No. 753,772. PATENTED MAR. 1, 1904.

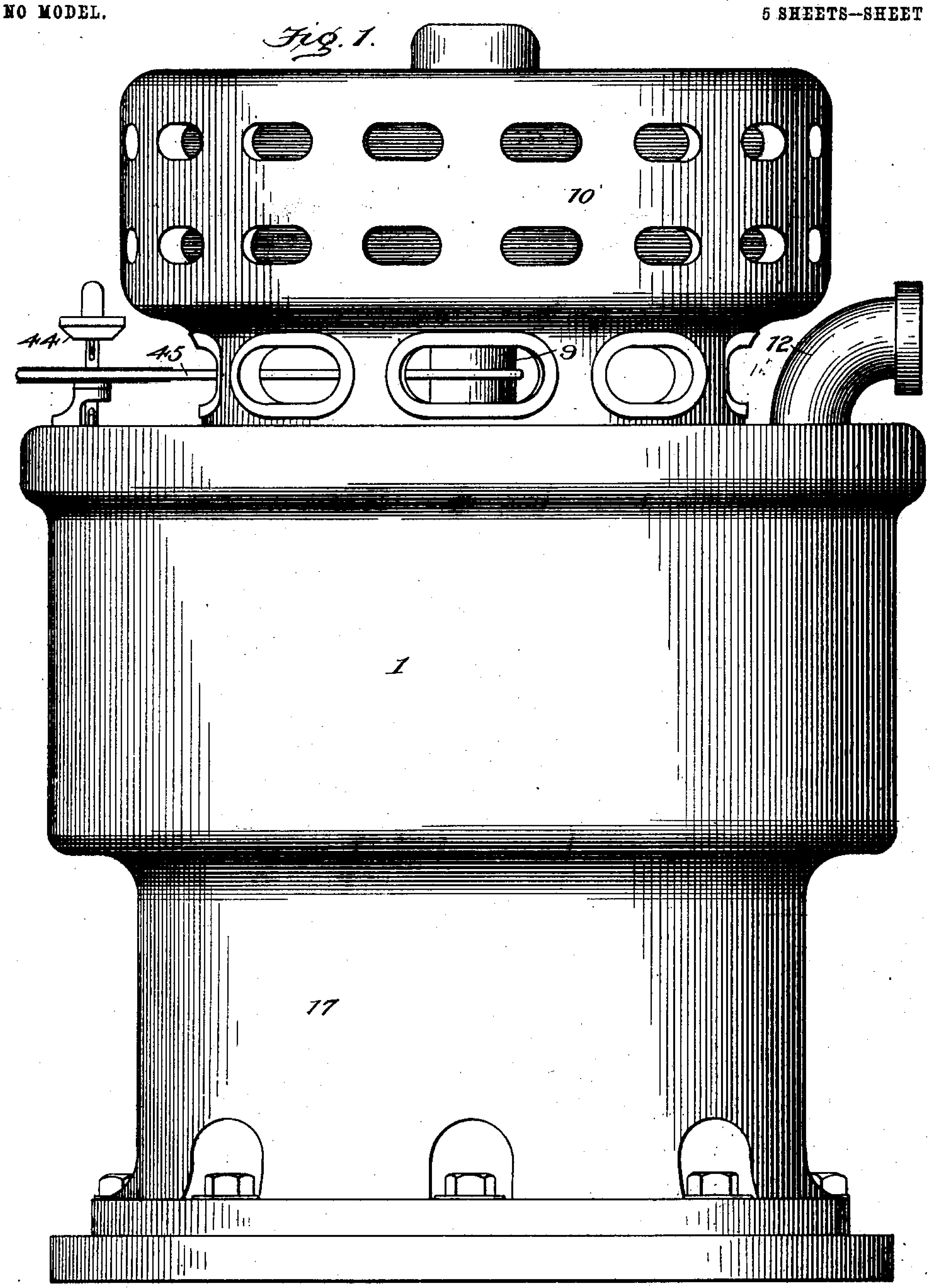
J. WILKINSON.

