No. 824,546.

PATENTED JUNE 26, 1906.

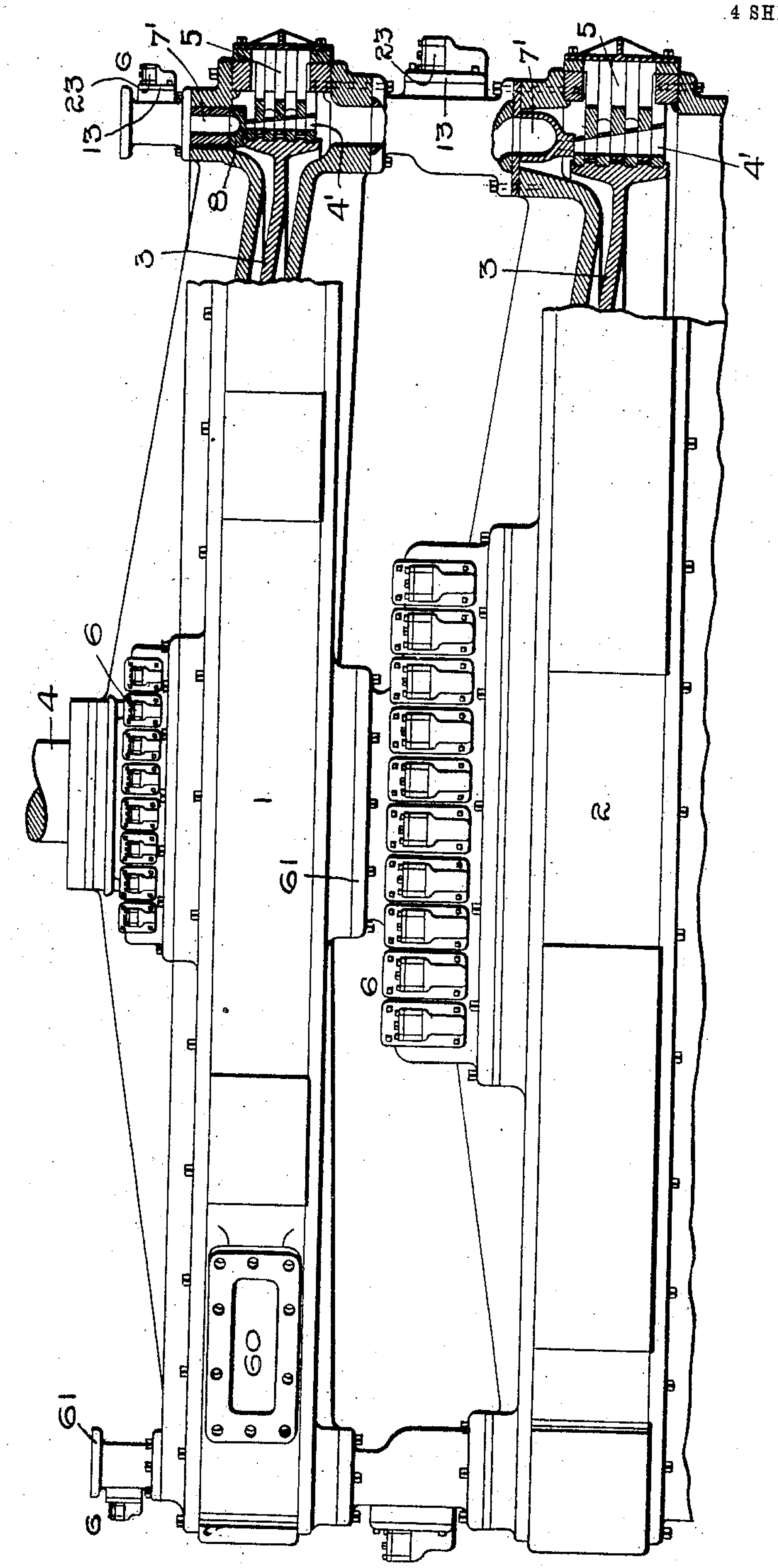
O. JUNGGREN.

GOVERNING MECHANISM FOR TURBINES.

APPLICATION FILED AUG. 26, 1902.

4 SHEETS—SHEET 1.

Fig. 1.



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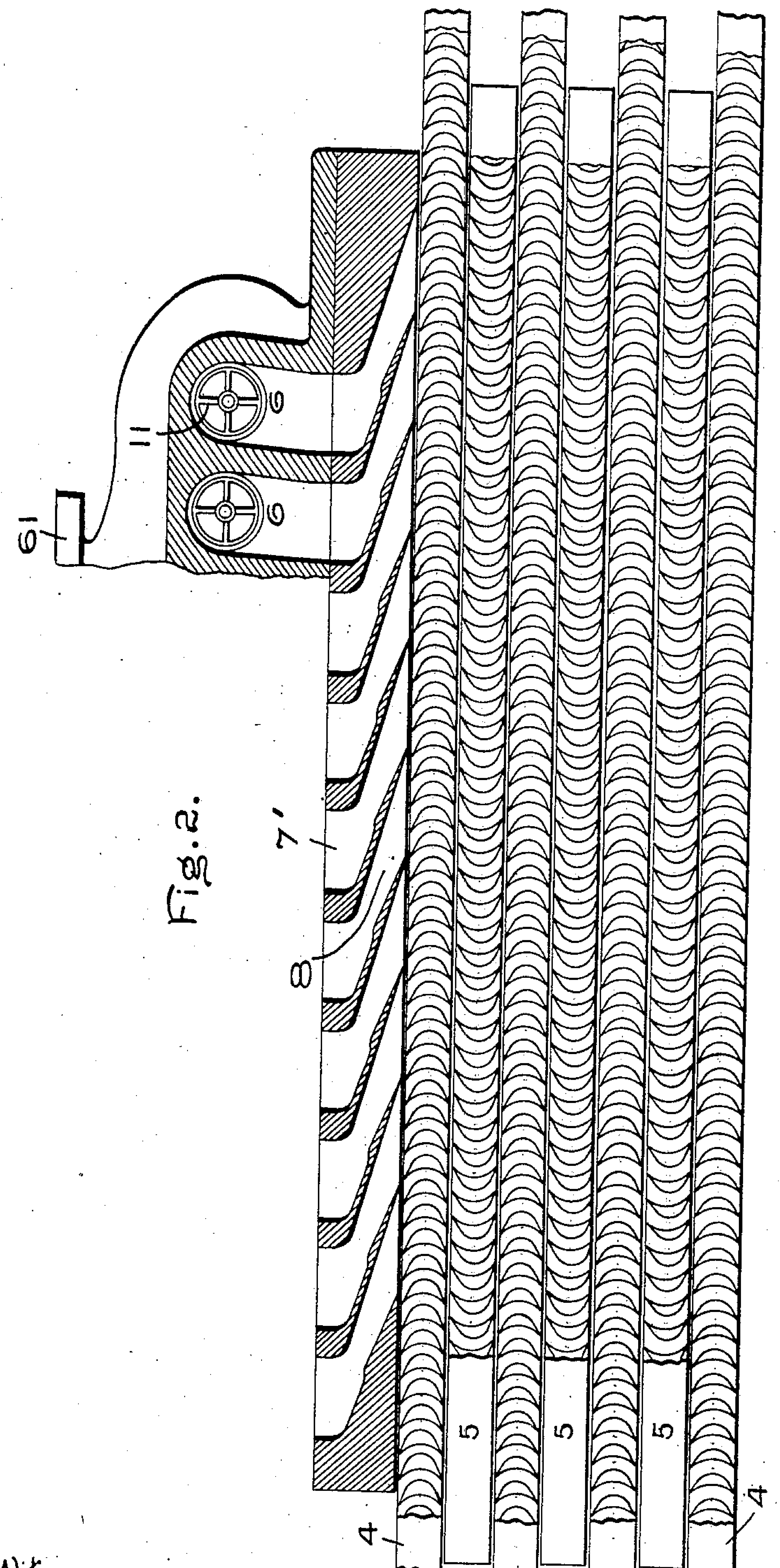

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4 SHEETS—SHEET 3.

