B. KRÄMER.

REGULATING MIXED PRESSURE TURBINES.

APPLICATION FILED FEB. 15, 1911.

1,110,799.

Patented Sept. 15, 1914.

2 SHEETS—SHEET 1.

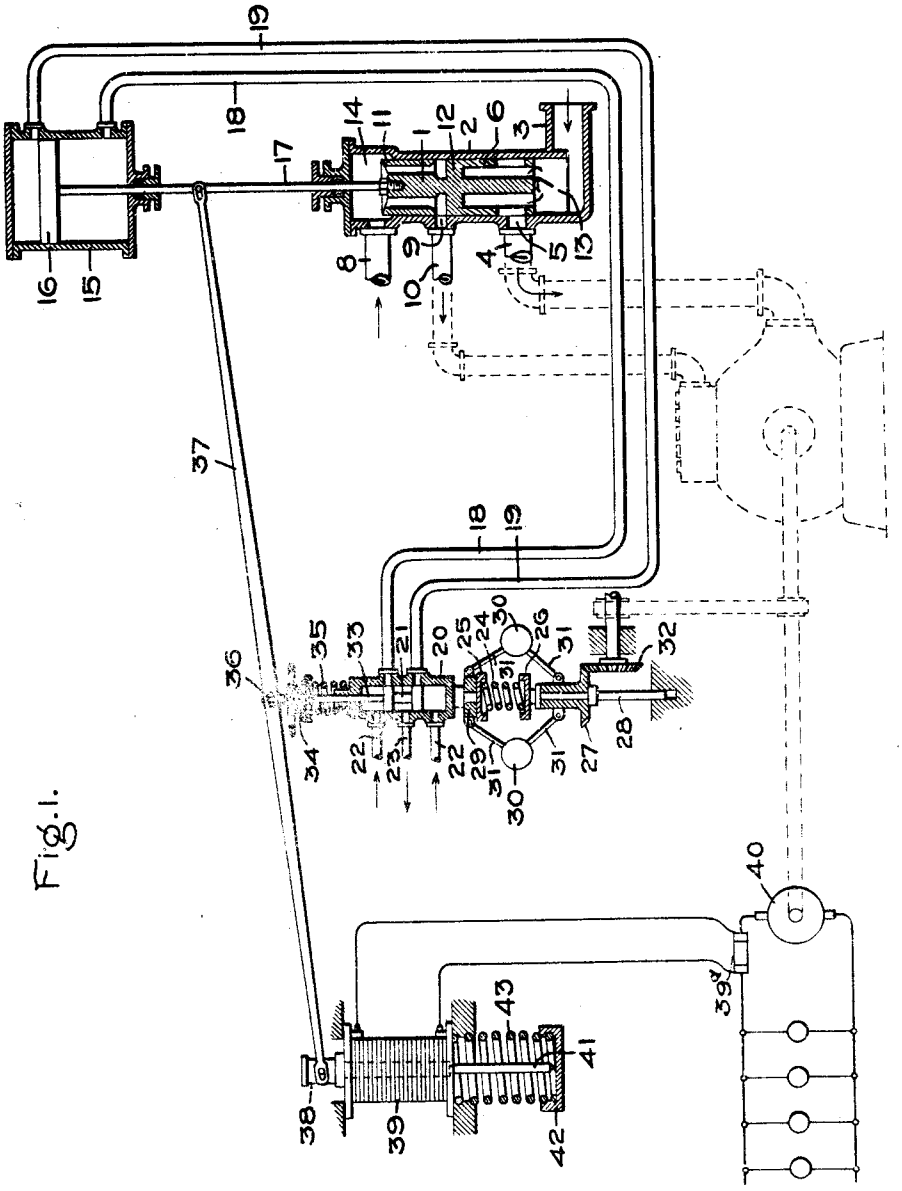


Fig. 1.