GOVERNING MECHANISM FOR TURBINES.

APPLICATION FILED NOV. 10, 1903.

NO MODEL. 5 SHEETS—SHEET 1.

Fig. 1.



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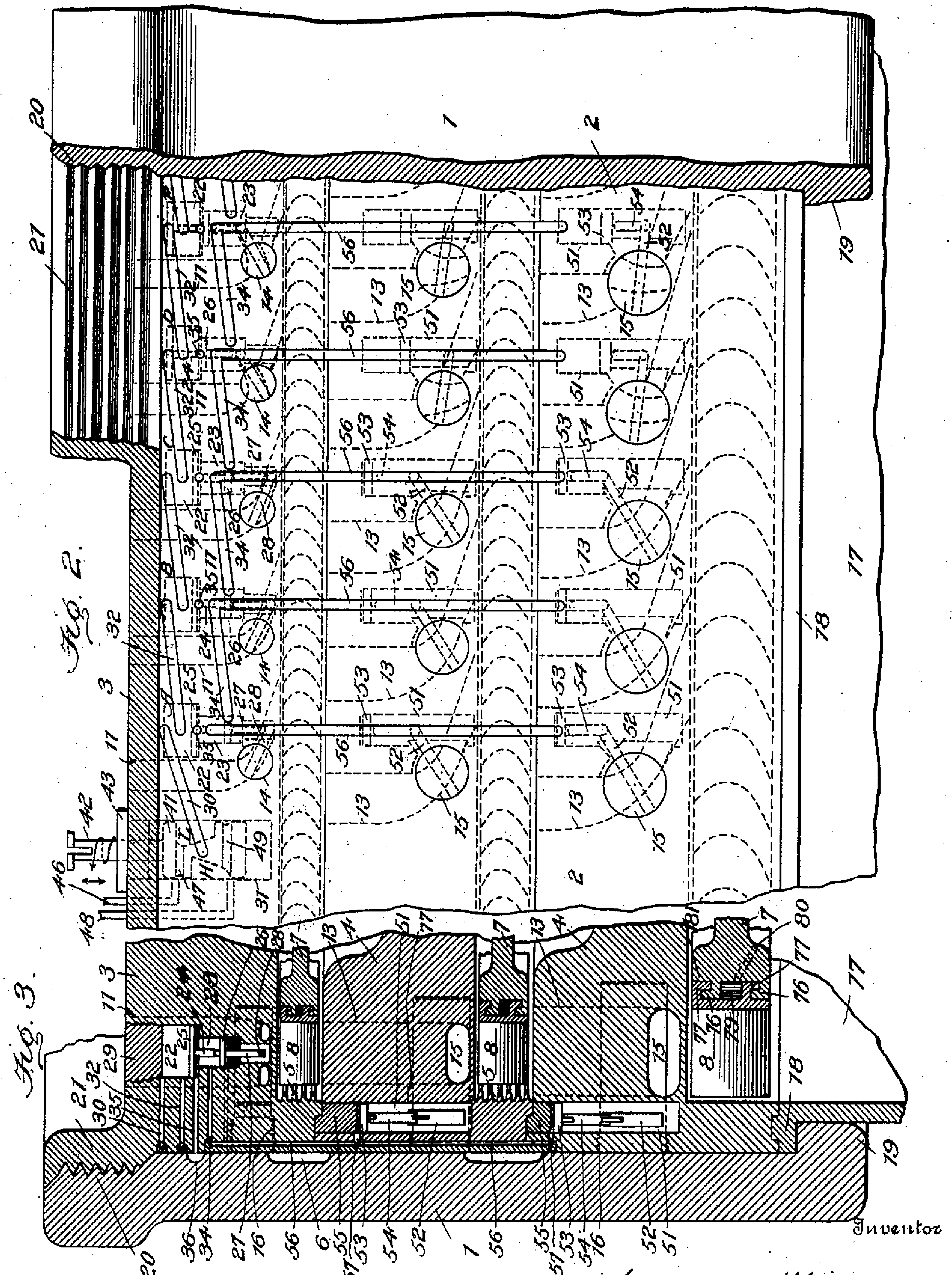

Fig. 2. Fig. 3.

