H. F. FULLAGAR.

APPARATUS FOR GOVERNING STEAM TURBINES.

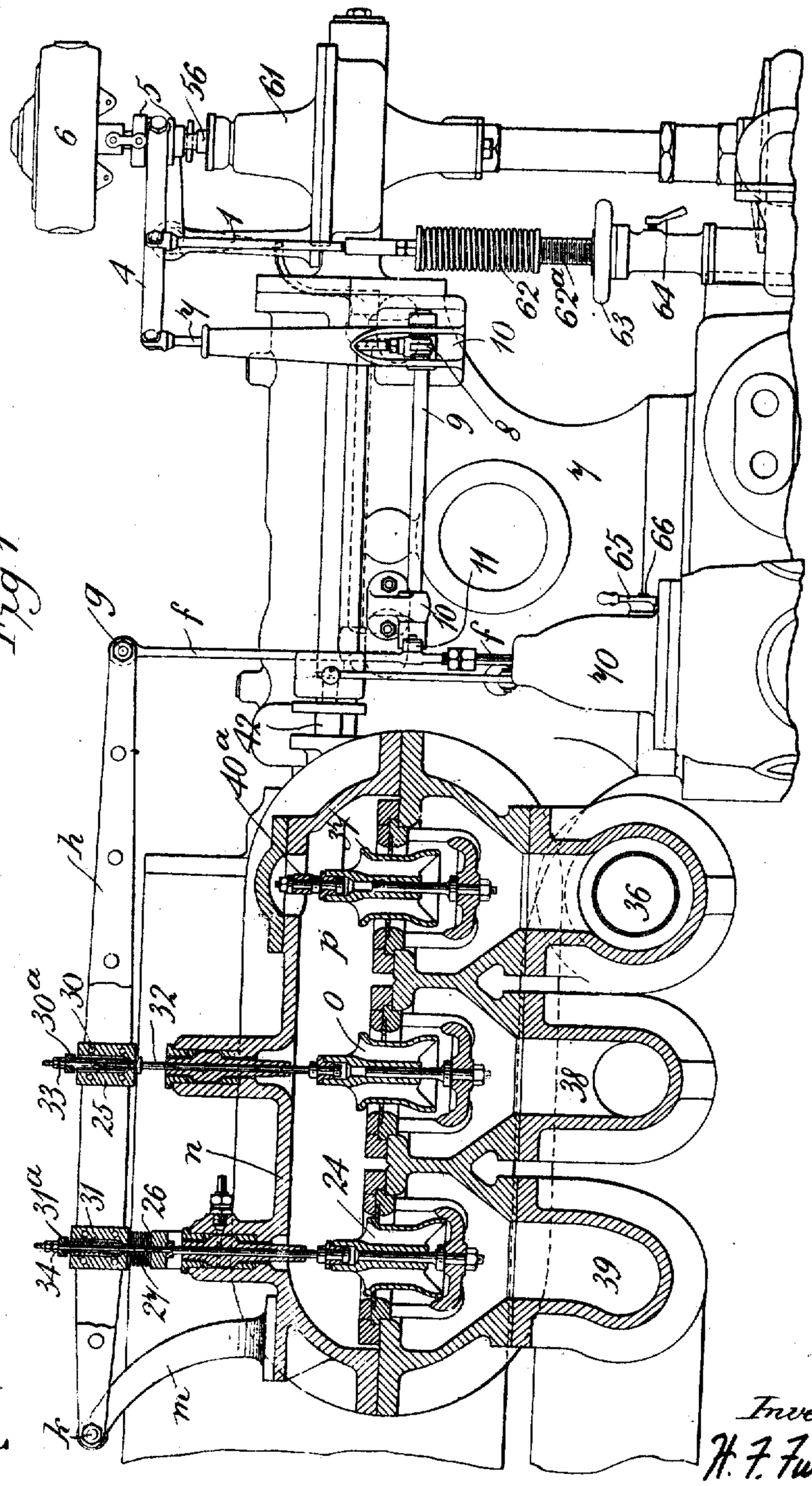
APPLICATION FILED JULY 24, 1905.

913,003.

Patented Feb. 23, 1909.