Witnesses:

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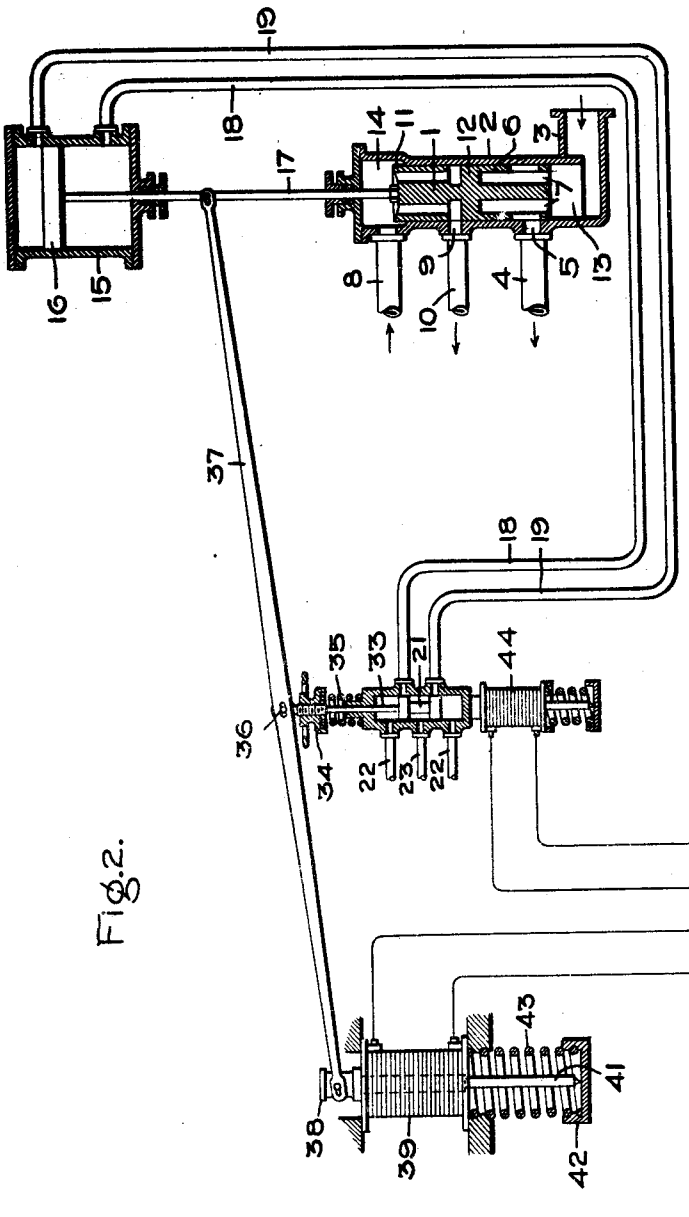


Fig. 2.

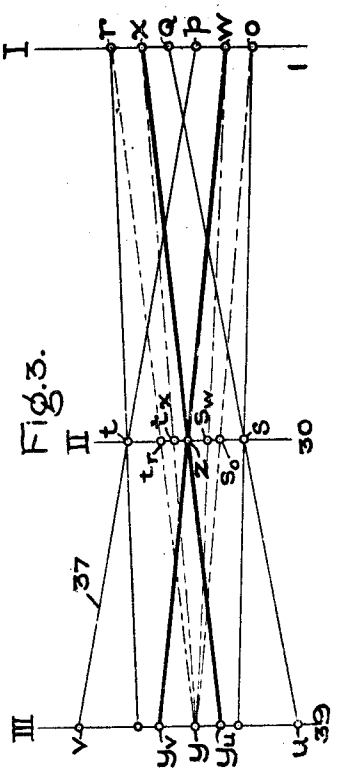


Fig. 3.

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UNITED STATES PATENT OFFICE.

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REGULATING MIXED-PRESSURE TURBINES.

1,110,799. Specification of Letters Patent. Patented Sept. 15, 1914.

Application filed February 15, 1911. Serial No. 608,755.

