Figure 1 is a side elevation, partly in section, of a hydraulic machine having a runner of the adjustable blade type and embodying blade adjusting and controlling means according to the present invention;

Fig. 2 is an enlarged vertical section of the lower end of the runner shaft, showing the construction of the parts within the hub of the runner;

Figs. 3, 4 and 5 are vertical sections on an enlarged scale of the mechanism at the upper end of the runner shaft for operating the runner blade adjusting means;

Fig. 6 is a horizontal section taken on the line 6—6 of Fig. 3;

Fig. 7 is a horizontal section taken on the line 7—7 of Fig. 4;

Fig. 8 is a detail plan of the electrical control devices operatively associated with the governor mechanism;

Figs. 9 and 10 are elevations of the structure shown in Fig. 8;

Fig. 11 is a vertical section of a portion of the governor mechanism;

Fig. 12 is a horizontal section taken on the line 12—12 of Fig. 11;

Fig. 13 is a diagrammatic view of the automatic electric control system shown in Fig. 1;

Fig. 14 is an enlarged diagrammatic view of the magnetic reversing switch device shown in Fig. 13; and

Fig. 15 is a diagrammatic view of a manually operated electrical control system.

Referring to the drawings, and especially to Fig. 1, the improved hydraulic turbine comprises a casing 11 which forms a peripheral water inlet in which are mounted an annular series of movable wicket gates 12 and an annular series

of stationary guide vanes 13, the guide vanes surrounding the wicket gates.

Projecting from the wicket gates 12, are shafts 14 which are journalled in suitable bearings carried by the casing 11 and terminate a suitable distance thereabove.

The wicket gates 12 are adapted to be rotated simultaneously into different angular positions to control the flow of water into the hydraulic turbine in a well-known manner, and for this purpose the upper ends of the shafts 14 are usually provided with gate operating arms 15 which are fixed to said shafts and operatively connected to a gate adjusting ring 16.

The gate adjusting ring 16 is connected by link means 17 to a shaft 18 which is usually vertically disposed, as shown at the right in Fig. 1.

Fixed to the upper end of the shaft 18, is an arm 19 which is connected by links 20 to a cross head 247 of a governor 21, (see Figs. 1, 8, 11 and 13).

If so desired, the governor 21 may be of the usual type employed with hydraulic machines to adjust the gates thereof and thereby maintain the turbine at its rated speed notwithstanding variations in the load thereon.

As shown in Figs. 1 and 11, the governor 21 includes in its construction a hand wheel 39 by which the governor can be manually operated in well known manner to effect adjustment of the relative positions of the wicket gates 12 preparatory to starting the hydraulic turbine, as will be hereinafter more fully described.

The governor hand wheel 39 is mounted on a shaft 240 carrying an eccentric 241 and a worm gear 242. The eccentric 241 is adapted to move the gear 242 into and out of meshing relationship with a worm gear 243. The worm gear 243 is fixed to a shaft 244 extending transversely of the governor, said shaft having also fixed thereon a pinion gear 245. The teeth of the gear 245 are in meshing relationship with teeth 246 formed on the cross head 247. The cross head 247 is slidably mounted in the housing of the governor 21, one end of the cross head 247 being connected to the links 20. The opposite end of said cross head is connected to the rod 248 of the main governor piston 249. The piston 249 functions as a servo motor for automatically operating the wicket gates 12 in accordance with changes in load, and fluid under pressure is adapted to be supplied by suitable mechanism (not shown) to the cylinder 250 through ports 251 and 252, connected respectively, to the chambers on opposite sides of the piston 249.

The lower end of the casing 11 forms an axially directed chamber 22 in which the runner 23 operates.

As shown in Fig. 2, the hub of the runner 23 is fixed to the lower end of a hollow or tubular shaft 24 which extends upwardly through the casing 11 in the usual manner.

The upper end of the runner shaft 24 is connected to the lower end of a tubular casing 40, the upper end of said casing being connected to the shaft 25 of an electric generator 26 which is mounted in superposed position above the hydraulic turbine, as shown in Fig. 1.

Any suitable type of setting may be used, a concrete setting 27 being shown in the present instance. This setting forms a scroll case 28 which surrounds the turbine inlet and is connected to receive water from a flume or other source of supply. The portion of the setting below the runner forms a draft tube 29 into which the water is discharged. The electrical generator 26 may rest on the top of the setting as shown.

As shown in Fig. 2, a suitable number of blades 30 are rotatably supported in the hub of the runner 23 and project radially therefrom. In the present instance four blades are shown (see also Fig. 1).

The inner end of each blade 30 is formed with a trunnion 31 which is journalled in bearings 32 and 33 supported in the hub. The construction is such that the blades are rotatable into different angular relationships with the axis of the runner.

Means are provided for simultaneously rotating all of the blades 30 and for maintaining them in equal angular relationships, such means comprising preferably an arm 34 rigidly fixed on the trunnion 31 of each blade and links 35 which pivotally connect each arm 34 to a cross head 36. The cross head 36 is guided to reciprocate in a direction axially of the runner by guide pins 37 which are mounted in the hub of the runner in the manner shown in Fig. 2.

It will be understood that the relative positions of the blades 30 governs the area of the water passage or openings between the blades, and that when the blades are rotated, the area of the water passages is increased or decreased depending upon the direction in which the blades are moved.

As shown in Fig. 1, a cap 38 is bolted or otherwise removably secured to the lower end of the hub of the runner 23. Since the hub of the runner is otherwise enclosed and the hub is hollow, the cap 38 provides a closed chamber or reservoir for containing a supply of grease for lubricating the various working parts of the mechanism contained within the hub of the runner.

In the usual construction of hydraulic turbines the runner shaft is made of sufficient length so that said shaft can be bolted directly to the lower end of the generator shaft. However, in the present instance, the shaft 24 is made comparatively short so that the elongated tubular casing 40 can be interposed between the shaft 24 and the generator shaft 25. The casing 40 encloses elements, to be hereinafter described, for operating the runner blade mechanism within the hub of the runner 23, and said casing is adapted to be bolted to the runner shaft 24 and the generator shaft 25 and thereby constitute a rotary portion of the main shaft of the turbine. For convenience of manufacture the casing 40 is composed of two vertically divided sections, which sections are adapted to be bolted together at intervals throughout their length, as shown in Figs. 3, 4, 6 and 7.

