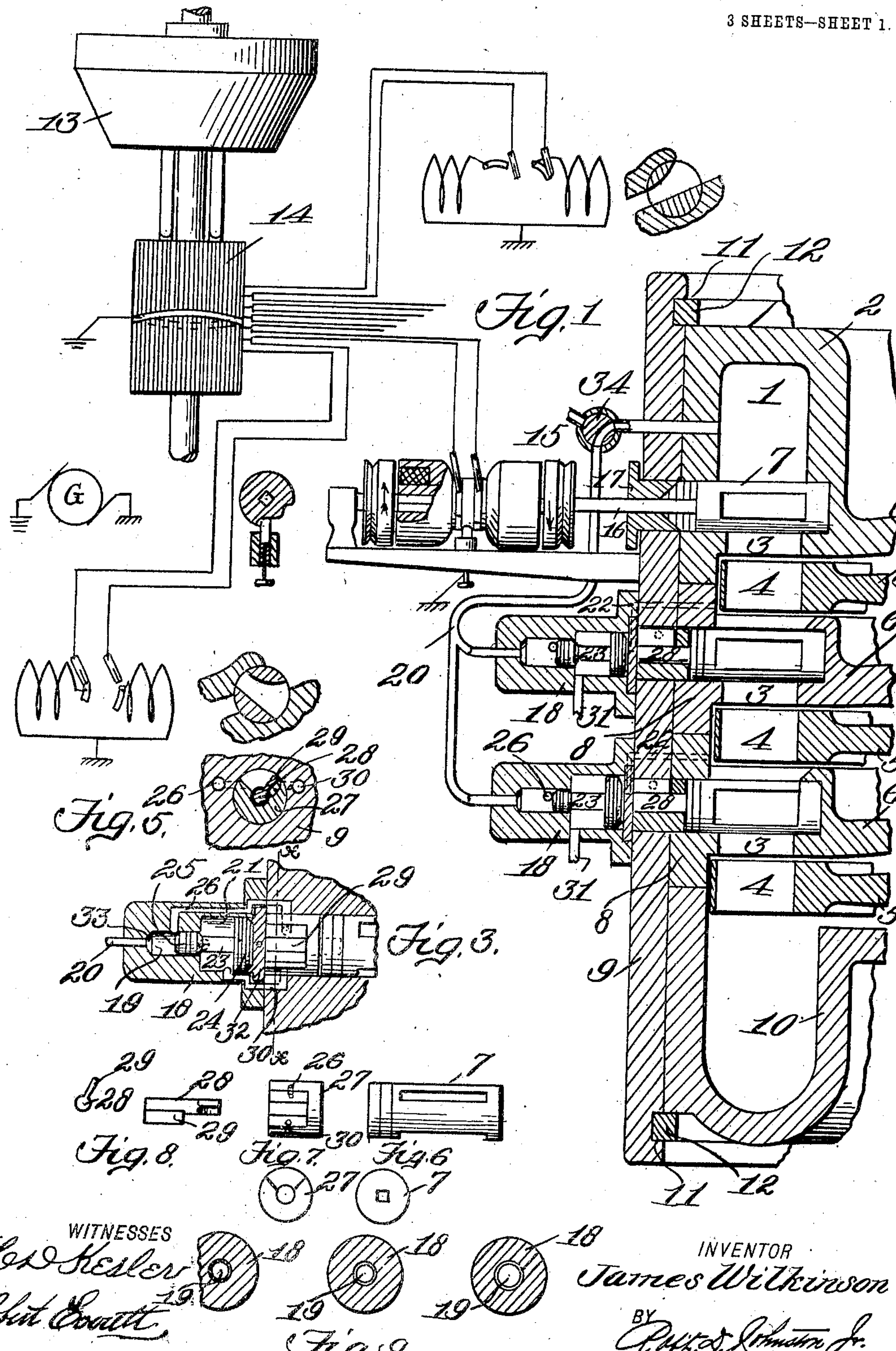
No. 818,008. PATENTED APR. 17, 1906.

J. WILKINSON.

GOVERNOR FOR ELASTIC FLUID TURBINES.

APPLICATION FILED JULY 14, 1903.

3 SHEETS—SHEET 1.



WITNESSES

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Robert Everett

INVENTOR

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BY

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3 SHEETS—SHEET 2.

Fig. 2.