To all whom it may concern:

Be it known that I, BERNHARD KRÄMER, a subject of the Emperor of Germany, residing at Charlottenburg, Germany, have invented certain new and useful Improvements in Regulating Mixed-Pressure Turbines, of which the following is a specification.

This invention relates to the regulation of machines supplied with energy from two different sources, such for instance as turbo-generators arranged to be driven by exhaust steam and also by live steam when necessary. In such a case, the principal problem to be solved is to furnish live steam to the turbine only when the supply of exhaust steam no longer suffices for carrying the load, and to do this without substantially changing the power developed by the machine. For the solution of said problem, the machine must be furnished with a regulating member for each kind of motive fluid, and these members must open one after the other and close in reversed sequence. Each member must also be capable of regulating the machine from no load to full load. If, however, such regulation is effected solely by an ordinary speed-responsive device, the speed of the machine will be different according as the exhaust steam or the live steam preponderates as a driving means, because in order to change from one to the other the speed-responsive device must change its number of revolutions. It may happen, however, that the exhaust steam is furnished from intermittent sources, such as hoisting engines or steam hammers, in which event the mixed pressure turbine would have to alter its speed at short intervals. If an attempt is made to restrict the difference in the number of revolutions to the smallest possible amount by using a sensitive speed governor, considerable oscillation or "hunting" is liable to occur.

In order to avoid these troubles, and enable the turbine to maintain a substantially constant speed at any constant load in spite of changes from operation by exhaust steam to live steam or mixed pressure operation, an additional regulating member is provided which responds to variations in the load on the generator driven by the turbine, since the variation in the number of revolutions of the machine depends upon its load. The additional regulating member is preferably either a solenoid, an ampere-meter or a wattmeter in combination with a spring balance, and connected with the regulating apparatus in such a manner as to effect a change therein about proportional to the change in the load on the machine. The speed-responsive device and this load-responsive member may be connected to a common rod or lever controlling a regulating valve in such a manner that the speed of the turbine will be substantially constant for a given load, notwithstanding the changes which may occur in the source of energy.

In the accompanying drawings, Figure 1 shows a centrifugal speed governor for a prime mover combined with a solenoid dependent upon the load on the generator driven by said prime mover, and both exerting control of the valve mechanism which regulates the admission of exhaust and live steam to the turbine; Fig. 2 shows a similar device, except that in place of the centrifugal speed governor there is substituted a solenoid dependent upon the voltage across the terminals of the generator; and Fig. 3 is a diagram illustrating the movements of the regulating devices under different conditions of operation.

The regulating valve 1 is inclosed in a casing 2 to which the exhaust steam is brought by a conduit 3, opening into said casing below the valve. A pipe 4 conveys the exhaust steam from the casing to the turbine shown in dotted lines. The port 5, through which the steam enters the pipe 4, is controlled by the piston 6 forming a part of the valve 1. The piston has openings 7 in it to permit the steam to flow to the ports in its wall. A pipe 8 leads live steam to the casing 2, from which it passes by a port 9 to a pipe 10 which conveys it to the turbine. A piston 11 on the valve 1, having longitudinal steam passages in it, controls the port 9. An imperforate piston 12 on said valve divides the low-pressure chamber 13 from the high-pressure chamber 14.

In Figs. 1 and 2, the valve is shown in the position for admitting live steam to the turbine through the openings in the piston 11 and exhaust steam through the openings 7. The pistons 6 and 11 are so arranged that when the valve moves downward the high-pressure steam will be entirely shut off before the exhaust steam supply to the pipe 4 through the openings 7 in the piston 6 be-

gins to be shut off. Conversely, when the valve moves upward from its lowest position, the exhaust steam valve will be entirely opened before the high-pressure steam can flow into the pipe 10.