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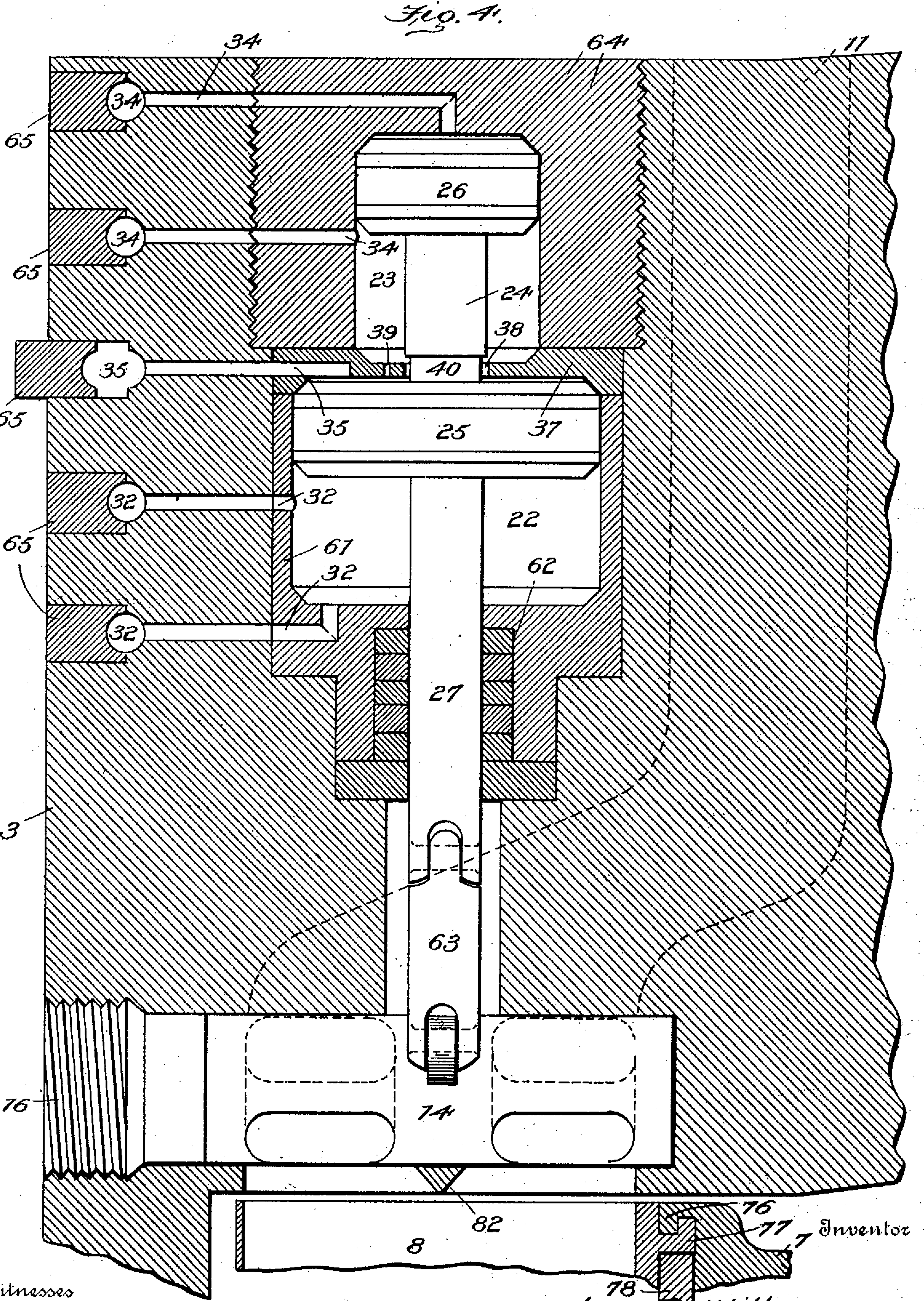
NO MODEL. 5 SHEETS—SHEET 3.