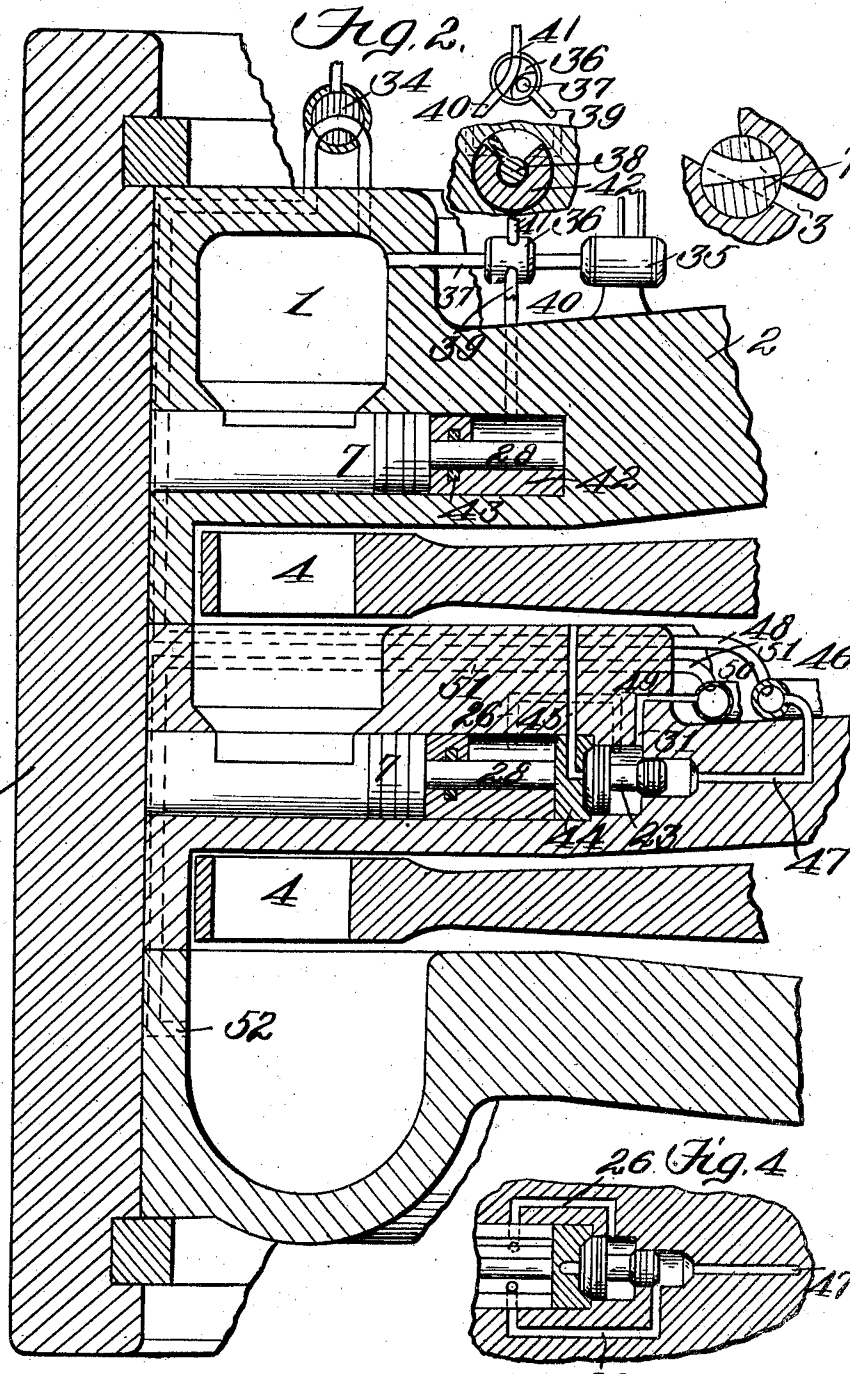

Fig. 4

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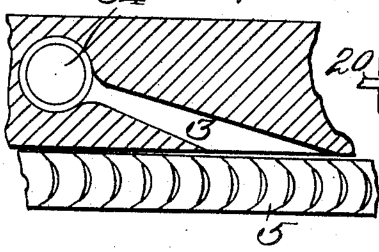

Fig. 11.

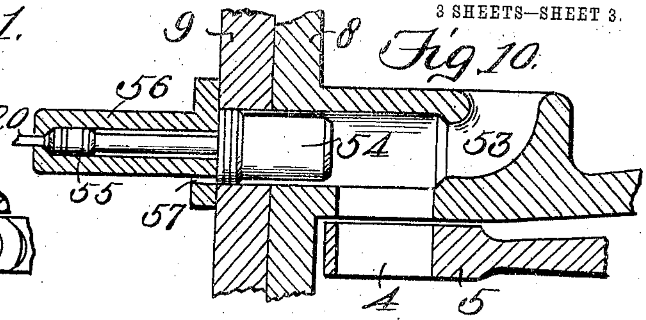

Fig. 10.