The valve is moved by a hydraulic motor comprising a cylinder 15 and a piston 16, the latter being connected to the valve by a piston rod 17. Tubes 18 and 19 convey hydraulic pressure to the ends of said cylinder for the purpose of driving the piston to and fro. These tubes are connected to a valve chest 20 in which is a pilot valve 21, preferably of the piston type as shown, controlling the admission to said tubes of fluid pressure supplied to the valve chest through the pipes 22, and exhausting therefrom through the pipe 23. The valve 21 is shown in its mid position, to which it has been moved after admitting pressure to the tube 18 and the lower end of the cylinder 15 to force up the piston 16 and the valve 1 to the position shown. The valve chest 20 is supported on a spring 24 inclosed between caps 25 and 26, the latter being mounted on the hub of a bevel gear 27 rotatably journaled on a stem 28. On the upper cap 25 is a collar 29 swiveled to the valve chest so that the collar, caps and spring are free to rotate with the bevel gear. Fly-balls 30 are connected by pivoted links 31 to the hub of the gear and to the collar 29. The gear is driven by a pinion 32 rotating in synchronism with the turbine. The stem 33 of the pilot valve is screw-threaded to receive a nut 34 by means of which one can adjust the tension of a spring 35 abutting between said nut and the top of the valve chest. The upper end of said stem is pivoted at 36 to a floating lever 37, one end of which is pivotally connected to the piston rod 17. The other end of said lever is pivoted to the movable core 38 of a stationary solenoid 39, through which is shunted a portion of the line current of the turbine driven generator 40, the terminals of the solenoid being connected across a suitable resistance 39^a. The core 38 has an extension 41 which rests upon a cup 42 secured to the lower end of a helical spring 43 which tends to lift said core against the downward pull of the solenoid. In the drawing, the line current is assumed to be at a maximum, so that the core is in its lowest position. The operation of these parts is as follows: Under the conditions shown the turbine is running at normal speed and carrying full load. If this load decreases, the turbine will tend to run faster. This means that the fly-balls will exert more centrifugal force, so that the valve chest 20 will be pulled downward, the pilot valve being held stationary for the moment by the lever 37. The result of this relative movement of the chest and valve is to admit fluid pressure into the tube 19 from the lower tube 22 and connect the tube 18 with the exhaust pipe 23. The piston 16 at once moves the regulating valve 1 downward to shut off the live steam more or less and slow down the turbine. The downward movement of the piston rod also acts to restore the pilot valve to a midway position so as to shut off both tubes 18 and 19 and stop the valve 1. This is accomplished by the lever 37, which fulcrums on its point of attachment to the core of the solenoid. Now when the turbine slows down owing to the throttling of the steam by the valve 1, the spring 24 overpowers the fly-balls and pushes up the valve chest. Since the pilot valve is held by the piston rod 17 and the lever 37 in a lower position than before, this action of the valve chest would tend to open the pipe 18 to the fluid pressure. To prevent this, and to lift the pilot valve sufficiently to keep the pipes 18 and 19 closed, the solenoid 39 also comes into play as the turbine speed decreases The decrease in load referred to above means a reduction in the line current, so that the solenoid is weakened, and its spring 43 is permitted to lift the core 38, thus raising the lever, which fulcrums on its point of attachment to the piston rod 17. This acts to lift the pilot valve sufficiently to keep up with the upward movement of the valve chest 20 due to the slowing of the centrifugal governor, and thus the valve 1 is maintained in its new position.

By adjusting the nut 34, the tension of the spring 35 is varied, which results in varying the effective action of the regulating device by varying the centrifugal force necessary to effect a relative movement of the casing 20 and the valve 21. It also serves to regulate the position of the valve in said casing when the parts are at rest, so that the mouths of the pipes 18 and 19 can be exactly covered.

In the modification shown in Fig. 2, the centrifugal speed-responsive device shown in Fig. 1 is replaced by a solenoid 44 connected across the terminals of the generator, so as to constitute a device responsive to changes in potential in the current developed by the generator. In all other respects the parts are constructed and arranged as in Fig. 1. Inasmuch as the potential of the current varies directly with the speed of the generator, the increase or decrease in speed, due to changes in load, will be effectually met by this device equally as well as by the centrifugal governor.