4 SHEETS—SHEET 1.

Fig 1



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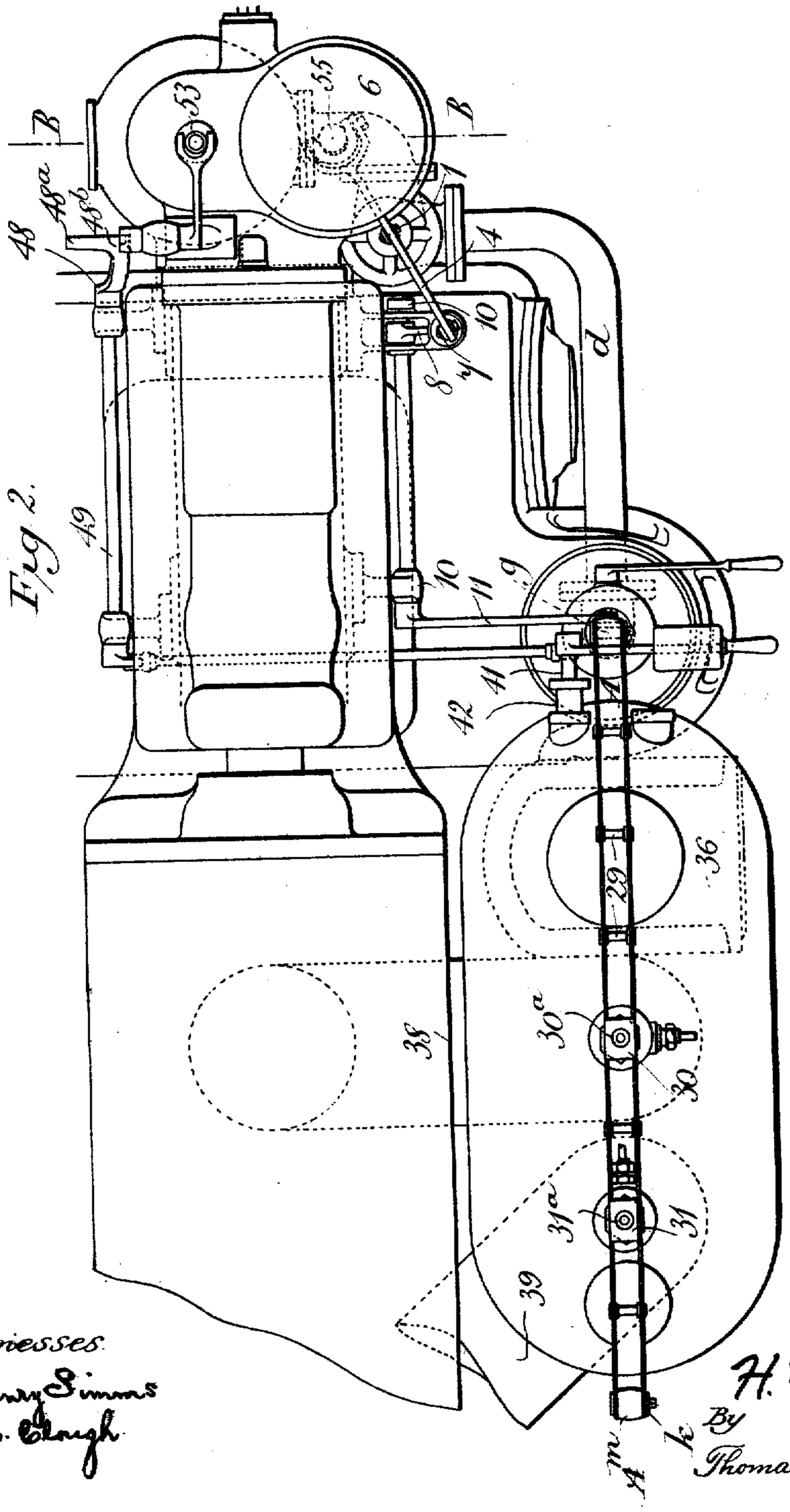
4 SHEETS—SHEET 2.

Fig 2.



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4 SHEETS—SHEET 3.

Fig. 3.