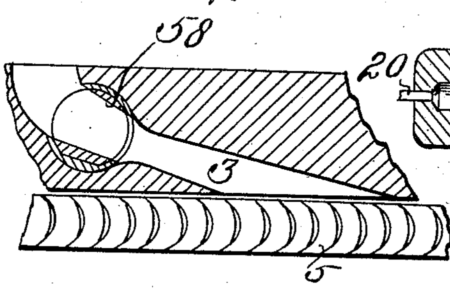

Fig. 13

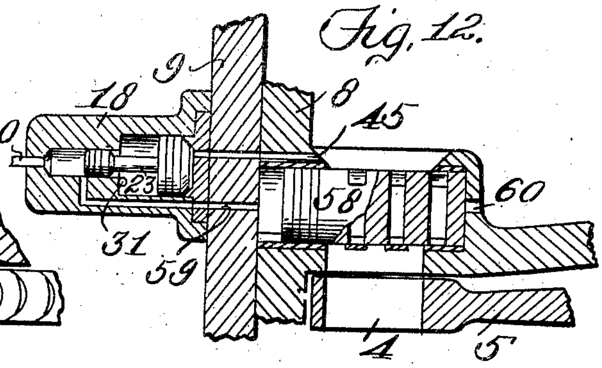

Fig. 12.

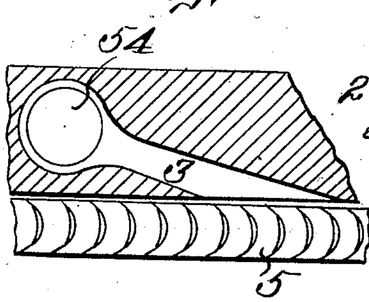

Fig. 15.

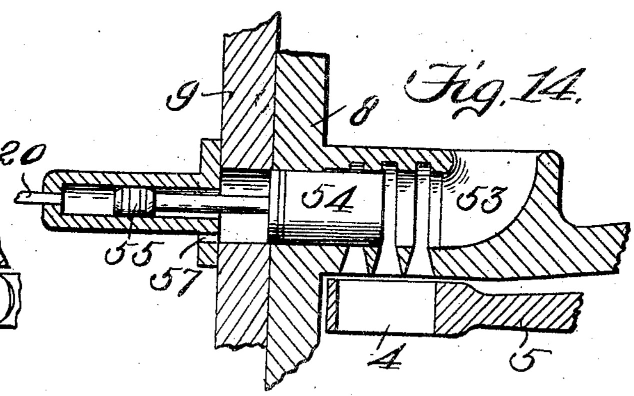

Fig. 14.

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GOVERNOR FOR ELASTIC-FLUID TURBINES.

No. 818,008. Specification of Letters Patent. Patented April 17, 1906.

Application filed July 14, 1903. Serial No. 165,512.

To all whom it may concern:

Be it known that I, JAMES WILKINSON, a citizen of the United States, residing at Birmingham, in the county of Jefferson and State of Alabama, have invented certain new and useful Improvements in Governors for Elastic-Fluid Turbines, of which the following is a specification.

My invention relates to improvements in automatic pressure-regulating mechanism for compound elastic-fluid turbines wherein the pressure is reduced in stages and fractionally abstracted by rows of revolving vanes which may rotate within a compound casing or a plurality of separate casings between which the conduits form nozzles. Heretofore in regulating turbines of this character under varying loads the pressure throughout the several stages has been simultaneously controlled by interposing valves in the stationary rows of nozzles and so linking them together across the rows that the same number of nozzles will be supplying fluid-pressure to each stage. Such an arrangement is shown in an application filed by me on the 16th day of June, 1903, Serial No. 161,708.

It is an object of my present invention to dispense with this positive and rigid method of operating the valves across the stages and to adapt the governor to control only the valves which admit pressure to the first or initial stage, while the valves in the succeeding rows of nozzles are automatically and independently operated by variations in their respective stage-pressures effected by the governed control of the volume of fluid-pressure admitted to the turbine. The action of these valves is not only automatic, but is capable of being varied according to conditions, so that they will act at any desired variation in the stage-pressures, and they will be so sensitive that any regulation of the valves in the first row will cause a corresponding valve action throughout the stages.

It is a further object of my invention to construct and arrange a compound turbine provided with these automatic stage-valves with a view to greatly increasing the strength of the turbine-casing. This I effect by arranging the valve-operating devices within the turbine, so that it will not be necessary to bore openings in the walls of the casing, which would weaken it, and to further strengthen the turbine I surround it with a heavy steel shell within which the casing elements are secured in a manner to increase their resistance strain to the pressure in all directions.