Fig. 4.



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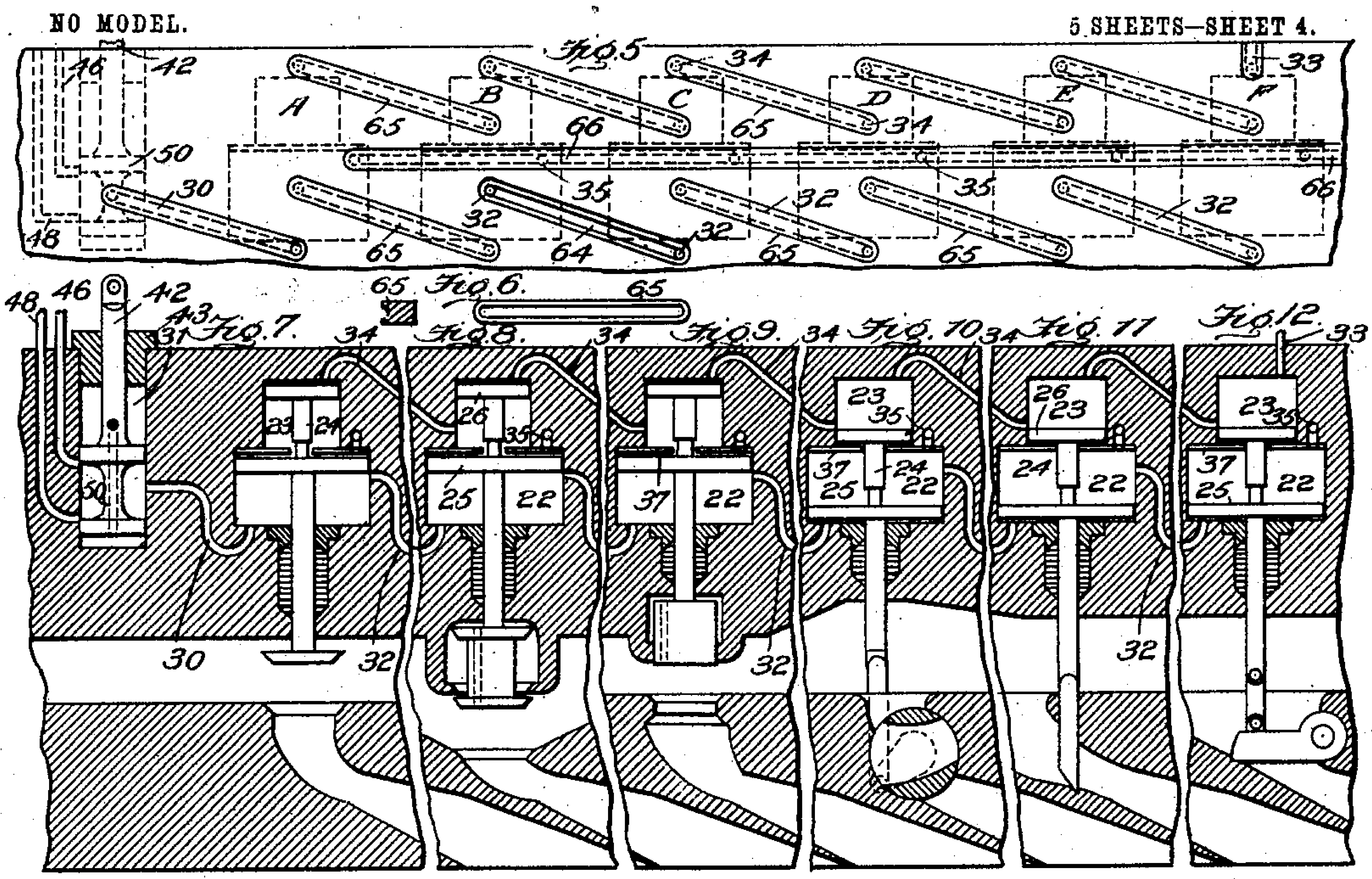