Fig.3

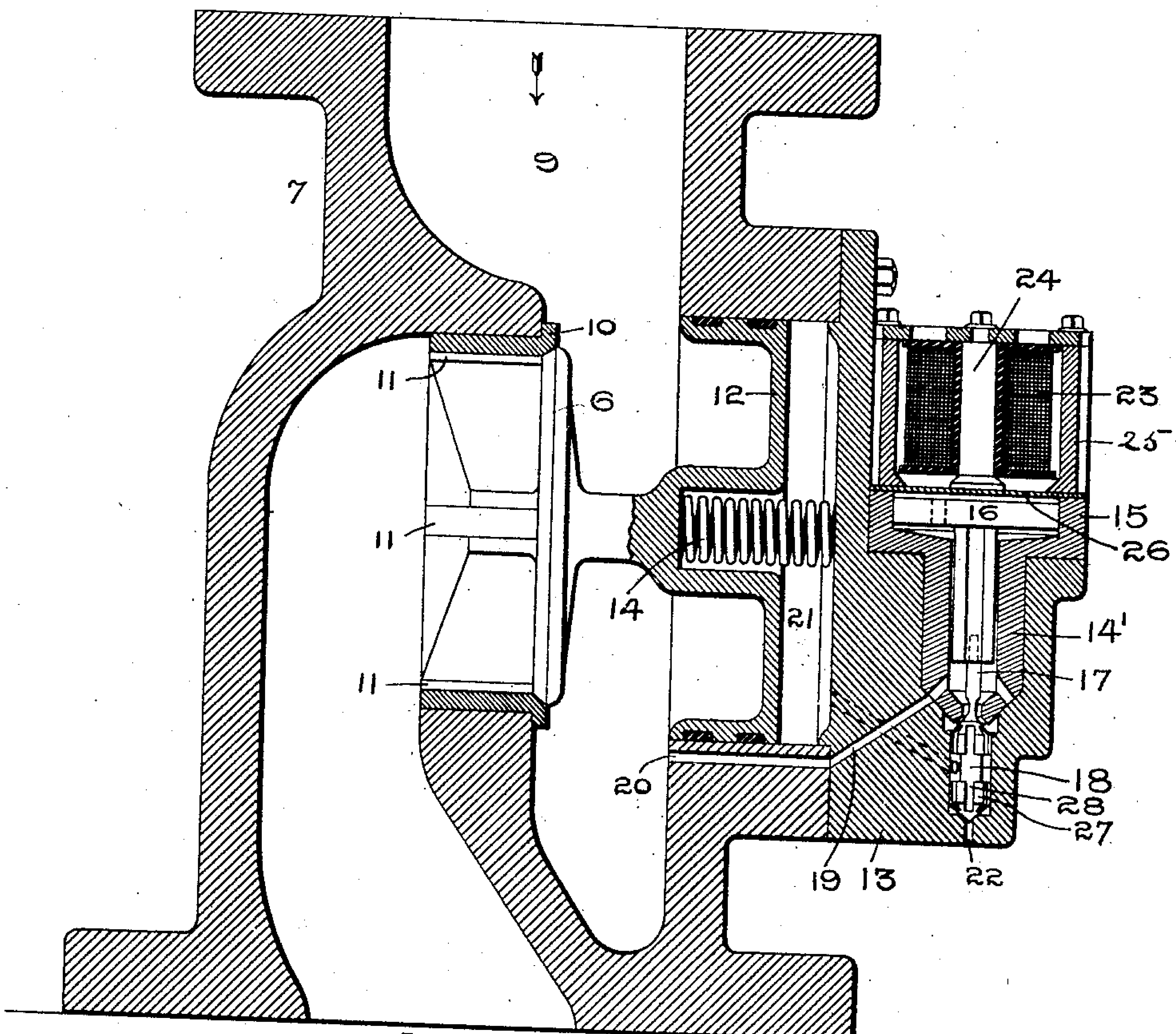


Fig.4.

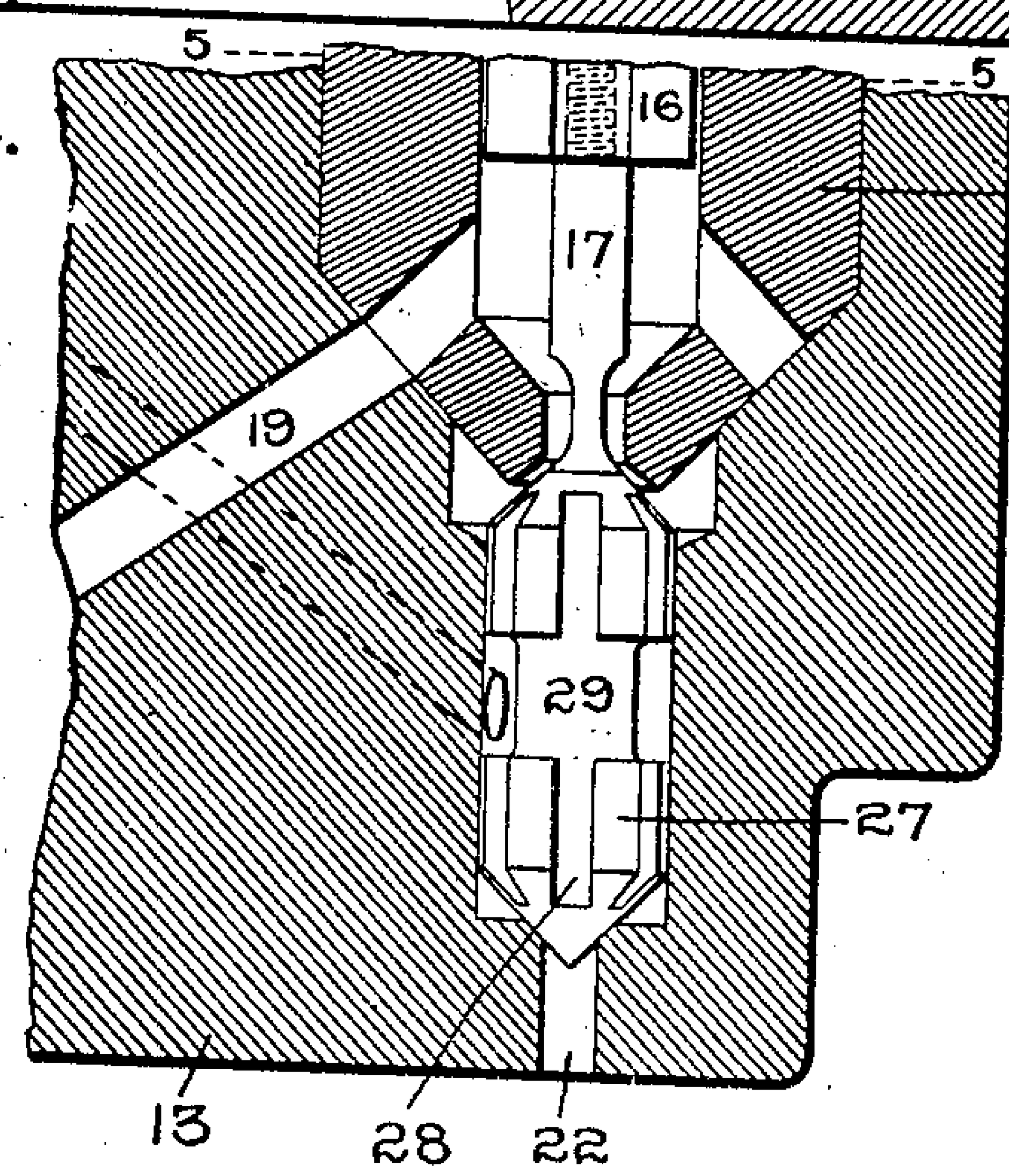


Fig.5.