My invention consists in the construction and arrangement of parts hereinafter described, and more particularly pointed out in the claims, reference being had to the accompanying drawings, forming a part hereof, and in which—

Figure 1 is a broken-away sectional elevation of a turbine with an illustrative governor action for controlling the valves admitting pressure to the turbine, while the automatic pressure-operating devices for the stage-valves are secured to the outside of the strengthening-shell about the casing proper. Fig. 2 is a similar view with the valve-controlling means dispensed within the turbine, which illustrates more clearly the construction of the turbine parts with a view to increasing strength and also my preferred governing mechanism. Figs. 3 and 4 are transverse sectional views of the automatic valves shown in Figs. 1 and 2, respectively, and disclose the fluid-conducting passages controlled by the compound valve, which lead to each side of the wing-valve. Fig. 5 is a section through x x of Fig. 3. Figs. 6, 7, and 8 are detail views of the valve parts. Fig. 9 shows a series of sectional views of the high-pressure cylinders in a row of valves set to operate at different pressures by varying their internal diameters. Figs. 10 and 11 cover a modified form of an automatic valve having only open and closed positions and which operates without the auxiliary compound valve. Figs. 12 and 13 illustrate another modification of the automatic valve in which a grid-nozzle is used to shorten the valve's stroke, so that it will not be necessary to drill so deep an opening in the shell to form its seat. Figs. 14 and 15 show a valve similar to that in Fig. 10, which operates with intermediate positions of control over a divided nozzle.

The same reference-numerals refer to the same parts throughout.

According to my invention as applied to a compound turbine operating by stage expansion the fluid-pressure is delivered by a supply-passage 1 in the head 2 of the turbine to a series of nozzle-passages 3, which convert a predetermined percentage of its energy of pressure into velocity and direct it against a row of revolving vanes 4, peripherally mounted on a rotor-wheel 5. Transverse diaphragm-partitions 6 divide the interior of the casing into compartments representing stages, within each of which a rotor-wheel 5 revolves, with its row of vanes in line with the intermediate stationary nozzle-passages arranged around the diaphragms, and all so disposed that the succeeding vanes and passages form continuous working passages for the fluid wherein the velocity is fractionally abstracted and the increased volume of the fluid accommodated by a proper proportioning of the passages circumferentially.

Within the throats or contracted portions of the nozzles 3 I place rotary valves 7, seated in circular openings bored from the outside radially into the shouldered peripheries of the diaphragms 6. These diaphragms have the usual circumferential flanges 8, which form the casing proper of the turbine, as shown and described in an application filed by me September 10, 1903, Serial No. 172,588. These turbines are intended to operate with high internal pressures by reason of the fact that the energy of pressure of the fluid is only fractionally converted into velocity in the earlier stages, and therefore exerts almost its full per-square-inch-pressure strain within the turbine. To provide for this, I materially increase the strength of the casing by surrounding it with a steel shell 9, which extends beyond the inlet-head 2 and the exhaust-head 10, being provided at these points with internal peripheral channels or grooves 11, within which are seated the retaining-rings 12. These rings, which may be formed of integral spring-strips of steel rectangular in cross-section, hold the elements of the casing securely in place between them, and thus the turbine is strengthened not only against transverse strain, but also against the disruptive pressure exerted longitudinally of the casing. The construction and arrangement of the strengthening-shell is more fully shown and described in my pending application Serial No. 172,923.

I control the operation of the first row of valves which serve to regulate the admission of pressure to the turbine by a suitable governor 13, whose collar 14 operates to maintain a part of the valves oscillating to admit impulses of fluid proportioned to slight variations in the load, while it maintains the rest of the valves open or closed, according to the load. This valve action is fully described in my prior applications Serial Nos. 136,229 and 151,504, with the exception that in the device shown in Fig. 1 the electromagnetic means is utilized in connection with a continually-rotating power-relay 15, driven either by the turbine itself or some other source of power, to transmit the desired motion to the valve-stems 16, which project outwardly from the turbine through openings in shell 9, in which suitable packing-glands 17 are inserted.

The direct and close regulation effected by the governor-controlled valves, while entirely satisfactory for the first stage in a compound turbine, does not give the best results when used to control all the valves throughout the stages. This is true because in the first stage the boiler-pressure is a constant factor with regard to which the nozzles and vanes are proportioned, and no leakage or condensation has arisen to disturb this proportion. When, however, we consider that these factors enter largely as uncertain elements into the difficulties presented in the proper proportioning of parts and regulating of the stage-pressures, it is evident that this manner of positively and simultaneously operating the valves across the stages will not regulate the turbine at the highest efficiency. To meet and obviate these difficulties, I construct and arrange the stage-valves so that they are automatically and independently sensitive to and operated by variations in their respective stage-pressures. This automatic pressure control of the stage-valves may be effected in several ways. Thus according to Fig. 1 I bolt or rivet to the shell 9 and opposite to the valve-openings therein a series of compound-pressure cylinders 18, whose high-pressure ends 19 are connected by pipes 20 with the initial pressure in the fluid-supply passage 1, so that the boiler-pressure is admitted thereto representing a constant pressure. The stage-pressure above the valve to be controlled is admitted to the low-pressure end 21 of the cylinder by a passage 22, leading through the compound casing. These two pressures act on a compound valve 23, whose piston-heads are so proportioned relatively that a predetermined stage-pressure against the head 24 will overcome the boiler-pressure against head 25, and the valve will then be shifted from the position shown in the drawings.