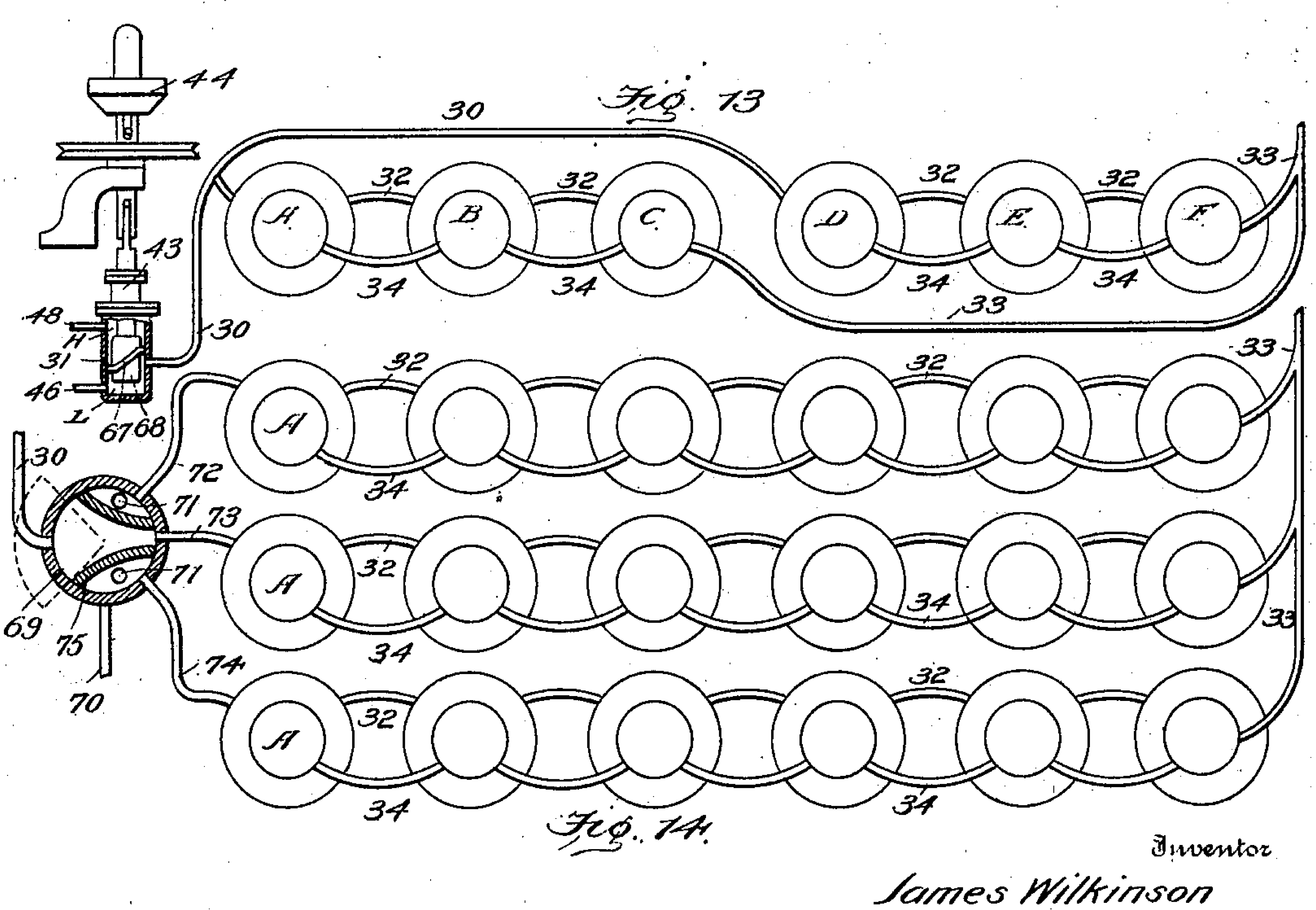

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NO MODEL. 