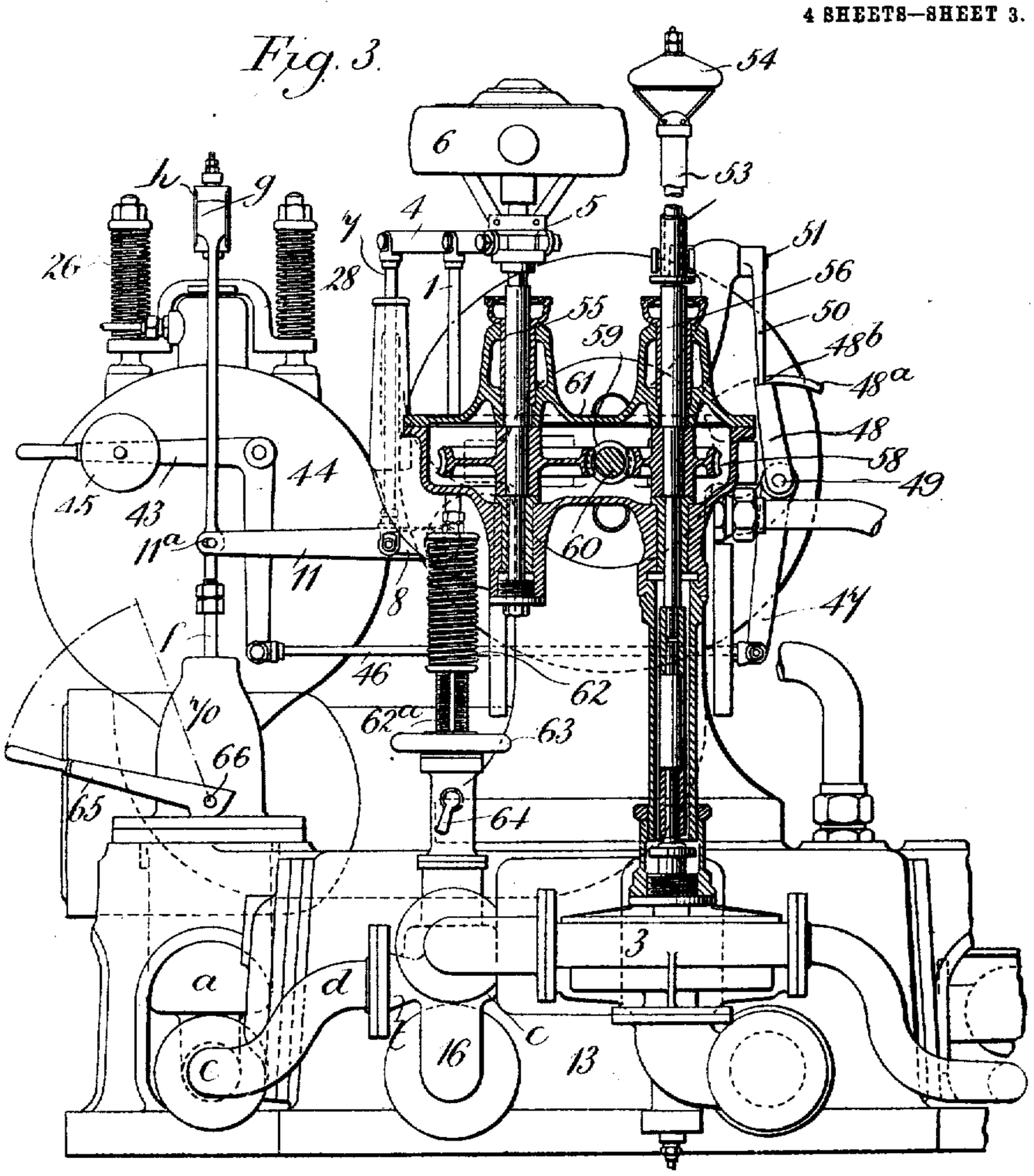


Fig. 1.

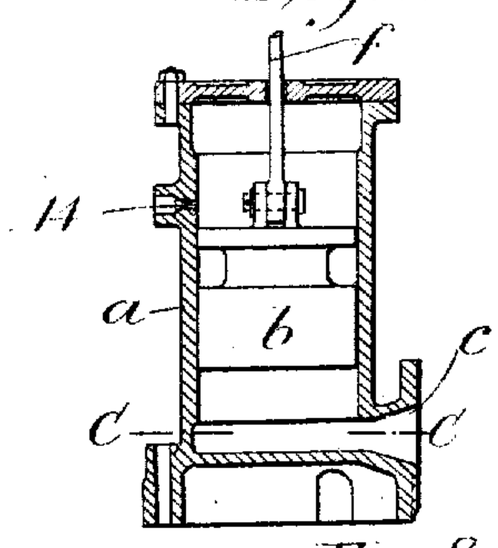


Fig. 5.

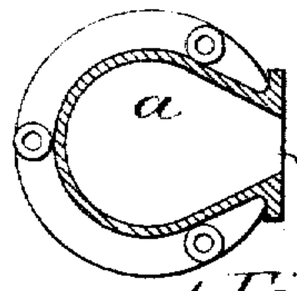


Fig. 6.

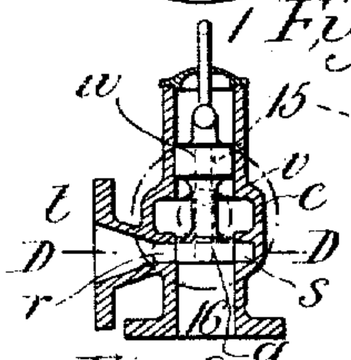


Fig 4

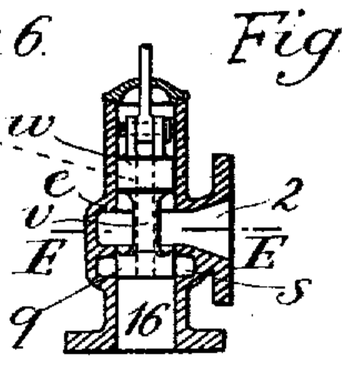


Fig 8

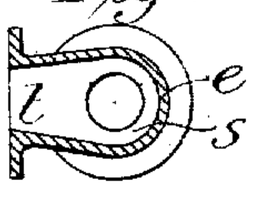
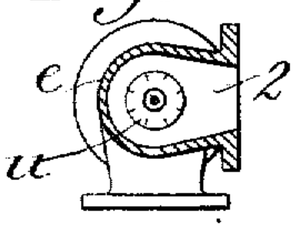


Fig 9.



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4 SHEETS—SHEET 4.