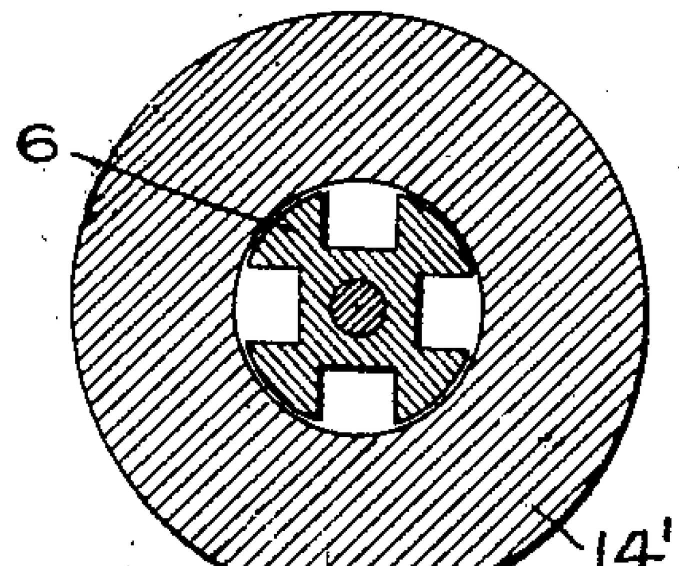
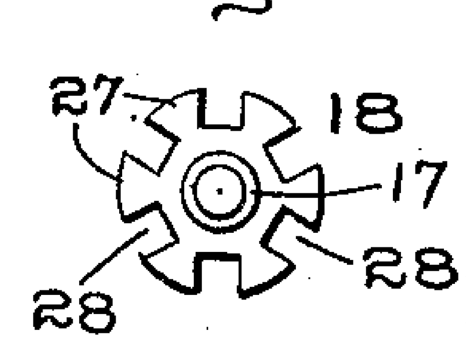


Fig.6.



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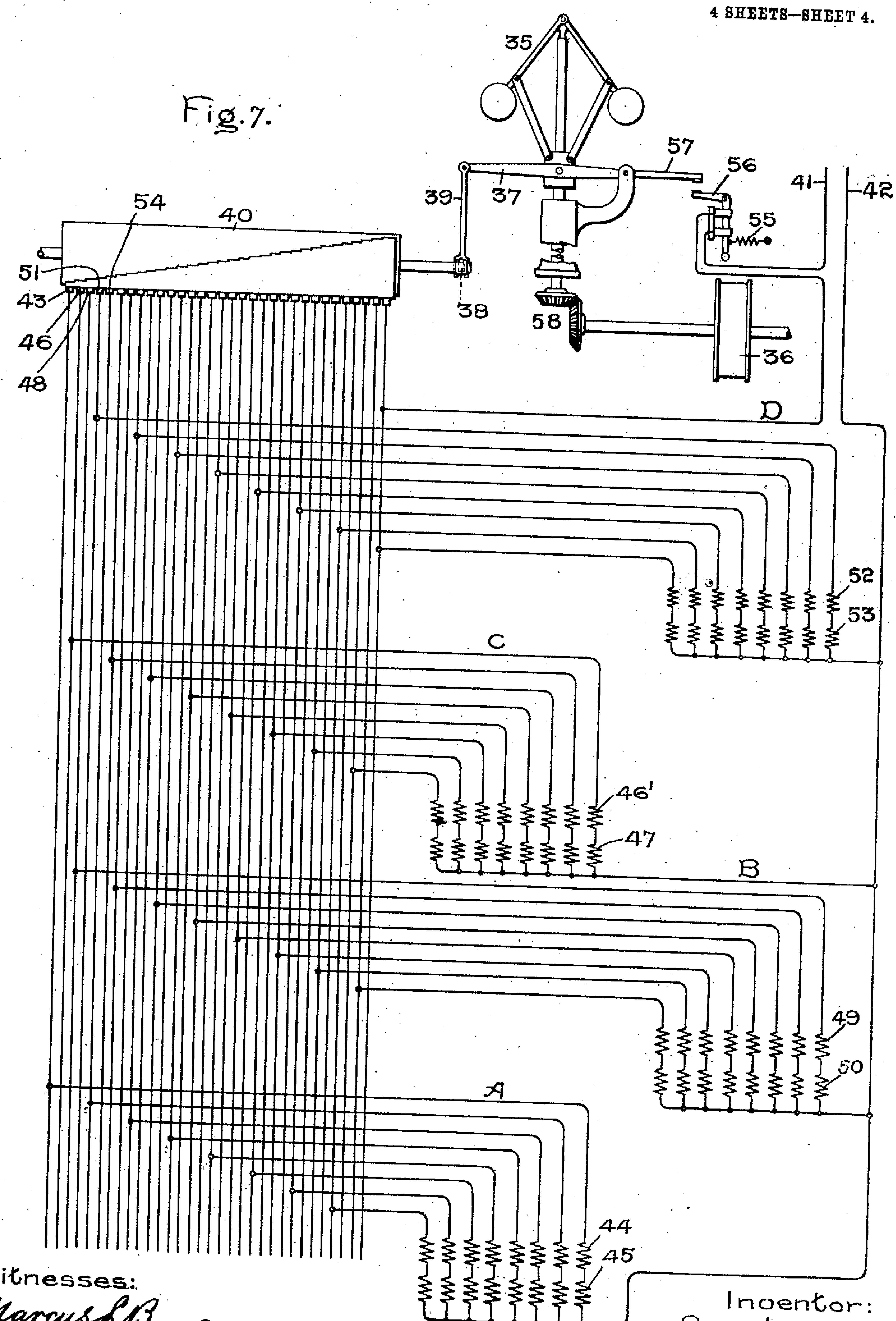
4 SHEETS—SHEET 4.

Fig. 7.



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UNITED STATES PATENT OFFICE.

OSCAR JUNGGREN, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

GOVERNING MECHANISM FOR TURBINES.

No. 824,546. Specification of Letters Patent. Patented June 26, 1906.

Application filed August 26, 1902. Serial No. 121,110.

To all whom it may concern:

Be it known that I, OSCAR JUNGGREN, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Governing Mechanism for Elastic-Fluid Turbines, of which the following is a specification.

It has been heretofore proposed to control elastic-fluid turbines having expanding nozzles and a single set of rotating vanes or buckets by manually cutting in or out one or more of said nozzles for wide variations in speed due to changes in load and to automatically compensate for minor variations by throttling the admission of steam to the remaining nozzles in service. Such an arrangement may be, to a certain extent, satisfactory with small machines and those having single wheels; but it would be impracticable with large turbines for several reasons. It has also been proposed to regulate a turbine by having a large piston-valve, which is mechanically connected to the governor and moved back and forth in a manner to cover or uncover one or more expanding-nozzle sections of a sectionalized nozzle. With such a construction there is of necessity a throttling of each nozzle section or passage prior to its being cut out—that is to say, the parts are so arranged that the governor may hold the piston in such a position that the passage is only partially covered, in which case the velocity of the jet is decreased, as is also the volume. Each time that this throttling takes place there is a slight loss in the efficiency of the turbine. Good practice dictates that a governor designed to control the admission of fluid to an engine or turbine within two or three per cent. shall be so constructed that the work required of it shall not exceed two or three per cent. of its capacity to do useful work. When this is considered in connection with large turbines—say of five-thousand-kilowatt capacity—having compound wheels and intermediates and requiring two hundred and fifty thousand pounds of fluid per hour, (this includes an overload capacity of fifty per cent.,) the objection to the ordinary governors is apparent. It is also obvious that hand regulation is unsuited for turbines of the character described, particularly when they are employed in driving dynamo-electric machines, where the load is constantly changing and frequently between wide limits.