The casing 40 is constructed in such a manner that the elements contained therein can be mounted on one half or one section of the casing so that the other half or section of the casing can be removed without dismantling any part of the turbine, the generator, shafts and motor operating mechanism. In this way inspection, adjustment and replacement of the parts within the casing 40 can be readily accomplished in a minimum amount of time.

As shown in Figs. 6 and 7, the casing 40 may have lower and upper inlet and outlet vent openings 255 and 256, respectively, formed therein for inducing currents of air to flow through the interior of the casing when the runner is in operation, so as to prevent overheating of the ele-

ments of the apparatus within the casing. In Fig. 6 the arrow indicates that the direction of rotation of the runner shaft is clockwise. As shown in Fig. 7, the wall 257 of the casing 40 at the inlet vent opening 255 is so formed that, during rotation of the runner, air will be directed by said wall towards the interior of the casing. On the other hand, as shown in Fig. 6, the wall 258 at the outlet opening 256 is so formed as to permit the air to pass outwardly from the interior of the casing.

The upper portion of the shaft 24 is enlarged, as indicated at 41, Figs. 4 and 5. This enlarged portion of the shaft 24 is secured to the lower portion of the casing 40 by a plurality of bolts 42, as shown in Figs. 4, 5 and 7.

The lower portion of the generator shaft 25 is formed with a flange 43 which is secured to the upper portion of the casing 40 by bolts 44, as shown in Fig. 3.

In this way rotation of the runner shaft 24 will be transmitted to the shaft 25 of the generator 26 by the casing 40.

Disposed within the casing 40 is an electric motor 45 which is adapted, through mechanism to be hereinafter described, to operate the runner blade adjusting mechanism in the hub of the runner 23.

Since the runner blades are adjusted by slowly moving the cross head 36 either upwardly or downwardly, and since it is of advantage to employ an electric motor of standard design, which motors usually have a comparatively high speed, it is necessary to provide means in the mechanism which is employed to operatively connect the electric motor with the cross head 36, for reducing the speed from the motor sufficiently to effect the desired slow movement of the cross head 36.

As shown in Fig. 2, the cross head 36 is bolted or otherwise fixed to the lower end of an operating rod 46 which extends upwardly through the hollow runner shaft 24.

As shown in Fig. 5, the upper end of the rod 46 is fixed to an internally threaded sleeve 47 which is slidably mounted in the bore of the runner shaft 24.

Fitted to the sleeve 47 is a screw 48, which is connected to the driven member 49 of a speed reducer 50.

As shown in Figs. 4 and 7, the speed reducer comprises a driving member in the form of a shaft 51, and the driven member 49.

The driving member or shaft 51, which is connected to the shaft 52 of the motor 45 by a coupling 53, has an eccentric 54 thereon which supports a ball bearing or other anti-friction bearing 55.

The outer member or race of the ball bearing 55 is surrounded by a series of radially disposed plungers 56. The inner ends of the plungers 56 bear on the outer race of the bearing 55 and the outer ends of said plungers are arranged to cooperate with teeth 57 formed concentrically within the outer or stationary member 58. Both ends of the plungers 56 are bevelled, and the teeth 57 are bevelled.

The number of teeth 57 differs from the number of plungers 56 so that rotation of the eccentric 54 will cause the plungers 56 to be forced outwardly in succession around the circular series of teeth 57 and in consequence will cause the plungers to creep around within the stationary member 58.

The plungers 56 are guided to reciprocate in a member 59 which is fixed to the driven member 49 by pins 60 so that the creeping motion of said plungers around the toothed interior of the stationary member 58 will be transmitted to the driven member 49. The motion of the driving member 51 is thus transmitted to the driven member 49, but at a great reduction in speed ratio.

The speed reducer 50 is mounted between upper and lower supporting members 61 and 62, respectively, which are fixed within the casing 40 by bolts 63 attached to the enlarged portion 41 of the runner shaft 24, as shown in Fig. 4.

Upper and lower roller thrust bearings 64 and 65 are, respectively, provided for the speed reducer 50, and above the upper thrust bearing 64 there is a ball bearing 66. The roller thrust bearings are adapted to carry the forces imposed on the operating rod 46 by the runner blades.

The driving member of the speed reducer 50 is connected to the armature or other rotating part (not shown) of the motor 45, so that the speed reducer will be actuated by said motor.

Since the driven member 49 of the speed reducer 50 and the screw 48 are directly connected together, the rod 46 will be operated by the sleeve 47 to effect changes in the angular positions of the runner blades.

For the purpose of indicating the relative positions of the runner blades, at a convenient point the runner shaft 24 is formed with an elongated slot 68 (see Figs. 1 and 5).

Disposed within the slot 68 is a pointed pin 69 which is fixed to the upper portion of the operating rod 46. In the present instance the pin 69 is shown as being carried by the sleeve 47.

As shown in Fig. 1 the exterior of the runner shaft 24 adjacent to the slot 68 carries suitable marks for indicating the several angles of runner blade positions, as determined by the position of the pointed pin 69.

Preferably the electric motor 45 is a three-phase alternating current induction motor which is adapted to be supplied with electric current from a main power line 125, 126 and 127, in such a manner that the motor will operate in either direction. The electric circuit for conducting high voltage electric current to the motor 45 will be hereinafter fully described.

When the motor 45 operates in one direction the screw 48 will, through the sleeve 47, cause a rectilinear movement of the rod 46 in one direction, and when the motor 45 operates in the other direction, the rod 46 will be moved in the opposite direction, due to the reversed movements imparted to the screw 48 by the motor.

As shown by the arrow, Fig. 2, when the rod 46 moves upwardly, the runner blades 30 are moved towards closed position, and when the rod 46 moves downwardly in a direction opposite to the arrow, Fig. 2, the runner blades 30 are moved toward open position.