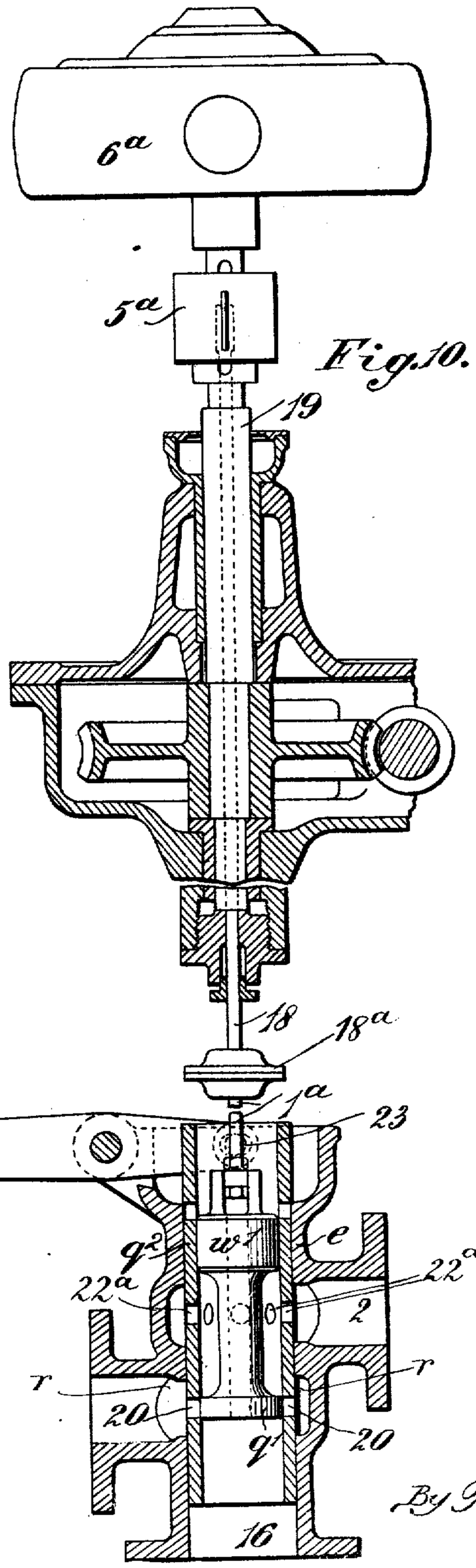

Fig. 10.

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UNITED STATES PATENT OFFICE.

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APPARATUS FOR GOVERNING STEAM-TURBINES.

No. 913,003. Specification of Letters Patent. Patented Feb. 23, 1909.

Application filed July 24, 1905. Serial No. 270,934.

To all whom it may concern:

Be it known that I, HUGH FRANCIS FULLAGAR, a subject of the King of Great Britain and Ireland, residing at Newcastle-upon-Tyne, in the county of Northumberland, England, have invented Improvements in or Relating to Apparatus for Governing Steam-Turbines and other Steam-Engines, of which the following is a specification.

In steam turbines and other engines, especially when of large size, a considerable amount of force is necessary to move the main regulating valve by which the supply of steam to the engine is controlled and to overcome the friction of the valve itself and of the mechanism used for operating it. Moreover, as there is a difficulty in exactly balancing the steam pressure on the valve in all positions thereof, it is important that the valve, especially when it is nearly closed, should be firmly controlled. Furthermore it is usually desirable in the case of a steam turbine, to provide a second or auxiliary regulating valve by which live steam can be admitted to a second inlet of the turbine in order that additional power may be produced, when desired, for enabling the turbine to deal either with an overload, or to meet a fall in the pressure of the steam supplied to the turbine. Such an auxiliary valve usually requires to be loaded, as by means of a spring or weight, to keep it steam tight when not in use, and it therefore requires considerable power to operate and control it. There is therefore a difficulty in operating such a valve directly by means of a governor of the ordinary type on account of the small power of such a governor, especially for small variations of speed. A steam relay, under the control of the governor, is therefore sometimes employed to operate the valve, or the two valves in due succession, such steam relay being capable of being controlled by a governor of small dimensions. It has however been found in practice that a steam operated relay is liable occasionally to stick and become inoperative owing to its controlling valve, which is operated by the governor, becoming incrusted or corroded by scale deposited by the steam escaping through the relay, so that such a relay requires to be cleaned from time to time to insure its working properly.

In steam turbines and other steam engines used for driving dynamos, it is of great importance that the governing arrangements should be reliable for long periods without attention, and should enable a close regulation to be obtained, and this invention has for object to provide governing apparatus designed to enable these results to be attained. For this purpose in governing apparatus according thereto there is employed in connection with an engine governor, the main steam regulating valve, or main and auxiliary steam regulating valves, of the steam turbine or other engine, (hereinafter called the turbine), and the means used for directly actuating the said valve or valves, a relay comprising a liquid pressure motor adapted to be operated in one direction by liquid under pressure, preferably oil, that is not liable to cause corrosion of the working parts, and in the opposite direction by gravity, or by a spring, or by both gravity and a spring, a valve (hereinafter called the controlling valve) for controlling the admission and exhaust of liquid (hereinafter called oil) to and from the motor and which normally closes the oil supply and exhaust ports or passages to and from the relay motor, and means comprising for example a floating lever or equivalent device or mechanism whereby the controlling valve is connected to the governor and to the relay motor so as to be subject to the joint but reversely acting influences of both of these parts, the arrangement being such that when the speed of the turbine falls below or rises above the predetermined normal speed, the valve will be moved by the governor from its normal closed position so as to place the motor in communication respectively with the oil supply under pressure, or with the exhaust, whereby the motor will be caused to immediately move the steam regulating valve or valves to a corresponding extent so as to partially open it or them or close it or them to a further extent, and will simultaneously return the controlling valve to its normal closed position. Thus, while the controlling valve is being moved in one or other direction by the governor it will be simultaneously moved in the opposite direction by the motor, and will be caused to resume its normal closed position immediately after the governor ceases to move it so as to quickly bring the motor and steam regulating valve or valves to rest when the required regulation in the steam supply to the turbine

has been made. Governing apparatus to act in the manner described can be constructed in various forms.