In order to maintain the efficiency of an elastic-fluid turbine, the fluid permitted to pass through the nozzle or nozzles whenever it or they are in service should have a definite velocity. Experiments have been made showing that by throttling the passage of fluid through a given nozzle by fifty per cent. the efficiency is decreased to thirty-five per cent., and if the passage is further throttled the efficiency will fall more rapidly. It is evident that it would be impossible to instantly cut a very large volume of fluid in a single stream into or out of service, and, moreover, such an arrangement would be undesirable for other reasons. This means that a plurality of nozzles, with their fluid streams, should be provided and the regulation accomplished by changing the number of nozzles delivering fluid to the moving element or vane-wheel, as the conditions of load change. In other words, a plurality of nozzles should be provided with mechanism for regulating each nozzle separately and intermittently and in such manner that it is either full open or closed, as conditions of service demand. This does not necessarily mean that all of the nozzles on the turbine are regulable, for under normal conditions the load does not vary from full to no load.

The object of my invention is to provide a governing mechanism for efficiently regulating turbines operated by elastic-fluid pressure, and for an understanding of the invention and the scope thereof reference is made to the drawings and description and claims appended thereto.

In the accompanying drawings, which illustrate an embodiment of my invention, Figure 1 is a front elevation of a compound two-stage elastic-fluid turbine. Fig. 2 is a sectional detail view of the expanding nozzles and buckets. Fig. 3 is a vertical section of an electromagnetically-controlled nozzle-valve for controlling the admission of elastic fluid to a nozzle and the motor which is employed to actuate the valve. Fig. 4 is a vertical sectional detail view of the motor-controlling valve which controls the action of the nozzle-valve. Fig. 5 is a transverse section taken on line 5 5 of Fig. 4. Fig. 6 is a plan view of the secondary valve, and Fig. 7 is a diagram of connections.

The mechanical construction and arrangement of the turbine itself form no part of the present invention, except in so far as it relates to the controlling mechanism.

In its broadest aspects my invention includes the idea of a turbine having a plurality of nozzle-openings for delivering a stream or column of motive fluid to the bucket-wheel and a plurality of individual valves for cutting the sections into and out of service, with electrically-actuated means controlled by a governor for regulating the action of the individual valves, whereby the cross-sectional area of the column of fluid delivered to the wheel is varied. When considered from a different point of view, the invention includes the idea of secondary control for a turbine wherein a plurality of nozzles and separately-actuated nozzle-valves are provided, each of which is governed by a small auxiliary or secondary means, with a governor acting on the secondary means successively, the governor being responsive to changes in operative conditions. In this manner a governing system is provided wherein the actual load on or work required of the governor is very small. Hence the turbine can be accurately regulated over wide ranges in load by varying the volume of motive fluid without changing its velocity, and the governing-curve will be the same or substantially the same under conditions of increasing or decreasing load. In this particular my claims are to be construed as generic.

My invention is applicable to turbines having one, two, or more stages. In the present instance I have shown a turbine comprising two stages 1 and 2, situated one above the other, although they may be placed side by side or in any other convenient position. They may even be entirely separate structures and arranged to drive separate shafts, if desired. Each stage is provided with a revolving vane or bucket wheel 3, and these wheels are mounted on a shaft 4, the latter being supported in the usual bearings. The vane or bucket wheels in both stages of the turbine are of the same construction, as are also the stationary vanes between the moving vanes, so that a description of one of them will be sufficient. Formed on the periphery of the wheel 3 and extending around it circumferentially is a plurality of vanes or buckets 4′, arranged in rows. A number of these rows are provided, and extending inward toward the center of revolution and between the vanes on the wheel are stationary vanes or intermediates 5. The stationary or intermediate vanes are arranged in short sectional groups instead of extending circumferentially around the wheel, and the number of vanes in each sectional group depends on the number of nozzle-sections admitting fluid to the wheel. When in certain positions, the passages or spaces between the vanes on the wheel coincide with the spaces between the stationary vanes 5. Such a condition is shown in Fig. 1 of the drawings. This being a sectional view, the nozzle-opening does not show; but the feature of gradually increasing the size of the passage between vanes from the inlet to the exhaust is clearly shown.

The turbine illustrated is what is known as a "two-stage" turbine, and the elastic medium in passing through it has a certain amount of its energy abstracted by the upper set of vanes, called the "first" stage, and the remainder by the lower set of vanes, called the "second" stage. The turbine may be operated as a single-stage machine by connecting the first-stage casing with the exhaust through the connection 60. The valves of the second stage can then be disconnected from those of the first or not, as desired.

The turbine illustrated is intended to operate with steam, and my improved controlling mechanism is therefore especially designed for controlling steam; but the invention is equally well adapted for governors controlling other forms of elastic fluid.

In order to avoid objectionable heavy moving parts, I subdivide the mechanism into a number of sections and provide a governor for controlling the action of all of the said sections or subdivisions by successive steps. Where the sections are relatively small and light, the governor may be arranged to act upon them directly in a manner to definitely and positively cut nozzles or sections of a nozzle into and out of service. Where the parts are relatively large and heavy, it is desirable to provide intermediate devices for actuating them and to regulate said devices through the intervention of means requiring only a small amount of power. This may take the form of electrical means arranged to close and open the various circuits; but the invention in its broadest aspect is not to be construed as limited to this. With this system of secondary control the parts acted upon by the governor are comparatively light. Hence the load thereon will be small and good regulation obtained. To put the matter in a different way, a system of secondary regulation is provided wherein the heavier parts are moved by motors which are under the control of small parts, the operation of which is regulated by the governor. By definitely and positively opening and closing the nozzle-openings I avoid all tendency to throttle the fluid admission, and hence the efficiency of the turbine is maintained.

Another important feature of my invention resides in the fact that if one valve refuses to close for any cause it does not affect the operation of any other valve, and the regulation of the turbine is not seriously impaired.

In carrying out my invention a plurality of individual and separately-actuated nozzle-valves 6, Figs. 1 and 3, are provided, each valve being the counterpart of every other valve in the stage to which it belongs. The valves of each stage are arranged in groups, and as many valves may be provided as there are nozzle-sections, or there may be a less number. The number of nozzles in each group depends principally on the output of the turbine and the degree of regulation required. For example, thirty-two nozzle-sections arranged in groups of eight each are sufficient to handle the total amount of fluid required by a given turbine, and when one nozzle is rendered inoperative by closing its valve the total admission of fluid to the turbine is reduced by a little over three per cent., and vice versa.

While I consider it desirable to use as many valves as there are nozzles, I may have a less number of valves than nozzles in a given stage, in which case the main throttle-valve would be depended upon in shutting down the machine. The arrangement just described will be found to be useful where the turbine is always working under a portion of its load—say fifty per cent.—and it is only necessary to regulate for ranges in load from a point slightly below this to the maximum. The nozzle-sections of the second stage are larger than those in the first to compensate for the increased volume of the fluid due to the decrease in pressure. The size of the nozzle-valves in the second stage is also increased over those of the first stage and for the same reason.