The construction of the speed reducer 50, screw 48, and sleeve 47 is such that, when the shaft 51 is rotated by the motor 45 in a clockwise direction, the runner blades will be moved toward closed position, and when the motor is reversed and the shaft 51 is rotated in a counter-clockwise direction, the runner blades will be moved toward open position.

For the purpose of controlling the operation of the electric motor 45, an electrical system is utilized which comprises a self-synchronous motor 71 operatively connected to the electric motor 45 and a self-synchronous motor 72 operatively connected with the governor 21. The motors 71 and

72 are electrically connected in a manner to be hereinafter described so that operation of one of said motors effects operation of the other motor.

The self-synchronous motors 71 and 72 are similar in construction, each having a single-phase field winding and a polycircuit armature winding, one of these windings being on the stator and the other winding on the rotor of the respective motors. The field windings are excited from a suitable source of single-phase alternating current and thereby set up fields which interlink with their respective armature windings. The like points of the polycircuit armature windings are electrically connected so that a change in the angular position of the rotor of one device will set up unbalanced voltages in the armature windings, in consequence of which a torque is developed which acts to bring the rotors of the different motors into the same or corresponding angular positions.

According to the present invention the self-synchronous motor 72 constitutes the transmitting device and the self-synchronous motor 71 constitutes a receiving device.

As shown in Fig. 3, the motor 71 has a spur gear shaft 78 carrying a gear 79 which is in meshing relationship with a gear 80 fixed to the shaft 52 of the motor 45. In this way the motors 71 and 45 are operatively connected for a purpose to be hereinafter more fully described.

The casing 40 carries a plurality of collector rings 81, 82, 83, 84, 85, 86, 87 and 88. These collector rings are preferably mounted on vertically disposed bars 89 which are connected to the upper portion of the casing 40, as shown in Fig. 3. Only one bar 89 is shown, but it will be understood that a suitable number of these bars can be arranged around the casing to rigidly support the collector rings.

The collector rings 81, 82 and 83 are connected to the electric motor 45 by conductors 91, 92 and 93, respectively.

The collector rings 84, 85, 86, 87 and 88 are connected to the self-synchronous motor 71 by conductors 94, 95, 96, 97 and 98 respectively.

The conductors are preferably contained within insulated cables which are passed through openings in the top of the casing 40 and extend downwardly to the motors 45 and 71, respectively, as shown in Fig. 3.

As shown in Figs. 1 and 13, brushes 101, 102, 103, 104, 105, 106, 107 and 108 which are carried by a bracket 109 suspended from the generator 26, engage, respectively, the collector rings 81, 82, 83, 84, 85, 86, 87 and 88.

For the purpose of controlling the motor 45, a magnetic switch device 73 is utilized.

As shown diagrammatically in Figs. 13 and 14, the switch device 73 comprises two sets of movable switch elements or blades 74 and 75, which are adapted to be operated by magnets 76 and 77, respectively.

The magnet 76 is associated with the switch 74 comprising the switch elements 128, 129 and 130.

The magnet 77 is associated with the switch 75 comprising the switch elements 202, 203 and 204.

The movable switch elements 128, 129 and 130 are adapted to engage electrical contacts 110, 111 and 112, respectively.

The movable switch elements 202, 203 and 204 are adapted to engage electrical contacts 113, 114 and 115, respectively.

The construction of the switch device 73 is such that when the magnet 76 is energized, the switch elements 128, 129 and 130 will be simultaneously operated to engage the contacts 110, 111 and 112, respectively, and thereby close an electric circuit through which electric current is supplied to the motor 45 for operating said motor in one direction, and when the magnet 77 is energized, the switch elements 202, 203 and 204 will be simultaneously operated to engage the contacts 113, 114 and 115, respectively, so that an electric circuit will be closed through which electric current is supplied for operating the motor 45 in the opposite direction.

As will be hereinafter more fully described, means are provided for controlling the electric circuits of the magnets 76 and 77 in such a manner that when current is supplied for energizing one magnet, the other magnet will remain de-energized.

The main power line conductors 125, 126 and 127 are connected to the contacts 110, 111 and 112 of switch 74, by conductors 116 and, 119, 117 and 120 and 118 and 121, respectively.

The main power line conductors 125, 126 and 127 are also connected to the contacts 113, 114 and 115 of switch 75, by conductors 116 and 122, 117 and 123, and 118 and 124, respectively.

The main power line conductors 125, 126 and 127 supply three-phase, sixty-cycle electric current to the apparatus from a suitable source of supply.

The terminal of the switch element 128 is connected to the terminal 131 of switch element 202 by a conductor 132, and terminal 131 is connected to terminal 133 of the switch device 73, by a conductor 134.

The terminal of switch element 129 is connected to the terminal 136 of switch element 204 by a conductor 137, and terminal 136 is connected to terminal 138 of the switch device 73, by a conductor 139.

The terminal of switch element 130 is connected to the terminal 141 of switch element 203 by a conductor 142, and terminal 141 is connected to terminal 143 of the switch device 73, by a conductor 144.

The brushes 101, 102 and 103 are connected to the terminals 138, 143 and 133, respectively, by conductors 145, 146, and 147.

A pilot switch device 150 is provided for controlling the electric circuits through which electric current is supplied for operating the magnets 76 and 77 of the reversing switch device 73.

As shown in Fig. 13, the pilot device 150 comprises two switch members 151 and 152, which are operated, respectively, by relays 153 and 154.

The switch member 151 is adapted to engage contacts 155 and 156, and the switch member 152 is adapted to engage contacts 157 and 158.

The contact 155 is connected to one terminal of the magnet 76, by a conductor 159, and the contact 158 is connected to one terminal of the magnet 77, by a conductor 160. The other terminals of the magnets 76 and 77 are electrically connected to the pilot switch device 150 in a manner to be hereinafter more fully described.

The shaft 161 of the self-synchronous motor or transmitter 72 carries an electrical contact 162, which contact is disposed between a pair of electrical contacts 163 and 164. The arrangement of the parts is such that the contact 162 has a limited swinging movement between the contacts 163 and 164, before the contact 162 engages either the contact 163 or the contact 164.

The movable contact 162 is connected to the

brush 104 by conductor 165, terminal 166, conductor 167, terminal 168 and conductor 169.