The invention further consists in the various novel features of construction and in the combinations and arrangements of parts all as hereinafter more particularly described and pointed out in the claims.

In the accompanying illustrative drawings, Figures 1, 2 and 3 show a portion of a steam turbine with governing apparatus according to this invention applied thereto, Fig. 1 being a side elevation partly in section on the line A A of Fig. 2; Fig. 2 a plan, and Fig. 3 an end elevation partly in vertical section on the line B B of Fig. 2. Fig. 4 is a central vertical section of an oil relay cylinder, and Fig. 5 a horizontal section thereof on the line C C of Fig. 4. Figs. 6 and 7 are vertical sections, taken at right angles to one another, showing one construction of controlling valve, and Figs. 8 and 9 are sections taken on the lines D D and E E respectively of Figs. 6 and 7. Fig. 10 is a sectional elevation showing a modified construction of controlling valve combined with a governor and relay lever.

In the arrangement shown in Figs. 1 to 9 inclusive, the relay motor comprises a vertically arranged cylinder *a* that is fitted with a piston *b* and is in communication at its lower end through a branch *c* with an oil supply and exhaust pipe or passage *d* that is connected to the casing *e* of the controlling valve. The piston *b* is provided with an upwardly extending rod *f* the upper end of which is connected at *g* to one end of a valve operating lever *h* that is pivoted at its other end *k* to a bearing *m* on a stationary part of the casing of the turbine *n*. The lever *h* is connected at an intermediate part of its length to the main regulating valve *o* of the turbine which is located in a steam chest *p* over which the said lever extends. *q* (Figs. 6 and 7) is the controlling valve of the relay motor. It is of piston type mounted to slide vertically in its valve casing *e* and to control an annular port *r*, or it may be an annular set of ports, communicating with an annular passage *s* that is in communication through a branch *t* with the oil supply and exhaust pipe or passage *d* leading to the relay cylinder *a*. The controlling valve *q* is made of a depth corresponding, or approximately so, to that of the port *r*, and, when this port is of annular shape, as is preferred and as shown, the said valve is provided at its periphery with upwardly extending ribs or lugs *u* that serve to guide it vertically and prevent it entering the port. The controlling valve *q* is connected by a rod *v* to a balancing piston *w* arranged to slide in the valve case *e* above it and, through the said piston, is connected to a valve operating rod 1, the valve case *e* being provided at a point between the controlling valve *q* and its balancing piston *w* with an oil inlet opening 2 connected to the oil pump 3 (Fig. 3) of the oil circulating system so that the oil will flow between the valve and its balancing piston and these parts will be in equilibrium. The valve rod 1 is connected to an intermediate portion of a normally horizontal floating lever 4 one end of which is forked and arranged to engage the sliding grooved collar or sleeve 5 of the turbine governor 6 which may be of the Hartung type, and the other end of which is jointed, as by a link 7, to the free end of a normally horizontal lever arm 8 which is suitably connected to the piston *b* of the relay motor *a b* as by fixing its other end upon one end of a horizontal rock shaft 9 mounted in suitable bearings 10 and to the other end of which is fixed a similarly arranged lever arm 11 the free end of which is jointed at 11^a to the piston rod *f* of the relay motor *a b*.

The operation of the arrangement described is as follows:—When one end of the floating lever 4 is moved in one or other direction by the governor 6 to move the controlling valve *q* from its normal closed position and supply oil under pressure to or allow oil to exhaust from the relay cylinder *a* and thereby cause or allow the piston *b* of the relay motor to move the main valve operating lever *h* and main regulating valve *o* in one or other direction, the said piston will, through the connecting mechanism described, cause the other end of the said floating lever to move in the reverse direction and so cause the said controlling valve to move back towards its normal closed position which it will resume when the floating lever ceases to be further moved by the governor, the valve operating lever *h* and main regulating valve *o* then remaining in the positions into which they have been moved until the controlling valve *q* is again operated by the governor. Oil that leaks past the motor piston *b*, which may be without packing rings, may be caused to flow to an oil exhaust pipe or direct into a receptacle 13 through a hole 14 formed in the wall of the motor cylinder above the piston. Oil that leaks past the balancing piston *w* of the controlling valve, both of which parts may be without packing rings, may be led through a hole 15 in the piston and valve to an exhaust branch pipe 16 into which oil exhausts from the motor cylinder when the controlling valve *q* is moved upward from its normal closed position.