The grouping of the nozzles and the nozzle-valves can be arranged as desired, it being preferable, however, to distribute them symmetrically around the wheel at equidistant points, so as to distribute the effects due to the fluid-jets evenly over the surfaces of the wheels. This arrangement is also desirable, as it avoids the introduction of heavy moving parts and affords more room for the valve mechanism and renders them more easily inspected.

In Fig. 2 is shown the arrangement of a group of closely-associated nozzle-sections and a vane or bucket wheel viewed in a plane parallel with the axis of the supporting-shaft. Each nozzle comprises a fluid-chamber or bowl 7′, that opens at its lower end into a diagonally-extending nozzle-passage 8, the end of which discharges the fluid against the wheel. The nozzle shown is of the expanding type, and the pressure of the fluid delivered thereby is the same or substantially the same as that of the wheel-casing; but nozzles having other characteristics may be used under certain conditions. As the fluid passes through each one of these nozzles the pressure is converted into *vis viva* or velocity and striking the vanes 4 of the vane-wheel causes rotation of the main shaft. After leaving the first set of vanes the steam enters the intermediates and is deflected thereby into the second row of buckets or vanes, and so on. It will be noted that the intermediates cover substantially the same arc as the nozzles, and the buckets formed thereon are so disposed that when a nozzle is cut out the buckets or vanes, both moving and stationary, which are in line therewith, are also cut out. By reason of this arrangement the total cross-sectional area of the fluid-passage is decreased or increased as the individual nozzles are cut out of or into service. This is an important feature, since it enables me to preserve the desired character of the fluid stream as to volume and velocity. When all of the nozzles are in service, it follows that the maximum number of moving buckets are employed and also the maximum number of intermediate buckets. To put the matter in a different way, the turbine is provided with a number of nozzles, each of which has a valve and a corresponding working passage or passages, each passage comprising movable and stationary buckets. The nozzles are under the control of a governor and so arranged that they are either closed or opened, there being no intermediate position. When one of the nozzles is closed against the entrance of the motive fluid, the working passage corresponding thereto is also closed, except for the spill from one bucket to another. The grouping of the nozzles, as shown, is advantageous, because the leakage between the stationary and moving parts is decreased.

In Fig. 3 is shown an enlarged sectional view of an automatically-controlled valve representing a means for carrying out my invention by regulating the admission of fluid to a nozzle. Each valve in the present illustration is under the control of an electromagnet and is independent as to its operation of every other valve in the same group. All of the nozzle-valves being similar in construction, except as to the size of the parts, a description of one of them will be sufficient. This similarity of construction is highly desirable, as the parts for a given size are interchangeable, and the cost of construction is greatly decreased. Moreover, the arrangement of a number of individual valves electrically operated or controlled from a separate governor affords a great mechanical simplification.

7 represents a valve-casing having finished top and bottom flanges, by means of which it is attached to the steam connection and to the flanged piece containing the chambers or bowls 7′ and nozzles 8, Fig. 2. The casing is provided with a passage 9, which is divided into two parts by the partition containing the nozzle-valve 6. The upper end of the passage communicates with the boiler and the lower end delivers fluid to a bowl 7′. The opening in the partition is made large

enough to receive the sleeve 10, the latter being provided with a conical valve-receiving seat. The valve is provided with four projections 11, which engage with the sleeve 10 and act as guides therefor. It is of the utmost importance that all of the valves 6 be capable of completely shutting off all the steam admitted to the first-stage nozzles, for if the load is suddenly removed when the turbine is running with a condenser and the valves close even a very small amount of steam will cause it to race. When only a part of the motive fluid is handled by the separately-actuated valves, the main throttle-valve must of course be depended upon to cut off the supply. Formed on the back of the valve is a rod which connects it with the motor-piston 12, the latter being larger than the valve and provided with packing-rings to prevent leaking. The piston and its cylinder are in line with the valve and are inclosed by the same casing. The motors and their controlling-valves are under the control of electromagnets, as will appear hereinafter, and when for any reason the magnets cease to operate the valves 6, controlling the admission of steam to the nozzles, will automatically close. This precaution is obviously advantageous, since it prevents accidents. I also provide an auxiliary governor, in addition to the main governor, which is set to operate at a definite increase in speed over the normal—as, for example, ten per cent. The governor is arranged to trip a circuit-breaker and interrupt the energizing-circuit of all of the magnets.

Between the plate 13 or other stationary abutment and the motor-piston is a compression-spring 14, that tends at all times to close the nozzle-valve. This spring is necessary in order to start the motor into operation when steam is admitted to its cylinder. When the nozzle-valve is wide open, the pressures balance and without the spring the valve could not close; but as soon as the valve moves a certain distance toward its conical seat this relation is upset and the valve is quickly closed.

Owing to the size of the nozzle-valves, it is impracticable to operate them directly by the governor, and for this reason double-acting fluid-motors are provided which utilize the motive fluid before it enters the expanding nozzle and has its pressure converted into velocity. The passage of the motive fluid is therefore under the control of a secondary valve, which is also mounted on the valve-casing 7. It will thus be seen that for every nozzle a main or nozzle valve, a motor, and a secondary or motor-controlling valve are provided, the secondary valve and motor being under the control of the governor, acting in the present case through an electromagnet. For small machines it is possible under certain conditions to actuate the nozzle-valves 6 directly by the electromagnets without the intervention of the motors, and certain of the claims in their broadest aspect include such an arrangement. The secondary or motor-controlling valve is mounted on a plate 13, which is bolted or otherwise secured to the valve-casing. The plate 13 is bored out to receive the tubular extension 14′ of the casing 15, which forms a part of the secondary-valve mechanism. The lower end of the extension is beveled, so as to make a tight fit with the plate around the ports and prevent the escape of steam. Mounted within the casing and suitably guided is a movable piece 16, having an enlarged head and downwardly-extending portion, the latter being screw-threaded to the stem 17 of the secondary valve 18. The lower end of the cylindrical extension 14′ is provided with a valve-seat, arranged to engage with the valve 18, and one or more ports or openings 19, which communicate with the passage 20 and admit live steam to the back of the motor-piston 12 when it is desired to close the nozzle-valve 6. The secondary or motor-controlling valve 18 is double-acting—that is to say, it is employed to control the admission of steam to the cylinder 21 and also to control the exhaust therefrom through the port 22. Situated above the casing 15 is an electromagnet 23, having a central core-piece 24 and side pole-pieces 25. Between the magnet and the casing is a thin non-magnetic plate 26 to prevent the armature from sticking to the pole-pieces. The enlarged head 16 constitutes an armature and is perforated, so as to equalize the pressures above and below it. When the magnet is energized, the head is attracted, which raises the secondary valve 18 and opens the cylinder 21 to the exhaust, at the same time closing the live-steam entrance.

The double-acting secondary valve 18 is made after the manner of a piston-valve and has a plurality of guides 27 formed on the periphery. Between these guides are slots 28, which communicate with the reduced portion 29 of the valve. The ends of the valve are made conical and are adapted to be seated on conical seats. The upper seat is formed on the cylindrical extension 14′, and the lower seat is formed in the plate 13. The construction of the valve is more clearly shown in Figs. 4 to 6, inclusive.

It is to be noted that the nozzle-valve and the motor are entirely inclosed and that there are no valve-stems or other parts projecting through the casing requiring packing. This is an important feature of my invention for it enables me to reduce the leakage and at the same time decrease the cost of maintenance. It also lessens the cost of attendance.