The contact 163 is connected to one terminal of the relay 153 of the pilot switch device 150 by conductor 170, terminal 171, and conductor 172.

Contact 163 is also connected to a terminal 193 of the magnetic switch device 73 by conductor 194, incandescent lamp bulb 195, terminal 186, conductor 188, terminal 189, and conductor 190.

The terminal 193 is connected to the magnets 76 and 77 of the magnetic switch device 73, by fuse 191 and conductor 192.

The contact 164 is connected to one terminal of the relay 154 of the pilot switch device 150 by conductor 173.

The other terminals of the relays 153, 154 together with the contacts 156 and 157 are connected to a conductor 175 leading to a terminal 176.

The terminals 171 and 176 are electrically connected to a time delay switch device 174 of a type adapted to hold the control circuit open for a predetermined length of time to prevent sudden reversals of the main operating motor 45.

From terminal 176 a conductor 177 leads to a terminal 178, and the latter terminal is connected by a conductor 179 to a switch element 180. The switch element 180 is adapted to engage a contact 181 which is connected to the main power line conductor 125 by a conductor 182.

Switch element 180 is one element of a double switch device 196, the other element 183 of which switch device is adapted to engage a contact 184 electrically connected to main power line conductor 126 by a conductor 185. The terminal of switch element 183 is connected to terminal 186 by a conductor 187.

The self-synchronous motor or transmitter 72 has a three-phase, delta-connected armature winding 205 and a field winding 206. One terminal of the field winding 206 is connected to a conductor 208 and the other terminal of the field winding 206 is connected to a conductor 209. The conductor 208 is connected to a terminal 210, and the conductor 209 is connected to terminal 166 heretofore referred to.

The terminal 210 is connected to the brush 105 by a conductor 211.

The different phase points of the armature winding 205 of the transmitter 72 are interconnected to the like phase points of the three-phase armature windings 213 of the motor 71, by conductors 214, 215 and 216, the brushes 106, 107 and 108, the collector rings 86, 87 and 88, and the conductors 96, 97 and 98, respectively.

The motor 71 has a field winding 217, one terminal of which is connected to the conductor 94 from the collector ring 84, and the other terminal of which is connected to the conductor 95 from the collector ring 85 so that the field winding 217 is excited.

For the purpose of actuating the contact 162, the shaft 18 has fixed thereon a plate 221 formed with a cam 222, as shown best in Figs. 8 and 13.

Projecting from the shaft 161 of the motor 72 is an arm 223 having a roller 224 mounted thereon for engaging the cam 222.

As shown in Figs. 1, 8 and 9 the transmitter motor 72 may be mounted on a portion of the housing of the governor 21 at a point adjacent to the shaft 18. This portion of the governor housing also serves as bearing means 225 for supporting the upper portion of the shaft 18.

Fastened to the bearing 225 is a bracket 226 which supports a solenoid device 227.

The movable part 228 of the solenoid 227 is connected to a rod 229 having an elongated slot 230 in its outer end.

The journal 231 of the roller 224 extends through the slot 230 so that when the rod 229 is actuated by the solenoid 227 in a manner to be hereinafter described, the arm 223 will be actuated to turn the shaft 161 of the transmitter motor 72.

When the solenoid 227 is deenergized the journal 231 will be disposed at the inner end of the slot 230 and the roller will be in engagement with the cam 222.

When the solenoid 227 is energized the rod 229 will be moved outwardly in a direction to disengage the roller 224 from the cam 222. However, due to the provision of the slot 230, the rod 229 can return to its normal position when the solenoid 227 is again deenergized without imparting a corresponding movement to the arm 223, since the journal 231 will move inwardly of the slot 230.

For the purpose of positively moving the roller 223 back against the cam 222 independently of any action of the solenoid 227 or rod 229, there is provided a counterweight 233 which is suspended from a cable 234 connected to one end of a coil spring 235 which is in turn connected at its other end to the journal 231. The cable 234 may be passed over a grooved wheel 236 carried by a bracket 237 secured to one end of the solenoid 227.

For energizing the solenoid 227 electric current is supplied from the main line conductors 125 and 126 when the switch device 196 is closed and the switch elements 180 and 183 engage the contacts 181 and 184, respectively. The solenoid electric circuit comprises, from the conductor 125, the line 182, 179, 197 and 198 to one terminal of the solenoid 227, and from the conductor 126, the line 185, 187, 188, 199, terminal 210, line 207, switch device 200 and conductor 201 to the other terminal of the solenoid 227.

The switch device 200 is operatively associated with the field switch 232 of the generator 26 in such a manner that when the field switch 232 is closed the solenoid switch device 200 will be in open position so that solenoid 227 will be deenergized.

As is well known, field switches for electric generators control the electric circuit from the exciter to the generator, and these switch devices may be of the double pole type as shown in Fig. 13, the operating arm of which is connected to the switch 201. When the generating apparatus is idle the field switch is open, and after the prime mover has been started up and attains its desired speed, the field switch 232 is closed, thereby connecting the generator to develop power on the power line.

In operation, the adjustable runner blades 30 are adapted to maintain a definite relative position with respect to the wicket gates 12. When the wicket gates 12 are moved to vary their angle and the area of the water opening to the runner, the runner blades 30 are adapted to be correspondingly moved. However, the actuation of the runner blades to effect a change in the position thereof to correspond with the new position of the wicket gates follows closely the initial actuation of the wicket gate operating mechanism to effect the change in the position of the wicket gates.

Assuming that the turbine is in operation and that the line switch 196 and the generator field switch 232 are both closed, when the governor 21 operates to swing the wicket gates 12 toward open or closed position to vary the gate opening to conform with variations in the load on the turbine, the arm 223, will, through the action of cam 222, turn the rotor shaft 161 of the transmitter 72, and move the contact 162 into engagement with either of the contacts 163 and 164 according to the direction in which the governor 21 operates, thereby closing the electrical circuit through which either the relay 153 or the relay 154 is energized.