It will be noted that the piston-heads are tapered and the seats 32 and 33 therefor are correspondingly shaped, which has the effect of reducing the surface area of the head that is exposed to the pressure when in its closed position. The object of this is to cause the valves to open fully each time, so that the rotary valves 7 will not have intermediate operating positions, for as soon as either head leaves its seat a greater surface area is at once exposed to the pressure, which having overcome the opposing pressure against the other head when acting against a smaller surface area will, as against this larger area, operate to throw the valve in an almost instantaneous manner the length of its stroke, fully opening or closing it. The movement of this valve 23 automatically controls the operation of the rotary stage-valves 7 in the following manner. A passage 26 leads from the cylinder 19, through its casing, the shell 9, and one side of a cylindrical bearing-block and seat 27, Fig. 7, for the stem 28 and its wing-valve 29, which serve to rotate valve 7. A similar passage 30 leads to the opposite side of valve 29 from the cylinder 21, from which also a port 31 opens to the atmosphere. These passages and the exhaust-port enter the compound cylinder at points so disposed that when the valve 23 is in the position shown in Fig. 3 the high pressure is admitted through cylinder 19 and passage 26 to throw wing-valve 29 and close the rotary valve. Pressure is relieved on the other side of valve 29 by passage 28, communicating with the atmosphere through 31. At the other end of its stroke the stage-pressure passes through passage 22, cylinder 21, and passage 28 to throw valve 29 and open the stage-valve, while passage 26 is in turn opened to the atmosphere. The pressures therefore which act against the compound valve are controlled by it and utilized to operate the rotary stage-valve, which is held open or closed according as the stage-pressure in the low-pressure cylinder rises above or falls below the boiler-pressure in the high-pressure cylinder. Inasmuch as the succeeding stage-pressures will have been diminished by the velocities extracted in the preceding stages, it follows that the relative areas of the piston-heads of the compound valves must be varied accordingly, since the boiler-pressure is constant. Thus for the lower stages the low-pressure cylinders and piston-heads increase in size, whereas the high-pressure parts decrease, whereby the relative action of the pressures on the compound valve is maintained throughout the stages and all automatic valves will be operated by a predetermined rise in the stage-pressures.

A three-way valve 34, opening to the atmosphere, is placed in pipe 20 to relieve the pressure against the pistons 25 when desired, so that the stage-pressures, however small, will open the rotary valves 7, and steam can be blown through the turbine to remove condensation.

In Fig. 9 I have shown a transverse section through a series of high-pressure cylinders for the same row of valves, and it will be noted that they are of different internal diameters. I construct them in this manner with a view to preventing the simultaneous action of all the valves in a row upon a stated increase in the stage-pressure, for if each valve in a row be set to open at a different pressure they will open successively even though the rise in pressure be sufficient to operate them all, and in this manner the strain on the turbine from sudden variations in the load will be to an extent relieved. Thus if there be ten valves in each row and one of them be set to open at a rise of two pounds in the stage-pressure I may add one-fifth of a pound opening-pressure to each of the succeeding valves, with the result that as the pressure admitted to the turbine increases with its load an increasing number of stage-valves will be affected thereby and operated to maintain the stage-pressures. If desired, one valve in each row may be set to act at such slight variations in the pressures as would occur when operating the turbine under a friction load, while the other valves do not respond to variations of pressure under two pounds, or the valves in each row may gradually increase in sensitiveness from the friction-load variation to the increase of pressure which will operate them all. Further, it will increase the accuracy of the regulation if the valves set to act at the same pressures in the several rows be relatively placed in the line of the flow of the fluid across the stages. This capacity of my automatica valve regulation to be varied at will gives it an adaptability to different conditions which is of great advantage to a universal turbine-governing device, and at the same time it is true that the sensitiveness of its independent valve control, directly responsive to variations in the stage-pressures, is much greater than if the valves were positively connected across the rows and simultaneously operated from a speed-controlled governor.