The action of each of the valves is as follows: When the circuit of the magnet is energized, it raises the secondary or motor-controlling valve 18 and cuts off the supply of live steam to the cylinder 21. At the same time the exhaust-port 22 is uncovered and the steam remaining in the motor-cylinder 21 is permitted to escape. The diameter of the motor-piston 12 being greater than that of the nozzle-valve 6 the valve will automatically open as soon as the pressure on the back of the piston is decreased to a certain extent. As soon as the nozzle-valve 6 is opened steam will enter the nozzle and pass through the turbine, as previously described. When, for any reason, it is desired to cut out a nozzle-section, the magnet is deënergized, which permits the motor-controlling valve 18 to drop and close the exhaust-port 22, at the same time admitting live steam to the motor-cylinder 21. The piston will then move forward under the action of the fluid and the compression-spring and close the nozzle-valve 6, thereby cutting off its nozzle. It will thus be seen that the motor is of the double-acting type and utilizes the same fluid that drives the turbine, and, furthermore, that the fluid delivered to the motor is taken from the boiler end of the expanding nozzle.

Referring to Fig. 7, the circuit connections will be described. Each motor-controlling valve in the first and in the second stage is provided with a magnet-winding, and the windings of corresponding valves are connected in series, although the multiple connection of windings may be used, if desired. As before stated, the nozzles are distributed around the circumference of the wheels at suitable points and are arranged in groups. In controlling the admission of steam to the turbine it is desirable to distribute the strains evenly over the entire circumference, and to accomplish this I arrange the connections for the controlling-magnets in such manner that the corresponding nozzles in the first and second stages are first cut out of one group, then the corresponding nozzles of the group diametrically opposite, and so on. This feature of progressively cutting in or out the nozzles will be more clearly shown by reference to the diagram. The first nozzles to be cut into or out of service should be located at the ends of the group. It does not matter particularly, however, whether the nozzles so affected are at one end of the group or the other. 35 represents a governor which is driven by a pulley 36 or equivalent means from the main shaft of the turbine. On the governor is a lever 37, which is connected to an arm 38 by the link 39. The arm is mounted on the shaft of the contact-cylinder 40, and as the lever 37 moves up and down under the action of the governor the cylinder is rotated in a manner to cut in or out the various magnet-windings. This cutting of the magnet-winding into and out of service is due to the tapered contact-plate on the cylinder. In the present instance the controllable nozzles of the turbine have been divided into four groups of eight each. It is to be observed that in the second stage there are certain valves which are not connected to the governor, but these may be connected, if desired. Current for actuating the magnets is taken from the circuit-wires 41 and 42. With the parts in the position shown all of the magnets are energized, and consequently all the nozzle-controlling valves are open. Assuming that for any reason the speed increases above a certain point, the contact-cylinder 40 is rocked so that the brush 43 is cut out of circuit. This means that the magnet-winding 44 of the first stage and 45 of the second stage, group A, will be cut out of circuit, and, as has been described, when the magnet is deënergized it permits the motor-controlling valve 18 to drop and the live steam to enter the cylinder 21 and close the nozzle-valve 6. A continued increase in speed due to a decrease in load or for any other reason will cause the brush 46 to move off of the contact-plate on the cylinder, thus interrupting the circuit of the magnet 46′ of the first stage and the magnet 47 of the second stage, these latter magnets being located in group of nozzles C, which group is located diametrically opposite to group A. A continued movement of the cylinder in the same direction will cut out brush 48, which brush controls the flow of current to the magnet-coil 49 of the first stage and magnet-coil 50 of the second stage, group B. As soon as the magnets are deënergized the nozzle-valves controlled by these magnets in both the first and second stages will close through the action of the fluid-motors. A continued movement of the cylinder in the same direction will break the circuit at brush 51, and the magnet 52 of the first stage and 53 of the second stage, group D, will be deënergized, and the nozzle-valves controlled thereby will be automatically closed. Continued movement of the cylinder in the same direction will interrupt the circuit at brush 54, which is connected to the magnets of group A of the first and second stages. Further description of this action is unnecessary, because the action is similar with respect to each of the contact-brushes and the circuits. By cutting out the nozzles in group A, then in group C, then in group B, and finally in group D the strains are distributed practically evenly around the circumference of the wheel. As the load increases the nozzles are again returned to service.

In addition to the main governor I provide an auxiliary governor, which in the present instance takes the form of an addition to the governor 35. It comprises a circuit-breaker which normally tends to open under the action of the spring 55. This action is opposed by the latch 56. Mounted on the governor in a manner to be actuated by the moving system is an arm 57, which when the speed of the turbine attains a definite increase—such as ten per cent., for example—strikes the latch 56 and releases the circuit-breaker, thus interrupting the continuity of the supply-wire 41. As soon as this is done the supply of current to all of the magnet-windings on the turbine will cease, and the armatures 16 will drop and close the exhaust-ports 22 and admit the motive fluid to the cylinders 21, which will cause the motors to close the nozzle-valves. It is to be borne in mind in connection with this closing that the area of the valve 6 is added to that of the piston 12. The governor shown is driven by means of the bevel-gears 58 and the pulley 36, the latter being belted to the main shaft of the turbine.

It is to be noted that the nozzles or nozzle-sections 8 are grouped together in such intimate relation that the fluid discharged by them acts as a single stream. This arrangement is important, because all of the passages directly in front of the active nozzles or nozzle-sections will work at their maximum efficiency. I find it preferable to cast each nozzle structure out of a single piece of metal and to form the several expanding passages at the same time, after which the nozzle-sections can be carefully machined to size. I do not wish, however, to be considered as excluding myself from making nozzles out of separate pieces and combining them in a manner to produce a nozzle having the same characteristics as the one shown. Cutting out one or more of the end sections of the nozzle changes the total volume of fluid delivered to the buckets without changing its velocity, and consequently the rotary and intermediate buckets directly in front of said sections are rendered inactive. It is evident with my arrangement that under normal running conditions certain of the nozzle-sections will be open and that one or more of the sections will be cut out. For any given position of the contact-cylinder it is also evident that there will be at least one contact which is continually making and breaking the circuit of a magnet. For any given position of the contact-cylinder it is also evident that there will be at least one contact which is continually making and breaking the circuit of a magnet, due to the fact that a given number of open valves and nozzles will seldom furnish exactly the amount of steam required—that is to say, a load may be of such magnitude that it requires an amount of steam equivalent to the discharge of five and a half nozzles, in which case five open valves and nozzles will not supply enough steam and six open valves and nozzles will supply too much. Under normal conditions of operation this will result in some of the valves and nozzles being in service, some out of service, and at least one valve at the critical point of regulation opening and closing to admit a pulsatory supply of fluid to the nozzle or nozzle-section which it controls. This same action is repeated for each of the other valves and nozzles under similar circumstances. This means that the valve controlled thereby is continually opening or closing, as the case may be; but it is to be noted that the construction of the valve is such that it can never assume an intermediate position, and thus cause the last section of the nozzle to be throttled and impair the efficiency of the turbine. All of the valves 6 in each group receive steam from the same chamber through the passages 9, the said chamber being found in the steam-chest 61. By reason of this arrangement large pipes can be employed to convey fluid to the valves, and the losses in the transmission will be small. The conduits between the steam-chest and the several valve-chambers are short and are relatively free from bends and other obstructions.

I have described my invention in connection with a turbine having expanding nozzles, since this is the preferred construction; but it is to be understood that the invention is not to be construed as being so limited in all of its aspects.

I am aware that it has been proposed to regulate the admission and exhaust ports of a reciprocating engine by means of electromagnetically-controlled valves, the circuits for the magnets being made and broken by a contact device driven by the engine, and hence do not make claim thereto. I am also aware that it has been proposed to regulate a radial impact-turbine comprising a number of independent non-expanding nozzles which deliver fluid tangentially to peripheral buckets on a single wheel and are spaced an appreciable distance from each other by providing a separate valve for each nozzle. The valves in the particular arrangement referred to are operated by a reciprocating bar having cam-surfaces, which are so arranged that the valves can assume intermediate positions, and thus throttle the admission of fluid to the periphery of the wheel. My claims are not to be construed as being broad enough to include this construction.