In the modified arrangement shown in Fig. 10, the controlling valve is made as a compound valve comprising a main inner piston valve q^1 and an outer tubular cut-off valve q^2 in which the main piston valve q^1 is arranged to slide endwise and which is itself arranged to slide between the piston valve and valve

casing *e* and control the communication between the relay motor *a*—*b* and the oil supply and exhaust passages 2 and 16 respectively. The piston valve q^1 is provided with a balancing piston w^1 as before, and is connected to the sliding collar 5^a or equivalent part of the governor 6^a, as for example through an endwise movable rod 18 that may extend downward through the governor driving shaft 19 and is connected at its lower end either directly, as through a swivel coupling 18^a, or indirectly through suitable connecting means, as for example a lever, to the rod 1^a of the main piston valve q^1 so that endwise movement of the collar 5^a will be transmitted either directly, or indirectly to the said piston valve. The cut-off valve q^2 is formed with ports 20 that are adjacent to the main piston valve q^1 and to the annular port *r* (or ports) in the valve casing *e* communicating with the motor cylinder, the main and cut-off valves being normally in the relative positions shown so that the main valve q^1 closes the ports 20 in the cut-off valve. The cut off valve q^2 is also formed with holes 22^a to allow oil to pass to its interior from the oil supply branch 2. The compound controlling valve is connected to the piston of the relay motor through suitable operating mechanism acting substantially like that used for the controlling valve in the arrangement of governing apparatus hereinbefore described with reference to Figs. 1 to 9 inclusive, and comprising for example a lever 22 one end of which is connected to the motor piston rod and the other end of which may be forked and connected to pins 23 on the cut off valve q^2. The arrangement is such that when the main piston valve q^1 is moved by the governor 6^a to open the ports 20 in the cut off valve q^2 and place the relay motor either in communication with the oil supply 2, or with the exhaust 16, according as the speed of the turbine falls below or rises above the normal, the cut-off valve q^2 will be moved in the same direction by the relay motor so as to bring the piston valve q^1 and cut-off valve q^2 into their original relative positions and close the communication between the relay motor and the oil supply 2, or exhaust 16, and cause the piston of the relay motor and attached parts to remain in the positions into which they have been moved for regulating the supply of steam to the turbine until the governor 6 again acts to operate the main piston valve q^1.

When a loaded auxiliary steam regulating valve 24 (Fig. 1) is required to be used for the purpose hereinbefore set forth, it may, as shown, advantageously be arranged to be operated from a part of the main valve operating lever *h* located between the pivoted end *k* of such lever and the point of attachment 25 thereto of the main regulating valve *o* so that a relay motor of comparatively small size and using only a small quantity of oil will suffice to lift such valve even when heavily loaded, as in the example by a pair of springs 26 acting upon the valve rod 27 through a yoke piece 28. The valve operating lever *h* may comprise as shown in Fig. 2, two bars held together at a distance apart by distance pieces 29 and arranged to embrace flanged sleeves 30 and 31 or equivalent devices, on the rods 32 and 27 respectively of the two regulating valves *o* and 24 and to normally bear against the flange 30^a of the sleeve 30 of the main valve *o* but not against the flange 31^a of the sleeve 31 of the auxiliary valve 24, the arrangement being such that the auxiliary regulating valve 24 will not be operated by the lever *h* until after the main regulating valve *o* has been fully opened. The sleeves 30 and 31 bear upwardly against nuts 33 and 34 on the two valve rods 32 and 27 respectively.

As will be obvious the details of construction can be variously modified. In the constructional arrangement shown, the steam chest *p* is arranged at one side of the turbine *n* and is constructed with a steam supply inlet passage 36 controlled by a stop valve 37; with a main steam outlet branch 38 for supplying steam, under the control of the main regulating valve *o*, from the steam chest *p* to one end of the turbine; and with an auxiliary steam outlet branch 39 for supplying steam, under the control of the auxiliary valve 24, from the said steam chest to a part of the turbine located between its main steam inlet and exhaust. The stop valve 37 is preferably adapted to act as a safety valve to automatically shut off the supply of steam to the steam chest and turbine in the event of the speed of the turbine exceeding a predetermined limit. For this purpose it is arranged to be opened by the forked end 40^a of a lever arm 40 fixed upon a spindle 41 that extends through a stuffing box 42 and has fixed to its outer end a bell crank lever 43—44, one arm 43 of which is loaded, as by a weight 45 and is adapted to serve as a hand lever whereby the valve can be opened for starting. The other arm 44 of the lever is connected by a link 46 to one arm 47 of a second lever 47—48 that is pivoted at 49 and the other arm 48 of which is adapted, as by providing it with a curved lateral extension 48^a, to be held by a depending trip arm 50 that is fixed to a spindle 51 to which is fixed a horizontal arm 52 arranged to be raised by the sleeve 53 of a safety governor 54. The arrangement is such that when the hand lever 43 is operated to open the safety valve 37, the extension 48^a of the lever 47—48 will be caused to move past the end of the arm 50 which finally snaps behind the extension at 48^b and holds the lever 47—48 and connected parts in the positions shown and so

holds the safety valve 37 open. Upon the speed of the turbine exceeding the predetermined limit, the governor sleeve 53 will operate the lever arms 52 and 50 so as to release the lever 47—48 and permit the weighted arm 43 to fall and insure the automatic closing of the valve.

The shafts 55 and 56 for the regulating and safety governors 6 and 54 are driven respectively by worm wheels 57 and 58 that are in gear with a worm 59 on the turbine shaft 60 and are inclosed in a casing 61. The oil pump 3 is driven from the same shaft 56 as the safety governor 54.

Means may be provided whereby the action of the regulating governor 6 can be varied, it may be while the turbine is running, for adjusting the normal speed of the turbine. For this purpose, in the example shown, the rod 1 of the controlling valve has connected thereto one end of an adjustable spring 62 the other end of which is connected to a vertically adjustable non-rotatable screw-threaded sleeve 62^a that extends through a nut 63 which is arranged to be rotated but not to move endwise and by means of which the said sleeve 62^a can be moved endwise. 64 is a set screw provided with a handle and by means of which the sleeve 62^a can be prevented from turning and by which it can be fixed in position after adjustment.