For instance, when the governor 21 operates to move the wicket gates toward open position, the cam plate 221 will be moved in the clockwise direction, indicated by the arrow in Figs. 8 and 13, and consequently the movable contact 162 will be moved into engagement with the contact 164, thereby closing the electrical circuit through which the relay 154 is energized. On the other hand, when the governor 21 operates to move the wicket gates toward closed position, the cam plate 221 will be turned in a counter-clockwise direction, and consequently the movable contact 162 will be moved into engagement with the contact 163, thereby closing the electrical circuit through which the relay 153 is energized.

When the shaft 161 is rotated and contact 162 engages with either contact 163 or contact 164, the shaft 161 may continue to rotate beyond the point at which the contact of the switch elements is made. Since the armature winding or rotor 205 is fixed to the shaft 161, obviously said rotor will also be rotated.

When the relay 154 is energized, the switch member 152 is engaged with the contacts 157 and 158, and the electrical circuit of magnet 77 is closed so that electric current is supplied for energizing the magnet 77 from the main power line conductors 125 and 126.

With the energization of the magnet 77, the switch 75 will be operated so that the switch blades 202, 203 and 204 engage the contacts 113, 114 and 115, respectively, and close the circuit from the main power line conductors 125, 126 and 127 to the brushes 103, 102 and 101, respectively. The motor 45 will then rotate in a counter-clockwise direction and its motion is transmitted through the speed reducer 50 to the screw 48. The screw 48, rotating in a counter-clockwise direction at greatly reduced speed within the threaded sleeve 47, will lower the operating rod 46, and said rod will correspondingly lower the cross head 36. The cross head 36, acting through the links 35 and arms 34 will simultaneously rotate the runner blades 30 about their trunnions as axes toward open position.

The motors 72 and 71 each have a single-phase, alternating current rotor with definite poles. These two motors are electrically connected together in the manner heretofore described, forming one system and energizing the rotors creates induced voltages of unequal magnitude in the three legs of the field windings or stators 206 and 217 respectively, with the voltages varying with the position of the rotors.

When the position of the armature winding or rotor 205 of the transmitter motor 72 corresponds with the position of the armature winding or rotor 213 of the receiver motor 71, the voltages in the field windings or stators 206 and 217, respectively, of both motors 72 and 71, are equal and opposite and there is no flow of electric current in either stator winding.

Movement of the transmitter rotor 205 from its original position unbalances the voltages at the three legs of the stators 206 and 217, creating a flow of electric current in the stator winding. This electric current sets up torque in both stators 206 and 217 and with the rotor 213 held in a definite position by the motor 45, the unbalanced torque causes the rotor 205 to hold the contact 162 in engagement with the contact 164.

Since the motor 45 is operatively connected to the armature winding or rotor 213 of the receiver motor 71, by gears 79 and 80, the rotor 213 will be rotated by the motor 45 when the motor 45 operates to effect a change in the angle or position of the runner blades.

The rotation of the rotor 213 of the receiver motor 71 is transmitted to the rotor 205 of the transmitter motor 72, under the influence of the voltages in the interlinked rotor windings tending to bring the rotors into angular agreement.

When the rotor 213 has been rotated by motor 45 to a position corresponding to the position into which the rotor 205 of the transmitter 72 has been rotated by cam 222, the voltages in the field windings 217 and 206 are equal and opposite and the flow of electric current in the stator winding ceases, with the result that contact 162 is caused to move away from the contact 164 so that the electric circuit through which the magnet 77 is energized is opened and said magnet deenergized.

When the magnet 77 is deenergized the switch 75 will be moved to open position, thereby opening the electric circuit through which electric current from the main power line conductors 125, 126 and 127 is supplied to the motor 45 for operating said motor. With the cessation in operation of the motor 45 the runner blades will have been brought to a position corresponding to the position of the wicket gates 12. The parts will then remain so positioned relative to each other until the wicket gates 12 are again operated, whereupon a runner blade adjusting operation similar to that just described will again take place to automatically move the runner blades into proper position with respect to the position assumed by the wicket gates 12.

On the other hand, when the governor 21 operates to move the wicket gates toward closed position, the cam 222 will be moved in a counter-clockwise direction, and consequently the movable contact 162 will be moved into engagement with the contact 163, thereby closing the electrical circuit through which the relay 153 is energized.

When the relay 153 is energized, the switch member 151 is engaged with the contacts 155 and 156, and the electrical circuit of magnet 76 is closed so that the switch 74 will be operated by said magnet and thereby close the circuit from the main power line conductors 125, 126 and 127 to the motor 45. The motor 45 will then rotate in a clockwise direction with the result that the runner blades will be rotated towards closed position.

When the rotor 213 of the receiver 71 has been rotated in the manner hereinbefore described to a position corresponding to the position into which the rotor 205 of the transmitter 72 was rotated by cam 222, the motors 72 and 71 will be synchronized, with the result that contact 162 is caused to move away from the contact 163 so

that the electric circuit through which the magnet 76 is energized is opened and said magnet deenergized. In this way the switch 74 will be moved to open position thereby opening the electrical circuit through which electric current from the main power line conductors 125, 126 and 127 is supplied to the motor 45. With the cessation of operation of the motor 45 the runner blades will have been brought to a position corresponding to the position of the wicket gates 12.

It has been described that there is an electric lamp bulb 195 in the electric circuit between the transmitter switch device and the magnet switch device 73. Another electric lamp bulb 220 is mounted in the circuit from the contact 164, conductors 219, 218, 177 and 175 to relay 154. The purpose of the lamps 195 and 220 is to indicate to an attendant at the hydro-electric power station when the wicket gates 12 and the runner blades 30 are synchronized. When the lamps 195 and 220 are not illuminated, it is an indication that the runner blades are synchronized with respect to the wicket gates, due to the fact that the motors 71 and 72 are correspondingly positioned. Should the runner blades, through some fault in the mechanism, fail to respond to a change in wicket gate movement, one or the other control circuits would remain alive, thereby causing a flow of electric current through one of the lamps. The exact position of the runner blades can then be noted by observing the position of the indicator 69 and the defect in the control system repaired.

In the above description of the operation of the apparatus it was assumed that the turbine was in operation and the manner by which the runner blades are maintained synchronized with the wicket gates was set forth.