The improvement in nozzle-valves disclosed in this application is not claimed herein, because it forms the subject-matter of a divisional application filed April 29, 1903, Serial No. 154,889.

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 and equivalent means.

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

1. In an elastic-fluid turbine, the combina-

tion of a bucket-wheel, a plurality of nozzles arranged to discharge motive fluid thereto, separate valves for the nozzles, individual secondary valves for controlling the nozzle-valves, a governor, and means under the control of the governor for successively actuating the secondary valves.

2. In an elastic-fluid turbine, the combination of a bucket-wheel, a number of closely-associated nozzle-sections delivering fluid to the wheel, intermediate buckets located between the wheel-buckets, nozzle-controlling valves each having an open and a closed position but no intermediate, individual secondary means controlling the nozzle-valves, a governor, and mechanism under the control of the governor for successively actuating the secondary means.

3. In a turbine, the combination of a wheel, a plurality of individual expanding nozzle-openings, separately-actuated valves for positively opening and closing the openings, thereby changing the volume delivered without varying the velocity, the said valves having no intermediate position, a secondary device for actuating each of the valves, and a governor for successively moving the devices into and out of operation.

4. In a turbine, the combination of a bucket-wheel, a stationary sectional intermediate, a plurality of nozzle-openings delivering fluid to the wheel and to the intermediate, separately-actuated valves for opening and closing the nozzle-openings, a separate secondary means for actuating each valve, each of said secondary means being independent in its action of every other means, and a device responsive to speed changes which regulates the action of the secondary means, substantially as described.

5. In a governing system, the combination of a turbine-wheel, a plurality of expanding nozzles therefor, an electrically-controlled valve for each nozzle acting to vary the total volume of fluid delivered to the wheel without affecting its velocity.

6. In a turbine, the combination of a plurality of nozzle-openings formed in a single structure, valves for the nozzles which are attached to said structure and have an open and a closed position but no intermediate, electrically-controlled means for regulating the valves, and a revolving element which is acted upon by the fluid from the nozzles.

7. In a turbine, the combination of a revolving wheel, intermediates which cover a section of the wheel, a number of nozzles delivering fluid to the wheel and to the intermediates, valves which have only an open and a closed position for definitely cutting the nozzles into and out of service, and electrical means for regulating the valves.

8. In a turbine, the combination of a wheel, a plurality of expanding nozzles which convert the pressure of the steam into velocity and deliver it with the velocity unimpaired to the wheel, separate valves for the nozzles, magnets for regulating the action of the valves, a governor, and contacts acted upon by the governor for opening and closing the circuits of the magnets.

9. In a turbine, the combination of a wheel, a plurality of nozzles which convert the pressure of the steam into velocity and deliver it with the velocity unimpaired to the wheel, electrically-controlled valves for cutting the nozzles into and out of service, each valve having two definite positions, and a device responsive to speed variations for varying the circuit connections of the valves.

10. In a turbine, the combination of a bucket-wheel, a plurality of nozzles which are closely associated and convert the pressure of the motive fluid into velocity and deliver it with a velocity unimpaired to the wheel, valves regulating the nozzles which have an open and a closed position but no intermediate, secondary valves controlling the nozzle-valves which are independent of each other in their action, a governor that is responsive to speed variations, and means under the control of the governor for successively cutting the secondary valves into and out of service.

11. In a turbine, the combination of a wheel having rows of vanes or buckets, segmental intermediate vanes or buckets between the rows of wheel-vanes, a casing for the wheel, a plurality of nozzles arranged in groups for imparting velocity to the motive fluid and delivering it to the wheel at substantially the pressure of the casing, and electrically-controlled valves for the nozzles which definitely put the nozzles into or out of service, whereby the total volume of fluid delivered to the vanes can be varied at will without impairing its velocity.

12. In a turbine, the combination of a bucket-wheel, a number of nozzles distributed at different points around the wheel, each nozzle comprising a number of closely-associated discharge-passages, nozzle-valves, secondary valves controlling the nozzle-valves, an automatic regulator, and means under the control of the regulator progressively acting on the secondary valves, one after the other, to cut the nozzle-sections into and out of service.

13. In a turbine, the combination of a wheel, having circular rows of buckets, intermediate buckets situated between the rows of wheel-buckets and arranged to cover a portion only of the wheel, a nozzle arranged in segmental form and situated in line with the intermediate bucket, the said nozzle comprising a plurality of closely-associated passages whereby the fluid therefrom is discharged in a solid stream, valves for the pas-

sages, pistons for operating them, independent secondary valves for controlling the pistons, and means for successively operating the secondary valves.

14. In a turbine, the combination of a fluid-admitting valve, a motive device for opening the valve when steam is admitted to the turbine, a magnet for causing said valve to close, and a governor which controls the magnet.

15. In a turbine, the combination of a plurality of nozzles, valves for definitely opening and closing the nozzles, motors for definitely moving the valves to an open or closed position, magnets arranged to permit the valves to close when they are deënergized, and a governor for controlling the magnets.

16. In a turbine, the combination of a plurality of nozzles, a separate valve for each nozzle, a fluid-motor for actuating each valve, a valve for governing the admission of fluid to each motor, a magnet for governing each valve, which is arranged to admit fluid to the motor whenever its circuit is interrupted and a governor which controls the motor-valves.

17. In a turbine, the combination of a number of nozzles, a number of nozzle-valves, a motor for each nozzle-valve, motor-governing valves, a separate magnet for operating each of the motor-valves, and a regulator which is common to the magnets.

18. In a turbine, the combination of a number of nozzles each acting to convert fluid-pressure into velocity, motors which tend to place the nozzles in service as soon as fluid is admitted to the turbine, and an electrically-actuated device which controls the action of the motors.

19. A turbine having a plurality of individual fluid-admitting nozzles, each nozzle having an open and a closed position, but no intermediate, with electrically-actuated means for definitely opening or closing the nozzles.

20. In combination, a turbine having an automatic valve, a speed-governor acting on the valve, and means causing the valve to close whenever the operative relation between the governor and valve is disturbed.

21. In a turbine, the combination of a number of nozzles, valves for the nozzles, magnets for controlling the valves, a contact device capable of simultaneously energizing all of the magnets at full load, and means for automatically actuating the contact device to cut them out of circuit one by one as the load decreases.

22. In a turbine, the combination of a number of nozzles, electrically-actuated valves for the nozzles which are operated in pairs, and a governor for cutting the valves into and out of service.

23. In a stage-turbine, the combination of nozzle-valves in the first stage, a number of nozzle-valves in lower pressure stage, valve-controlling mechanism, electrical connections extending between the mechanism of the stages whereby the sets of valves are caused to act simultaneously, and a governor which controls their action.

24. In combination, a turbine, a sectionalized nozzle, a plurality of separately-actuated valves for regulating the admission of fluid to the turbine, magnets for the valves, a contact-cylinder which controls the magnets and a governor for actuating the cylinder.

25. In combination, a turbine, a plurality of electromagnetically-actuated valves, a contact-cylinder which is capable of simultaneously energizing all of the magnets and cutting them out step by step, and a governor which is driven by the turbine for moving the cylinder.

26. In combination, a turbine, a plurality of electromagnetically-actuated valves for regulating the turbine, a governor for regulating the valves, and an auxiliary device acting under abnormal conditions, which renders the magnet inoperative.

27. In combination, a turbine, a plurality of electromagnetically-actuated valves, a speed-governor for regulating the normal action of the valves, and a device acted upon by the governor which cuts the magnets out of circuit under certain conditions.