Means may be combined with the piston rod *f* of the relay motor for raising the valve operating lever *h* and attached parts by hand for starting the turbine or at other times. Such means (hereinafter called starting gear) comprises a hand lever 65 fixed upon a spindle 66 that is connected to means such as a cam which is arranged within a casing 70 and is adapted to act upon a shoulder on the valve rod *f* and lift it when the hand lever 65 is raised. This lever will be held in the raised position until the pressure of the oil supplied to the relay cylinder rises sufficiently to relieve the cam of the weight of the valve operating lever and attached parts when it will be automatically released and allowed to fall into its inoperative position.

It is preferred to arrange the regulating governor, safety governor, oil pump and attached parts at one end of the turbine, as in the example shown, but they can be arranged in other positions if desired.

It will be evident that various other changes can be made in the construction of the governing apparatus hereinbefore described without departing from the spirit and scope of the invention so long as the relative arrangement of the main parts of the apparatus or the mode of operation described is preserved.

What I claim is:—

1. In governing apparatus for a fluid pressure engine, the combination of a valve for regulating the supply of fluid to the engine, a lever fulcrumed at one end and connected intermediate its ends to such valve, a fluid relay for operating said lever to open said valves, a fluid pressure supply for operating the fluid relay, means depending upon the speed of the engine for governing the supply of fluid to the relay, and means independent of the fluid pressure for returning the relay to its normal position.

2. In governing apparatus for a fluid pressure engine, the combination of a valve chest, a main regulating valve adapted to control the passage of motive fluid from said valve chest to the engine, a lever pivoted at one end and adapted to actuate said regulating valve, a speed governor driven by said engine, a reciprocating motor relay adapted to operate said lever and regulating valve, a valve for controlling the operation of said relay, and connecting means between the controlling valve and the governor and relay , ed whereby the controlling valve will be opened by the governor upon variation in speed of the engine from the normal and will be afterwards closed by said relay.

3. In governing apparatus for a fluid pressure engine, the combination of a valve chest, a main regulating valve adapted to control the passage of motive fluid from said valve chest to the engine, a lever pivoted at one end and adapted to actuate said regulating valve, a loaded auxiliary regulating valve adapted to control the passage of steam from said valve chest to another part of said engine and to be operated from a part of said lever between its fulcrum and the connection thereto of the main regulating valve after the main regulating valve has been fully opened, a speed governor driven by said engine, and means under the control of said governor for operating said lever when the normal speed of the engine varies.

4. In governing apparatus for a fluid pressure engine, the combination of a valve chest, a main regulating valve adapted to control the passage of motive fluid from said valve chest to the engine, a lever pivoted at one end and adapted to actuate said regulating valve, a loaded auxiliary regulating valve adapted to control the passage of steam from said valve chest to another part of said engine and to be operated from a part of said lever between its fulcrum and the connection thereto of the main regulating valve after the main regulating valve has been fully opened, and a relay under the control of said governor and whereby said lever will be operated in one direction or the other when the speed of the engine varies from the normal.

5. Governing apparatus for a fluid pressure turbine comprising a valve chest having main and auxiliary outlet passages leading

to different parts of the turbine, an endwise movable main regulating valve and a loaded endwise movable auxiliary regulating valve for controlling the passage of motive fluid from said valve chest to the respective said outlet passages, a lever pivoted at one end and connected to the main valve and adapted to open the auxiliary valve when the main valve has been fully opened, a speed governor driven from said turbine, a reciprocating motor relay having its piston connected to the other end of said lever and a controlling valve subject to the combined and opposing actions of said governor and relay and adapted to control the passage of actuating fluid to and its exhaust from the relay cylinder.

6. In governing apparatus for a fluid pressure engine, the combination with a main regulating valve and the engine governor, of a reciprocating oil motor relay comprising a cylinder provided with a piston connected to said valve and with a combined fluid pressure supply and exhaust passage, an oil pump, an exhaust pipe, a controlling valve comprising a casing having three separate branches one of which is in communication with said pump, another with said combined supply and exhaust pipe and the third with the exhaust pipe, a piston valve that normally closes the communication between said combined supply and exhaust pipe and the pump and exhaust pipe, and a balancing piston connected to said piston valve and arranged to work in the valve casing, the oil supply inlet to said casing being located between said piston valve and balancing piston, a rod for reciprocating said piston valve and balancing piston, and a floating lever connected to said rod, to said governor and to the piston of said relay.

7. In engine governing apparatus, a fluid pressure relay comprising a cylinder having a combined inlet and outlet passage, a controlling valve comprising a casing having an inlet branch, a combined inlet and outlet branch connected to said inlet and outlet passage, and an exhaust branch, a piston valve controlling the combined inlet and outlet branch, a balancing piston connected to said piston valve and arranged to work in said valve casing, the inlet for fluid under pressure to said casing being between said piston valve and balancing piston, a rod whereby the combined piston valve and balancing piston can be reciprocated from the engine governor and relay piston, and a drain passage connecting the end of said casing at the outer side of said balancing piston to the exhaust branch of the casing.