When a unit is idle the wicket gates 12 and the runner blades 30 are in closed position, and it is necessary to first manually operate controls to put the turbine in operation, before the unit functions automatically in the manner heretofore described.

In starting up an idle unit embodying the present invention, the first operation is to close the switch device 196 so that the magnetic control circuit will be energized from the power line conductors 125 and 126.

As shown in Figs. 1 and 13, when the apparatus is idle, the generator field switch 232 is open and the switch 200 of the electric circuit of the solenoid device 227 is closed. Thus, when switch 196 is closed electric current will energize the solenoid 227, thereby moving contact 162 into engagement with contact 164. Magnetic switch 75 will then be operated to close the electric circuit through which electric current is supplied from the main power line conductors 125, 126 and 127 to motor 45, in the manner heretofore described, so that the runner blades are moved toward open position.

The movement of the runner blades toward open position, which is effected in the manner just described at the beginning of the operation of starting up a unit, is independent of any movement in the governor 21 and its associated mechanism. In other words, the runner blades are first moved towards open position while the wicket gates are closed.

When the runner blades have thus been opened, an operator moves the worm gear 242 into meshing relationship with the worm gear 243 by operating the eccentric 241 (see Figs. 11 and 12). The hand wheel 39 is next rotated manually to move the cross head 247 in the direction in which the wicket gates 12 are opened.

The opening of the wicket gates 12 admits water to the chamber 22 thereby actuating the runner 23.

As the turbine attains speed, the governor mechanism will function to control the operation of the cross head 247 and consequently the movements of the actuating piston 249 of the governor will be transmitted to the wicket gates 12 and to the transmitter 72. The operator then actuates the eccentric 241 so as to disengage the worm gear 242 from the worm 243, thereby uncoupling the hand wheel 39. The generator field switch 232 is then closed, and this action automatically opens the switch 200 of the electric circuit of solenoid 227, so that the solenoid is deenergized.

When the solenoid 227 is deenergized the roller 224 is pulled into contact with cam 222 by the counterweight 233. With the roller 224 engaging the cam 22 the transmitter 72 will function in the manner heretofore described so as to maintain the runner blades in definite relationship with the wicket gates.

In some cases it is desirable to provide a turbine with a manually operable control. In such cases the transmitter 272 is usually mounted on a control panel or switchboard in the power house. A form of manual control embodying the present invention is shown in Fig. 15. The shaft 261 of the transmitter 272 carries an operating knob 262 by which said transmitter can be manually operated to close the electric circuits to the magnetic switch device 73. In a manual control system the same types of control and switch devices may be used as has been heretofore described, only the transmitter is not operatively connected with a governor to be operated thereby. Therefore, in Fig. 15 the parts corresponding to the same parts shown in Fig. 13 are given corresponding reference numerals.

Under manual operation, an operator moves the transmitter to the position at which it is desired that the turbine operate, such as half gate opening, three-quarter gate opening, etc. The receiver motor 71 will then function in the manner heretofore described to maintain the angular position of the runer blades synchronized with the position at which the transmitter 272 is set.

A manually controlled system is advantageous for use in hydro-electric power plants where units deliver substantially uniform loads. At intervals when changes in the load occur, the transmitter 272 of the manually controlled unit can be operated to effect a corresponding change in the position of the runner blades.

Having thus described my invention, what I claim is:

1. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, and means operable independently of the governor for setting the runner blades at a predetermined position without imparting any movement to said wicket gates.

2. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runer blades and said wicket gates in accordance with variations in load on the runner, and means operable independently of the governor when the machine

is being started up from an idle condition for initially setting the runner blades at predetermined position without imparting any movement to the wicket gates.

3. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, means operable independently of the governor when the machine is being started up from an idle condition for initially setting the runner blades at a predetermined position without imparting any movement to the wicket gates, and means for operating said wicket gates toward open position after the runner blades have been initially set to admit operating fluid to the runner for driving the runner.

4. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, an electric motor for actuating the runner blade operating mechanism, electrical control means for controlling the operation of said motor and comprising a receiver unit operatively connected to said motor and transmitter unit, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, means operatively connecting said transmitter unit with said governor, and means operable independently of the governor when the machine is being started up from an idle condition for initially actuating said transmitter unit so as to set the runner blades at a predetermined position without imparting any movement to the wicket gates.

5. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates, a governor for controlling said wicket gates in accordance with variations in load on the runner blades, said governor having an automatically operable servo-motor for actuating said wicket gates and said runner blades, means operatively connecting said governor and said runner blades for maintaining said runner blades correspondingly positioned with respect to said wicket gates and adapted to change the position of the runner blades when said wicket gates are moved by said governor, means operable independently of the governor for setting the runner blades at a predetermined position without imparting any movement to the wicket gates when said wicket gates and runner blades are in closed position and the machine is being started up from an idle condition, and manually operable mechanism adapted to be actuated independently of said governor servo-motor for setting said wicket gates at a position corresponding to the position at which the runner blades have been initially set.

6. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, mechanism for operating the runner blades and comprising an electric motor and electric means for controlling the operation thereof, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner and having direct mechanical connection with said wicket gates and electrical means controlled thereby connected to said runner blade motor controlling electrical means, and electrical means operable independently of the governor for controlling the operation of said runner blade motor controlling means so that the runner blades can be set at a predetermined position independent of any movement being imparted to said wicket gates.

7. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, mechanism for operating the runner blades and comprising an electric motor and electric means for controlling the operation thereof, a governor for automatically controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner and having direct mechanical connection with said wicket gates and electrical connection with said runner blade operating mechanism, electrical means operable independently of the governor for controlling the operation of the runner blade motor controlling means so that the runner blades can be set at a predetermined position independent of any movement being imparted to said wicket gates, and means for manually moving the wicket gates so that the wicket gates can be set at a position corresponding to the position of the runner blades, said last named means being adapted to be uncoupled from the wicket gate operating mechanism when the position of the wicket gates corresponds to the position of the runner blades so as to permit automatic operation of the governor.

8. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the positions of said wicket gates in accordance with variations in load on the runner, said runner having a shaft containing operating mechanism for the runner blades and an electric motor for operating said mechanism, a pair of synchronous motor devices having rotatable rotors electrically connected together whereby movement of the rotor of one device effects a corresponding movement to the rotor of the other device, one of said motor devices being operatively connected to said runner blade motor and the other motor device being operatively connected to said governor and being operated by said governor whereby movements of the governor to effect changes in the positions of the wicket gates is transmitted by said governor motor device to said runner motor device so as to effect corresponding changes in the positions of the runner blades.

9. In combination, a runner shaft, adjustable runner blades carried by said shaft, means for moving said runner blades and including an electric motor in said runner shaft, control means for said motor comprising two self-synchronous electric motor devices one of which is operatively connected to said runner blade motor and the other motor device being disposed remotely with respect to the runner shaft and being electrically connected to the first motor device whereby operation of said motor devices is synchronized, and means initially operating said second motor device for controlling the operation of all of said motors.

10. In a hydraulic turbine, a rotating shaft, runner blades carried thereby and adjustable upon their axes, an electric motor carried by the shaft, operative connections between said motor and said blades for turning the blades upon their axes, two self synchronous electric motor devices one of which is carried by the runner shaft and has its rotor operatively connected to the rotor shaft of said runner blade motor and the other

motor device being remotely disposed with respect to said runner shaft and having its rotor and its stator electrically connected to the rotor and stator, respectively, of said first motor device whereby movement of the rotor of one of said motor devices is effective in causing a corresponding movement to the rotor of the other said motor device, electric switch means operatively connected to the rotor of the second motor device, electric circuits controlling the operation of said runner shaft motor, said electric circuits being controlled by the electric switch means of the second motor device, and means for controlling the operation of said second motor device.

11. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, the runner having a shaft containing operating mechanism for the runner blades and an electric motor for operating said mechanism, two self-synchronous electric motor devices one of which is carried by the runner shaft and has its rotor operatively connected to the rotor shaft of said runner blade motor and the other motor device being remotely disposed with respect to said runner shaft and having its rotor and its stator electrically connected to the rotor and stator, respectively, of said first motor device whereby movement of the rotor of one of said motor devices is effective in causing a corresponding movement to the rotor of the other said motor device, electric switch means operatively connected to the rotor of the second motor device, electric circuits controlling the operation of said runner shaft motor, said electric circuits being controlled by the electric switch means of the second motor device, and means for controlling the operation of said second motor device.

12. In a hydraulic turbine, a runner having blades movable into different angular positions, gates movable into different angular positions and controlling the flow of the driving fluid to the turbine, a governor for adjusting the angular positions of the gates, mechanism for adjusting the runner blades, said mechanism being operable in opposite directions, an electric motor for operating said runner blade adjusting mechanism, magnetic switches for controlling the motor, one of said switches being operative to control the operation of the motor in one direction and the other said switch being operative to control the operation of the motor in the opposite direction, an electrically operated pilot switch device having means for selectively controlling each of said magnetic switches, a pair of synchronous motor devices having rotors electrically connected together whereby movement of the rotor of one device effects a corresponding movement to the rotor of the other device, one of said motor devices being operatively connected to said runner blade operating motor and the other motor device being operatively connected to said governor, and electrical switch means operatively connected to the rotor of said second named motor device for controlling the operation of said pilot switch device.

13. In a hydraulic turbine, a runner having blades movable into different angular positions, gates movable into different angular positions and controlling the flow of the driving fluid to the turbine, a governor for adjusting the angular positions of the gates, mechanism for adjusting the runner blades, said mechanism being operable in opposite directions, an electric motor for operating said runner blade adjusting mechanism, magnetic switches for controlling the motor, one of said switches being operative to control the operation of the motor in one direction and the other said switch being operative to control the operation of the motor in the opposite direction, an electrically operated pilot switch device having means for selectively controlling each of said magnetic switches, a pair of synchronous motor devices having rotors electrically connected together whereby movement of the rotor of one device effects a corresponding movement to the rotor of the other device, one of said motor devices being operatively connected to said runner blade operating motor and the other motor device being operatively connected to said governor, electrical switch means operatively connected to the rotor of said second named motor device for controlling the operation of said pilot switch, and means operable independently of the governor for actuating said last named electrical switch means whereby the runner blades can be moved without imparting any movement to said gates.

14. In a hydraulic turbine, a runner having blades movable into different angular positions, gates movable into different angular positions and controlling the flow of the driving fluid to the turbine, a governor for adjusting the angular positions of the gates, mechanism for adjusting the runner blades, said mechanism being operable in opposite directions, an electric motor for operating said runner blade adjusting mechanism, magnetic switches for controlling the motor, one of said switches being operative to control the operation of the motor in one direction and the other said switch being operative to control the operation of the motor in the opposite direction, an electrically operated pilot switch device having means for selectively controlling each of said magnetic switches, a pair of synchronous motor devices having their stators and rotors, respectively, electrically connected whereby movement of the rotor of one device effects a corresponding movement to the rotor of the other device, one of said motor devices being operatively connected to said runner blade operating motor and the other motor device being operatively connected to said governor, electrical switch means operatively connected to the rotor of said second named motor device for controlling the operation of said pilot switch, a cam operatively connected with said governor, an arm extending from the rotor of said second named motor device and carrying a roller adapted to engage said cam whereby movement of the cam is effective to operate the electrical switch means of the second motor device, a rod having slotted connection with the arm for operating said arm independently of the cam, a solenoid for operating said rod, and means for controlling the operation of said solenoid.

15. In a hydraulic turbine having adjustable runner blades, a shaft rotatable by the runner, a housing attached to said shaft, a blade operating rod extending coaxially of said shaft, an electric motor within said housing, electrical means including a reversible electrically operated switch for controlling the direction of rotation of said motor, a pair of synchronous motor devices having their rotors and stators, respectively, electrically connected whereby movement of the rotor of one device effects a corresponding movement to the rotor of the other device, one of said motor

devices being operatively connected to said runner blade operating motor, and means for actuating said reversing switch in accordance with the movement of the rotor of said second named motor device.

16. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, and means also connected to said cam operated mechanism for operating the same independently of said governor.

17. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, and means for operating the cam operated mechanism independently of said governor.

18. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, and means for operating the cam operated mechanism independently of said governor whereby the runner blades can be adjusted to a predetermined position without imparting any movement to the wicket gates.

19. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, a rod having slotted connection with said cam operated mechanism for operating the cam operated mechanism independently of said governor, and means for operating said rod.

20. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runer blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, a rod having slotted connection with said cam operated mechanism for operating the cam operated mechanism, a solenoid for operating said rod, and means independent of said governor for controlling the operation of said solenoid.

21. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, a rod having slotted connection with said cam operated mechanism for operating the cam operated mechanism independently of the cam, a solenoid for operating said rod, and means for controlling the operation of said solenoid.

22. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, a rod having slotted connection with said cam operated mechanism for operating the cam operated mechanism independently of the cam, an electrical device for operating said rod, and means independent of said governor for controlling the operation of said electrical device.

23. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, and means for also operating the cam operated mechanism independently of said cam.

24. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, means for also operating the cam operated mechanism independently of said cam, and a solenoid device for operating said last named means.

25. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, means for also operating the cam operated mechanism independently of said cam, a solenoid device for operating said last named means, and means for controlling the operation of said solenoid whereby the runner blades can be adjusted to a predetermined position without any movement being imparted to said wicket gates.

26. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades

and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, means for also operating the cam operated mechanism independently of said cam, a solenoid device for operating said last named means, means for controlling the operation of said solenoid whereby the runner blades can be adjusted to a predetermined position without any movement being imparted to said wicket gates, and means for manually moving the wicket gates to a position corresponding to the position of the runner blades.

27. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, means for also operating the cam operated mechanism independently of said cam, a solenoid device for operating said last named means, means for controlling the operation of said solenoid whereby the runner blades can be adjusted to a predetermined position without any movement being imparted to said wicket gates, and means for manually operating the governor so as to impart movement to the wicket gates to a position corresponding to the position of the runner blades.

28. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including a cam operatively connected to said governor and mechanism operated by said cam, means for also operating the cam operated mechanism independently of said cam, a solenoid device for operating said last named means, means for controlling the operation of said solenoid whereby the runner blades can be adjusted to a predetermined position without any movement being imparted to said wicket gates and said solenoid will remain operative as long as the runner blades are out of synchronization with respect to the wicket gates, means for manually moving the wicket gates to a position corresponding to the position of the runner blades, and means for rendering the solenoid inoperative when the wicket gates and runner blades are correspondingly positioned so as to disconnect the solenoid operated means from the cam operated mechanism and allow said mechanism to be operated solely by said cam.

29. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, and mechanism operated by said cam for operating said transmitter unit.

30. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, a rod having slotted connection with said cam operated mechanism for operating the cam operated mechanism independently of said governor, and means for operating said rod.

31. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, a rod having slotted connection with said cam operated mechanism for operating the cam operated mechanism, a solenoid for operating said rod, and means independent of said governor for controlling the operation of said solenoid.

32. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, a rod having slotted connection with said cam operated mechanism for operating the cam operated mechanism

independently of the cam, an electrical device for operating said rod, and means independent of said governor for controlling the operation of said electrical device.

33. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated py said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, and means for also operating the cam operated mechanism independently of said cam.

34. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, and electrically controlled means for also operating the cam operated mechanism independently of said cam.

35. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, means for also operating the cam operated mechanism independently of said cam, and a solenoid device for operating said last named means.

36. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, means for also operating the cam operated mechanism independently of said cam, a solenoid device for operating said last named means, and means for controlling the operation of said solenoid whereby the runner blades can be adjusted to a predetermined position without any movement being imparted to said wicket gates.

37. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, means for also operating the cam operated mechanism independently of said cam, an electrical device for operating said last named means, means for controlling the operation of said electrical device whereby the runner blades can be adjusted to a predetermined position without any movement being imparted to said wicket gates, and means for manually moving the wicket gates to a position corresponding to the position of the runner blades.

38. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, means for also operating the cam operated mechanism independently of said cam, an electrical device for operating said last named means, means for controlling the operation of said electrical device whereby the runner blades can be adjusted to a predetermined position without any movement being imparted to said wicket gates, and means for manually operating the governor so

as to impart movement to the wicket gates to a position corresponding to the position of the runner blades.

39. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, a cam operatively connected to said governor, mechanism operated by said cam for operating said transmitter unit, means for also operating the cam operated mechanism independently of said cam, an electrical device for operating said last named means, means for controlling the operation of said electrical device whereby the runner blades can be adjusted to a predetermined position without any movement being imparted to said wicket gates and said electrical device will remain operative as long as the runner blades are out of synchronization with respect to the wicket gates, means for manually moving the wicket gates to a position corresponding to the position of the runner blades, and means for rendering the electrical device inoperative when the wicket gates and the runner blades are correspondingly positioned so as to disconnect the electrical device operated means from the cam operated mechanism and allow said mechanism to be operated solely by said cam.

40. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, a reversible electric motor for actuating the runner blade operating mechanism, an electrical receiver unit operatively connected to said motor, an electrical transmitter unit remotely disposed with respect to said receiver unit and electrically connected to the receiver unit whereby movement of one unit effects a corresponding movement of the other unit, electrical switch means operated by said transmitter unit for controlling the operation of said motor, means operatively connected to said governor operating said transmitter unit to effect automatic operation of the runner blades and the wicket gates in unison, means for operating the transmitter unit independently of said governor to adjust the positions of the runner blades, and means for manually adjusting the positions of the wicket gates independently of the automatic operation of said governor.

41. In combination, a hydraulic machine having adjustable runner blades and movable wicket gates adapted to operate in unison, a governor for controlling the operation of said runner blades and said wicket gates in accordance with variations in load on the runner, mechanism for operating said runner blades, means for controlling the operation of said mechanism and including an electric motor operatively connected to said mechanism and electrical switch means operatively connected to said governor, means for operating the electrical switch means independently of the governor to adjust the position of the runner blades independently of the governor, and means for operating the governor to adjust the position of the wicket gates independently of the operation of the runner blade adjusting mechanism.

GRANT C. WHISLER.