28. In a turbine, the combination of a rotating element, a plurality of valves delivering fluid thereto, magnets controlling the valves, a contact device, conductors connected in multiple to the magnets, and a governor acting on the device in a manner to include more or less of the conductors in the circuit.

29. In a turbine, the combination of a rotating element, a plurality of valves delivering fluid thereto, magnets controlling the valves, which are connected in multiple, and a contact device for simultaneously deënergizing the magnets.

30. In a turbine, the combination of a rotating element, a plurality of valves delivering fluid thereto, magnets controlling the valves, which are connected in multiple, a contact device capable of simultaneously energizing the magnets, and a second contact device capable of deënergizing the magnets irrespective of the position of the first contact device.

31. In combination, a turbine, magnets for governing the admission of fluid thereto, and a contact-cylinder arranged to include the magnets in circuit simultaneously, and cut them out in a step-by-step manner.

32. In a turbine, the combination of a sectionalized nozzle, a valve-chamber opening into each of the sections, and separately-actuated valves in said chambers for controlling the admission of fluid to the nozzle-sections.

33. In a turbine, the combination of a noz-

zle having a plurality of working passages formed therein, a valve-chamber opening into each of the passages, separately-actuated valves situated in the chambers, and a steam-chest with which the chambers all communicate.

34. In an elastic-fluid turbine, a governor, a plurality of inlet-nozzles, an independent valve controlling each nozzle, and valves controlled by the governor for regulating the action of the independent nozzle-valves.

35. In an elastic-fluid turbine, the combination of a plurality of inlet-nozzles, a separately-actuated valve for controlling each nozzle, and a second set of valves controlled by the speed of the turbine for regulating the action of said nozzle-valves.

36. In an elastic-fluid turbine, the combination of a plurality of inlet-nozzles, an independent valve controlling each nozzle, auxiliary valves which control the nozzle-valves, and a contact device for controlling the action of the auxiliary valves.

37. In a steam or gas turbine, a plurality of inlet-nozzles, an independent valve controlling each nozzle, actuated by motive fluid, and valves controlled by the speed of the turbine to admit motive fluid to, and cut it off from, said turbine, substantially as described.

38. In combination, a bucket-wheel, nozzles, a plurality of independent valves for regulating the admission of fluid thereto, a governor for regulating the valves, and an auxiliary device acting under abnormal conditions for rendering the valves inoperative.

39. In combination, a bucket-wheel, nozzles, a plurality of individual valves for regulating the discharge of fluid therefrom, a governor, means under the control of the governor for controlling the valves, and a device responsive to abnormal conditions for rendering said means inoperative and causing the valves to close.

40. In an elastic-fluid turbine, the combination of nozzle-sections for discharging motive fluid, a bucket-wheel situated in front of the nozzle-sections, means for cutting the sections into and out of service, a separate motor for each of the means, a secondary controlling device for each of the motors, and a governor that acts on all of the secondary devices and successively renders them active and inactive.

41. In an elastic-fluid turbine, the combination of a bucket-wheel, a nozzle arranged to discharge motive fluid against the wheel, the nozzle being composed of a plurality of closely-associated sections which discharge the fluid as a solid stream or column, a separately-actuated controlling means for each section, which has an open and a closed position but no intermediate, an automatic governor, and mechanism between all of the controlling means and the governor acting to cut the end section into and out of service whereby the continuity of the intermediate portion of the fluid stream or column is preserved at all times.

42. In an elastic-fluid turbine, the combination of a bucket-wheel, a plurality of groups of nozzles, each group comprising a plurality of closely-associated nozzle-sections which discharge the motive fluid in the form of a solid stream or column, an automatic governor, an independent valve for controlling each section of each group, and connecting means between each valve and the governor whereby the end sections of the several groups are cut into or out of service successively and the continuity of the several streams or columns is preserved.

43. In an elastic-fluid turbine, a plurality of nozzles, a valve in each nozzle, a speed-governor, and electromagnetic means controlled thereby for opening or closing said valves progressively according to variations in the load.

44. In an elastic-fluid turbine, a series of fluid-actuated valves controlling the supply of fluid to the turbine, a series of passages for the valve-actuating fluid, and a governor-controlled valve for each passage.

45. In an elastic-fluid turbine, an induction-nozzle, a fluid-actuated valve therefor, a passage for the valve-actuating fluid, and an electrically - operated governor - controlled valve therein.

46. In an elastic-fluid turbine, a series of supply-valves, and independent governor-controlled devices which control a fluid-relay power to actuate said supply-valves.

47. In a turbine, an induction-nozzle delivering fluid-pressure against a rotating element, a fluid-actuated valve therefor, a passage for the valve-actuating fluid, a valve therein, and a governor-controlled motor to actuate said latter valve.

48. A turbine which is divided into stages of expansion and is provided with wheel-buckets and fluid-discharging devices for each stage, in combination with valves admitting fluid to the turbine, a means responsive to load conditions for successively operating the admission-valves, and successively operating stage-valves controlling the passage of motive fluid from one stage to another.

49. A turbine which is divided into stages of expansion and is provided with wheel-buckets and fluid-discharging devices for each stage, in combination with valves admitting fluid to the turbine, valves controlling the passage of motive fluid from one stage to another, and a speed-responsive means causing the admission and stage valves to open and close successively to vary the volume of fluid passing through the turbine as the load changes.

50. A turbine which is divided into stages of expansion and is provided with wheel-

buckets and fluid-discharging devices for each stage, in combination with valves admitting fluid to the turbine, a speed-governor for controlling the action of the admission-valves, and fluid-actuated stage-valves for controlling the passage of motive fluid.

51. A turbine which is divided into stages of expansion and is provided with wheel-buckets and fluid-discharging devices, in combination with valves admitting fluid to the turbine, a speed-governor for controlling the operation of the valves, stage-valves controlling the passage of motive fluid from one stage to another, and fluid-actuated motors for actuating the valves.

52. An elastic-fluid turbine comprising movable buckets and fluid-discharging devices, in combination with valves regulating the passage of fluid through the devices, electromagnets for operating the valves, and means modifying the circuit relations of the magnets to open and close the valves in accordance with load-changes, said means being so constructed as to permit a valve to open and close to admit a pulsatory supply of fluid to a discharging device.

53. An elastic-fluid turbine comprising movable buckets and fluid-discharging devices, in combination with valves regulating the passage of fluid through the devices, electromagnets for controlling the operation of the valves, a contact means for modifying the circuit relations of the magnets in a manner to cause the valves to open and close in accordance with load-changes, said means being so constructed as to permit a valve at the critical point of regulation to open and close to admit a pulsatory supply of fluid to a discharging device, and a load-responsive device acting on the contact device.

54. An elastic-fluid turbine having movable buckets and a nozzle comprising a plurality of closely-associated passages arranged to discharge motive fluid in an unbroken column to the buckets, in combination with valves for the passages having an open and a closed position but no intermediate, and a means responsive to load changes for opening and closing the valves as the load changes, said means being so constructed as to permit a valve at one end of the column to open and close and admit a pulsatory supply of motive fluid to a discharging device for the purpose described.

55. An elastic-fluid turbine having movable buckets and a plurality of fluid-discharging devices, in combination with valves for the devices which have an open and a closed position, motors for actuating the valves, a separate and independently-acting regulator for each motor, and a load-responsive means which is common to the regulators and causes them to act successively to vary the number of valves in service, said means being so constructed as to permit movement of one of the regulators in a manner to cause a valve at the critical point of regulation to open and close and admit a pulsatory supply of fluid to a discharging device for the purpose described.

In witness whereof I have hereunto set my hand this 25th day of August, 1902.

OSCAR JUNGGREN.

Witnesses:

BENJAMIN B. HULL,

FRED ROSS.