Fig. 3 is a diagram illustrating graphically the operation of my improved regulators under different conditions. The line I represents the path of the steam valve 1; the line II the path of the casing 20 and pilot valve 21, and the line III the path of the core of the solenoid 39. On the line I the section *o p* represents the travel of the

steam valve 1 to open the port 5 admitting exhaust steam to the pipe 4. p q represents the length of the movement up to the beginning of the opening of the port 9 admitting live steam to the turbine. q r is the path traveled by the valve 1 in opening the live steam port 9. s and t on the line II represent the two points at which the centrifugal regulator 30 has its highest and lowest number of revolutions respectively, or the core of the potential coil 44 is drawn in most or least. On line III, the points u and v indicate the lowest position and the highest, respectively, of the core of the current solenoid 39; that is, the points at which the load of the distribution system acting on the solenoid is greatest or smallest the lines passing through points on said three lines represent positions of the lever 37.

The steam valve 1 may occupy a position w with purely exhaust drive, or a position x corresponding to purely live steam drive or mixed pressure drive. In passing from one drive to the other, the valve has thus to travel over the path w x.

The method of operation of the device is as follows: If the load regulator is conceived to be held fast at any point y, and the speed regulator acts upon the regulating valve in the ordinary way, then the regulating sleeve has to pass over, for the movement of the valve from o to r, the path s_o—t_r. For a shifting of the valve between the points w and x, that is, for passing from one kind of drive to the other the path to be traversed would accordingly be s_w—t_x. A case where the load regulator might be held fast at the point y would be where the machine works alone in a distribution system and the load remains unchanged. Actually however the point y is not held fast by the load regulator. There occur on the contrary, changes in the load of the system, so that the point y is shifted. This shifting is such that the regulating valve 1 is raised or lowered in the same way as by the regulator 30 or 44, so that either of said regulators is supplemented in its action by the load regulator 39 and a condition of stability results. If, however, the machine is operating in a system, wherein for the sake of simplicity a three-phase system will first be assumed, in which the speed of all the machines is directly dependent one upon the other, then the speed regulator may be assumed to be held fast at a given load, since the speed is prescribed by the system. In direct-current operation moreover all the machines in circuit are likewise dependent one upon the other as to speed, since at the smallest load the potential of the current establishes the number of revolutions. Thus if the speed regulator 30 or 44 is regarded as fixed at a point z, then the regulator 39 must move the end of the lever 37 over the path y_u—y_v, the path of the regulating valve 1 being u—v. Accordingly a change of load on the turbo-generator takes place in passing from the one method of driving to the other, which must be equalized by the remaining machines connected in parallel. The effort will be to keep this change of load as small as possible, that is, the path y_u—y_v should be only a small fraction of the total path u—v,—a condition which may be readily secured by suitable lever-transmission conditions.

The above-mentioned change in the load distribution of the system causes in turn a change in the number of revolutions, and in the example selected, that is, in passing from exhaust drive to live-steam or mixed pressure drive, a reduction in the number of revolutions will take place with a decrease in the work performed. This decrease in the number of revolutions has the result that the speed regulator 30 or 44 assists the process of regulation, so that the stability necessary for the entire system is preserved, and the difference in the work performances of the combined machine is not so great as it would have become without the variation of the number of revolutions. This variation of the number of revolutions is smaller in proportion to the difference between the loads corresponding to the points Y_u and Y_v.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof; but I desire to have it understood that the apparatus shown is only illustrative, and that the invention can be carried out by other means.

What I claim as new and desire to secure by Letters Patent of the United States, is,—

1. The combination with a prime mover, and valve mechanism for controlling the admission of motive fluid to the prime mover, of a fluid-actuated motor for actuating the valve mechanism, a valve for controlling the supply of motive fluid to the motor, a movable seat for the valve, a device responsive to the speed of the prime mover, and a device responsive to the driven load on the prime mover, one of said devices being connected to the valve and the other to the seat.