Though I have referred to the boiler or initial pressure as constant, it may vary somewhat as supplied in practice without affecting the relative proportions that must necessarily be maintained between it and the stage-pressure to control the action of the stage-valves accurately, sensitive to variation in load, for any variation in the boiler-pressure communicates itself to the stage-pressure. Hence it follows that each increase or decrease of the boiler-pressure makes itself felt equally in the high and low pressure ends of the compound cylinder, whose sensitiveness to load variations remains unaffected thereby, which would not be the case if the stage-pressure had to act against a constant force, such as gravity, in controlling the action of the stage-valves.

To describe in detail the cycle of action of the governing mechanism in regulating the turbine, I will open the three-way valve 34 to the atmosphere or the condenser, and considering the governor controlled as well as the stage-valves open will admit pressure to the circular passage 1 through a throttle by-pass valve. This pressure after driving out all water of condensation will act on the vanes to bring the turbine up to speed, when the governor acts to close off all the governed valves except those necessary to maintain the speed.

The high pressure may now be turned into the compound cylinders 18, with the result that the compound valves 23 will be shifted and the rotary valves 7 closed, which will cause the pressure to rise in the various stages successively until it reaches the operating-point. The turbine, which is now running under only its friction-load, is ready to receive its operating-load. If now a several thousand horse power load be thrown on, it would cause a reduction in the turbine's speed, which would act through the governor device to sweep open the required number of valves in the first row of nozzles and admit pressure proportioned to the load. The effect of this would be to immediately raise the pressure in the first stage, so that overcoming the boiler-pressure against the compound valves it would open in turn a number of valves corresponding with the number of governed valves open, and this same action would take place in the second stage and throughout the turbine. If this load be steady, the governor will deliver to the first row of nozzles streams of fluid-pressure directly proportioned to the load, a part of the streams being constant and part pulsatory, and this same effect will be carried out through the stages, for the constant boiler-pressure acts automatically through the compound valves to maintain the stage-pressures constantly at the critical or operating point. Therefore every variation in the pressure supplied by the governed valves will be instantly felt throughout the stages. So if a certain number of governed valves are delivering constant streams a similar number of stage-valves will do the same, and if a governed valve is pulsating with only open and closed positions one of each row of stage-valves will deliver similar pulsatory blasts, by reason of the fact that they have only open and closed positions, and each impulse admitted by the governed valves in addition to the constant blasts varies the stage-pressure sufficiently to effect a corresponding valve action. If the load be of a constantly-varying character, the governor will sweep its valves open and closed according to the load, and the stage-valves will be automatically swept open or closed by the consequent variations in the stage-pressures resulting from this governed control of the pressure-supply. If all the load be thrown off, the governor will sweep its valves closed and the resulting fall in the stage-pressures will close the stage-valves, which will then permit only sufficient pressure to pass through the turbine to maintain its speed under a friction-load. It is therefore evident that the main function of the stage-valves is to maintain the stage-pressures at a predetermined amount at which they will at all times respond readily to the governor's control of the fluid-pressure supply.

Having thus fully described the action of my automatic stage-pressure valves, I will now refer to Fig. 2. Here the outer steel shell 9 is shown very thick and strong, and by arranging the valve-operating devices within the turbine it is unnecessary to weaken it with openings. In operating the governed valves I employ separate governor-controlled electric motors 35 for each valve, which are mounted on top of head 2 and whose shafts turn the four-way rotary valves 36, so that fluid-pressure conducted from the supply-passage 1 through pipe 37 is admitted alternately to either side of the wing-valve 38 through passages 39 and 40. The passage not open to the pressure is open to the atmosphere through port 41 in valve 36. The bearing-block and valve-seat 42 for the valve 38 is placed at the inner end of the valve within a continuation of the cylindrical valve-opening bored into head 2, which is shown sufficiently large to receive this elongated opening without being weakened. A packing 43 may be used in the valve-seat 42, if desired, to prevent leakage of pressure around the wing-valve's stem and past the rotary valve 7. Each motor 35 is controlled separately by a governor-collar similar to that shown and described in applications hereinbefore referred to, and they are required to exert only sufficient power to turn the valve 36, which controls the high pressure used to rotate valve 7. A separate motor controls each separate rotary valve, so that they may be independently controlled separately or in groups. The circumferential shoulders around the diaphragms are made wider, so that they will receive the elongated valve-openings, the inner ends of which are suitably shouldered to form compound cylinders 18, which are separated from that portion of the openings in which the bearing-blocks 42 and wing-valves 38 are placed by circular metal blocks 44, whose inner faces are beveled to form the low-pressure seats for the compound valves 23. The inner end of each high-pressure cylinder is also beveled, and both seats are so formed that when the valve is seated against them the pressure will have access to the whole flattened surface area of the head, as will be seen more clearly in Fig. 4. The stage-pressure is admitted to the low-pressure end of the cylinder through a passage 45, leading down through the diaphragm and at right angles through the seat 44. On top of the diaphragm and inside its shoulder I place a circular high-pressure pipe 46, from which the boiler-pressure is supplied to all the high-pressure ends of the cylinders through passages 47, leading at right angles through the diaphragm. This pipe 46 is supplied with the initial or boiler pressure by a pipe 48, leading up from the supply-passage 1 through head 2 to a three-way valve, as 34, and then downwardly through the inner turbine-casing and across the peripheral shoulder of the diaphragm. Passages 26 and 28 are as described in Fig. 1, and the exhaust-port 31 opens through a passage 49 to a circular exhaust-pressure pipe 50, which opens to the condenser-pressure through a passage 51, leading across the diaphragm and down through the casing to the exhaust-passage 52. According to this construction the turbine is greatly strengthened by the steel shell and its retaining-rings and uses its own pressure to operate both the automatic and the governed valves, which relieves the governor of having to exert much power of itself in actuating the fluid-supply valves.