8. In governing apparatus for a fluid pressure engine, the combination with a main valve for regulating the supply of motive fluid to said engine, a lever for operating said valve, and a speed governor driven by said engine, of a reciprocating fluid pressure motor relay having its piston and rod connected to said valve operating lever, a controlling valve connected to said governor and to the relay piston rod so as to be operated from each of these parts for controlling the action of said relay as set forth when the speed of the engine varies, and starting gear whereby the relay piston rod can be moved by hand for operating the valve operating lever and main regulating valve for starting the engine.

9. In governing apparatus for a fluid pressure engine, the combination with a main regulating valve for controlling the supply of motive fluid to said engine, and a governor driven by said engine, of a reciprocating fluid pressure motor relay for operating said regulating valve, a reciprocatory controlling valve for said relay, a valve rod and floating lever through which said controlling valve is connected to said governor and to the piston of said motor relay, a spring arranged between said rod and a fixed support and acting upon said rod, and means for varying the action of said spring.

10. In governing apparatus for a fluid pressure engine, the combination with a main regulating valve for controlling the supply of motive fluid to said engine, and a governor driven by said engine, of a reciprocating fluid pressure motor relay for operating said regulating valve, a reciprocatory controlling valve for said relay, a valve rod and floating lever through which said controlling valve is connected to said governor and to the piston of said motor relay, a coiled spring encircling said rod and connected at one end thereto, an externally screw threaded non-rotatable sleeve connected to the other end of said spring, and a rotary nut through which said sleeve is screwed and which is held in an endwise direction.

11. Governing apparatus for a fluid pressure turbine, comprising a valve chest arranged at one side of the turbine and provided with an inlet for motive fluid and with an outlet connected to said turbine, a main regulating valve controlling said outlet, a lever pivoted at one end, connected at an intermediate part of its length to said regulating valve and extending in a longitudinal direction over said valve chest, a reciprocating motor relay arranged at the corresponding side of said turbine and having its piston rod connected to the free end of said lever, a speed governor arranged at one end of said turbine and driven from the driving shaft of said turbine, a reciprocating controlling valve for said relay, said valve being adapted to control the flow of liquid under pressure to and from said relay, a floating lever that is normally in an approximately horizontal position and is connected at one end to the movable portion of said governor,

and a downward extending rod connecting an intermediate portion of said floating lever to said controlling valve, a second downwardly extending rod jointed to the other end of said floating lever, and a longitudinally arranged rock shaft provided with two lever arms that are normally held in an approximately horizontal position and extend in the same direction from said rock shaft and one of which is connected to the piston rod of said relay motor and the other to the lower end of the secondly mentioned downward extending rod.

12. Governing apparatus for a steam turbine, comprising a valve chest arranged at one side of the turbine and provided with a main valve for regulating the supply of motive fluid to said turbine, a longitudinally arranged valve operating rod pivoted at one end and connected to said valve at an intermediate part of its length, a vertically arranged reciprocatory oil motor relay adapted to operate said rod, a rotary oil pump arranged at one end of said turbine, and driven from the turbine shaft, an oil receptacle, a normally closed controlling valve adapted to control the passage of oil under pressure from said pump to the relay and from the relay to the oil receptacle, a speed governor arranged at the same end of said turbine as the pump and driven from the driving shaft of the turbine, a floating lever that is normally held in an approximately horizontal position and is connected at one end to the engine governor, a downwardly extending rod connecting an intermediate portion of said floating lever to said controlling valve, a second downwardly extending rod connected to the other end of said floating lever, and connecting means between said second rod and the relay piston and whereby the second end of the floating lever will be raised when the motor piston is raised.

13. In governing apparatus for a fluid pressure engine, the combination of a valve chest, a main regulating valve adapted to control the passage of motive fluid from said valve chest to the engine, a speed governor driven by said engine, a relay piston adapted to operate said regulating valve, a valve for admitting pressure fluid to one side of said relay piston or exhausting it therefrom, means constantly opposing the action of the pressure fluid on said relay piston, and connecting means between the controlling valve and the governor and relay, and whereby the controlling valve will be opened by the governor upon variation in speed of the engine from the normal and will afterward be closed by the resulting movement of said relay.

14. In governing apparatus for a fluid pressure engine, the combination of a valve chest, a main regulating valve adapted to control the passage of motive fluid from said valve chest to the engine, a loaded auxiliary regulating valve adapted to control the passage of steam from said valve to another part of said engine, means connecting said valves whereby the auxiliary valve will not open unless the main regulating valve is first fully opened, a speed governor driven by said engine, and means under the control of said governor for operating said valve connecting means when the normal speed of the engine varies.

15. In governing apparatus for a fluid pressure engine, the combination of a valve chest, a main regulating valve adapted to control the passage of motive fluid from said valve chest to the engine, a speed governor driven by said engine, a relay adapted to operate said regulating valve, a valve controlled by the governor for admitting pressure fluid to move the relay one way, and means opposing such movement, said means being adjustable while in operation.

Signed at Newcastle-upon-Tyne, England, this fifth day of July 1905.

HUGH FRANCIS FULLAGAR.

Witnesses:
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CHAS. T. BRIGGS.