2. The combination with a prime mover, and valve mechanism for controlling the admission of motive fluid to the prime mover, of a fluid-actuated motor for actuating the valve mechanism, a valve for controlling the supply of motive fluid to the motor, a movable ported seat for the valve, means for adjusting the valve and seat relative to each other, a device responsive to the speed of the prime mover, a device responsive to the driven load on the prime mover, one of said devices being connected to the valve and the

other to the seat, and means for preventing overtravel of the motor.

3. In combination, a prime mover, an electric generator driven by any prime mover, valve mechanism for controlling the admission of motive fluid to the prime mover, a fluid-actuated motor for actuating the valve mechanism, a valve for controlling the supply of motive fluid to the motor, a movable ported seat for the valve, a device responsive to the speed of the prime mover, and a device responsive to the current generated by the electric generator, one of said devices being connected to the valve and the other to the seat.

4. In combination, an electric generator, a mixed pressure turbine driving the generator and having a valve mechanism for controlling the flow of exhaust and live steam to said turbine, a motor for actuating said valve mechanism, a pilot valve for said motor, a casing for said pilot valve adapted to be moved in response to changes in the speed of said turbine, a current coil in circuit with said generator and having a movable core, and a lever pivoted to a moving part of said motor, to said pilot valve and to the core of said current coil.

5. The combination with a prime mover, and valve mechanism for controlling the admission of motive fluid to the prime mover, of a fluid-actuated motor for actuating the valve mechanism, a valve mechanism for the motor comprising a valve member and a movable seat member, a device responsive to the speed of the prime mover, a device responsive to the driven load on the prime mover, means connecting one of the valve members to a moving part of the motor and to one of said devices, and a connection between the other valve member and the other device.

6. The combination with a prime mover, and valve mechanism for controlling the admission of motive fluid to the prime mover, of a fluid-actuated motor for actuating the valve mechanism, a valve controlling the supply of motive fluid to the motor, a movable seat for the valve, a device responsive to the speed of the prime mover, a device responsive to the driven load on the prime mover, one of said devices being connected to the seat and the other to the valve, and means actuated by a moving part of the motor for preventing overtravel of said motor.

7. In combination, a prime mover, an electric generator driven by the prime mover, valve mechanism for controlling the admission of motive fluid to the prime mover, a fluid-actuated motor for actuating the valve mechanism, a valve for controlling the supply of motive fluid to the motor, a movable ported seat for the valve, a speed responsive device for moving the seat, a device responsive to the current generated by the generator, and lever means connected to a moving part of the motor, the valve and the current responsive device.

8. The combination with a mixed pressure turbo-generator, of valve mechanism for controlling the admission of live and exhaust steam to the turbine, a fluid-actuated motor for actuating the valve mechanism, a valve controlling the supply of motive fluid to the motor, a movable seat for the valve, a spring connection between the valve and seat, a device responsive to the speed of the turbine, a device responsive to the current generated by the generator, one device being connected to the seat and the other to the valve, and means for preventing overtravel of the motor.

9. The combination with a mixed pressure turbo-generator, of valve mechanism for controlling the supply of exhaust and live steam to the turbine, a fluid-actuated motor for actuating the valve mechanism, a valve for controlling the supply of motive fluid to the motor, a movable ported seat for the valve, a stem for the valve, an adjustable abutment on the stem, a spring arranged between the abutment and the seat, a speed responsive device connected to the seat, a device responsive to the current generated by the generator, and lever means connecting the current responsive device and a moving part of the motor to the valve stem.

10. The combination with a prime mover, and valve mechanism for controlling the admission of motive fluid to the prime mover, of a fluid actuated motor for actuating the valve mechanism, a valve for controlling the supply of motive fluid to the motor, a movable seat for the valve, and a plurality of governing devices for the prime mover, one of which is connected to the valve and the other to the movable seat so that either may be moved relative to the other in response to variations in the operating conditions of the prime mover.

In witness whereof, I have hereunto set my hand this 26th day of January, 1911.

BERNHARD KRÄMER.

Witnesses:
ERNST USBERKE,
OSCAR EBERTH.