In Figs. 10 and 14 I illustrate a more simple and direct means for effecting my automatic stage-valve action, for I construct the stage-valve itself in the form of a compound differential piston-valve, which moves in a cylinder between the initial and stage pressures in the same manner as the controlling-valves 23 in the other figures. To this end the high and low pressure ends of these piston-valves will have the same varying differentials described for valves 23.

In Figs. 10 and 11 the stage-pressure is admitted through a curved passage 53 against the ends of a reciprocating plunger-valve 54, which represents the low-pressure end of a compound valve, whose high-pressure end 55 enters the cylinder 56, which communicates with the boiler-pressure. 57 is the opening to the atmosphere. The piston heads and seats are tapered to cause the valve to open fully without intermediate operating positions. A similar construction is shown in Figs. 14 and 15, except that I show a divided nozzle-passage and do not taper the valve heads or seats, so that here the valve assumes positions of intermediate control and operates with a loss of efficiency.

In Figs. 12 and 13 I show my invention as applied to a grid-valve 58, with the compound cylinder 18 and valve 23 operating to move said grid-valve by admitting the boiler-pressure directly against its outer end through passage 59, while the stage-pressure is admitted against its inner end through opening 60. The advantage of this construction lies in the fact that the fluid stream is not deflected and the stroke of the valve is short, so that it is not necessary to make the shoulder around the diaphragm so large.

The principle of the automatic pressure-operated valve control of stage-pressures may be carried out in a series of separate turbines acting to expand the presssure in stages, provided the supply to the first stage be governed according to the load on all the turbines. When I refer to "governing" or "controlling" the stage-pressures, it is to be understood that I do not include the last stage which is opened to the exhaust and whose pressure therefore is determined by the pressure of the atmosphere or condenser. By the term "stage" I mean a compartment within which a rotor-wheel revolves, which includes the delivery-nozzles thereto and the discharge-valves therefrom, which valves constitute what I term the "stage-valves." In practice the stage-pressure is automatically maintained in a compartment by the action of its stage-valves at a point of pressure substantially the same as the pressure of efflux of the nozzles supplying the fluid to the stage. This compartment-pressure constitutes what I term the "stage-pressure." It is understood that I do not contemplate maintaining a stage-pressure in the compartment open to the pressure of the exhaust or condenser.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. In an elastic-fluid turbine which is divided into stages and is provided with buckets and fluid-discharging devices, the combination with successively operating controller-valves which respond automatically to variations in pressure within the turbine, of fluid-operated stage-valves which are opened and closed by said controller-valves to vary the flow of fluid between stages, substantially as described.

2. In an elastic-fluid turbine operating by stage expansion, a series of automatically-controlled valves between two wheel-compartments which are adapted to operate successively and without assuming intermediate operating positions to admit fluid-pressure to the succeeding stage when the fluid-supply to the turbine varies.

3. In an elastic-fluid turbine operating by stage expansion, means to deliver a variable supply of motor fluid to the turbine, passages between stages, and valves, for fully opening and closing said passages without assuming intermediate position, which operate automatically sensitive to variations in their respective stage-pressures.

4. In an elastic-fluid turbine operating by stage expansion, means to deliver a variable supply of motor fluid to the first stage, fluid-operated valves for passages between stages, and automatic stage-pressure-controlled secondary valves which control the operation of said stage-valves and the supply of fluid to the succeeding stage or stages.

5. In an elastic-fluid turbine which is subdivided into a plurality of stages and provided with a plurality of nozzle-passages between stages, the combination with a plurality of independently-operable supply-valves of a corresponding number of stage-valves between each two stages, means to successively operate said supply-valves, and means responsive to the variation in stage-pressures to successively and automatically operate

the corresponding valves for the several stages.

6. In an elastic-fluid turbine which operates by stage expansion, a working passage for the motor fluid comprising a plurality of independently-controllable supply and stage nozzle passages, governor-controlled valves to vary the cross-sectional area of the supply-passages, and stage-pressure-controlled valves to automatically vary the cross-sectional area of the discharge-passages between the several stages in correspondence with the area of the supply-passages.

7. In an elastic-fluid turbine which operates by stage expansion, a subdivided working passage for the fluid between stages by means of which independently-controllable streams of fluid flow across stages, rotatable elements acted upon by said separate streams, governing mechanism to successively cut off the supply of fluid from the initial subdivisions of said passages, and means responsive to internal pressure to automatically close the corresponding subdivisions of the working passage between each stage.

8. In an elastic-fluid turbine operating by stage expansion and having a variable supply of fluid delivered to the first stage, automatic compound valves exposed to a constant and a varying pressure and controlling the supply of the fluid to succeeding stages.

9. In an elastic-fluid turbine operating by stage expansion, a series of automatic compound pressure-actuated stage-valves, the relative proportions of whose high and low pressure heads differ between one or more of said valves.

10. In an elastic-fluid turbine operating by stage expansion, a passage between wheel-compartments, and automatic pressure-controlled means to effect a pulsatory discharge of fluid from a wheel-compartment through said passage to a succeeding wheel-compartment.

11. In an elastic-fluid turbine operating by stage expansion, passages between wheel-compartments, and means sensitive to the pressure in a wheel-compartment to pulsate part of the fluid-pressure discharged from said wheel-compartment through one or more of said passages to a succeeding wheel-compartment.

12. In a turbine, a plurality of passages for discharging fluid-pressure from a wheel-compartment, and means sensitive to variations in said wheel-compartment pressure for regulating the volume of the discharge into a succeeding wheel-compartment and pulsating a part of said discharge.

13. In an elastic-fluid turbine, a passage for the motor-fluid, and a compound piston-valve automatically moved by stage-pressure to open and close said passage without intermediate operating positions.

14. In a fluid-motor, a working passage for the fluid-pressure, and a valve interrupting the flow of said fluid through said passage, said valve being actuated by the initial fluid-pressure and controlled automatically by the variations between the initial and an intermediate pressure automatically maintained thereby in a stage.

15. In an elastic-fluid turbine comprising head-sections, and an intermediate casing, in combination with an outer shell which holds the head-sections together by curved metal strips forming stops which are seated in suitable recesses in the inner face of said casing.

16. In an elastic-fluid turbine wherein the fluid-pressure admitted is fractionally converted into velocity, head-sections between which intermediate partition-sections are held, and an outer shell surrounding the casing and having inner grooves so disposed that curved metal strips seated therein form abutments to hold the head-sections together.

17. In an elastic-fluid turbine operating by stage expansion, valves controlling the supply of fluid to the first stage, rows of automatic pressure-controlled valves between the several stages, two or more of said valves in each row being operated by relatively different variations in the preceding stage-pressures, the valves sensitive to the same pressures in the several rows being relatively disposed in the direction of the fluid's flow across the stages.

18. In an elastic-fluid turbine operating by stage expansion, means to pulsate the supply of elastic fluid to the first stage, and stage-pressure-controlled means to pulsate the supply to the succeeding stage or stages.

19. In an elastic-fluid turbine operating by stage expansion, means to deliver a part constant and part pulsatory supply of elastic fluid to the first stage, and means to pulsate part of the supply to the succeeding stage or stages.

20. In a turbine, a working passage in which the velocity of the motor fluid is fractionally abstracted, a compound valve for interrupting the flow of fluid through said passage, a low-pressure cylinder for said valve disposed within the turbine, and a high-pressure cylinder for said valve secured to the turbine-shell.

21. In an elastic-fluid turbine operating by stage expansion, a stage-valve, and stage-pressure-controlled means to intermittently actuate said valve to pulsate the fluid-supply admitted to a succeeding stage.

22. In an elastic-fluid turbine operating by stage expansion, a passage between stages, and a valve automatically controlled by stage-pressure and adapted to intermittently and fully open and close said passage responsive to fluxations in its controlling-stage pressure.

23. In an elastic-fluid turbine operating by

stage expansion, a row of stage-valves independently, and intermittently actuated under the control of stage-pressure to vary the fluid-supply to the succeeding stage.

24. In a turbine which operates by stage expansion, fluid-operated stage-valves, motors for actuating said valves comprising cylinders supported by the valve-bearing portion and open at one end to the stage-pressure.

In testimony whereof I affix my signature in presence of two witnesses.

JAMES WILKINSON.

Witnesses:
R. D. JOHNSTON,
ORIA MAE SMITH.