5 SHEETS—SHEET 5.

Fig. 16.

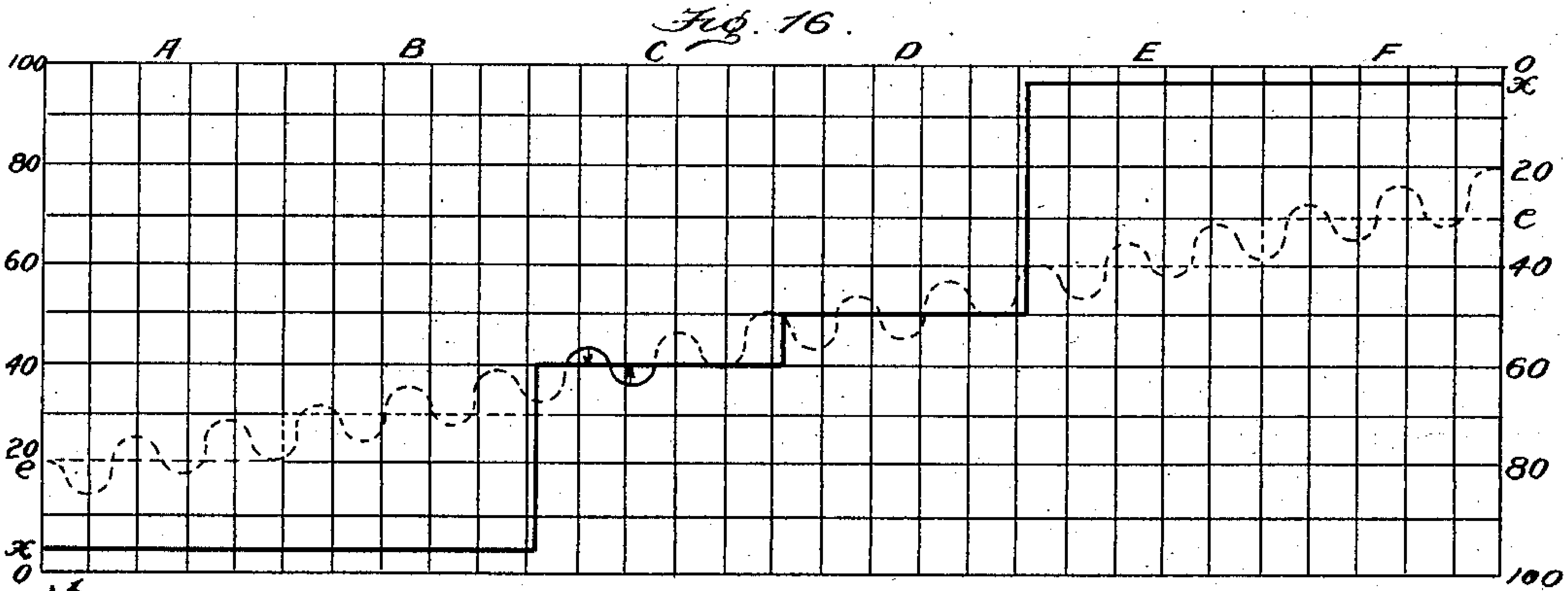


Fig. 15.

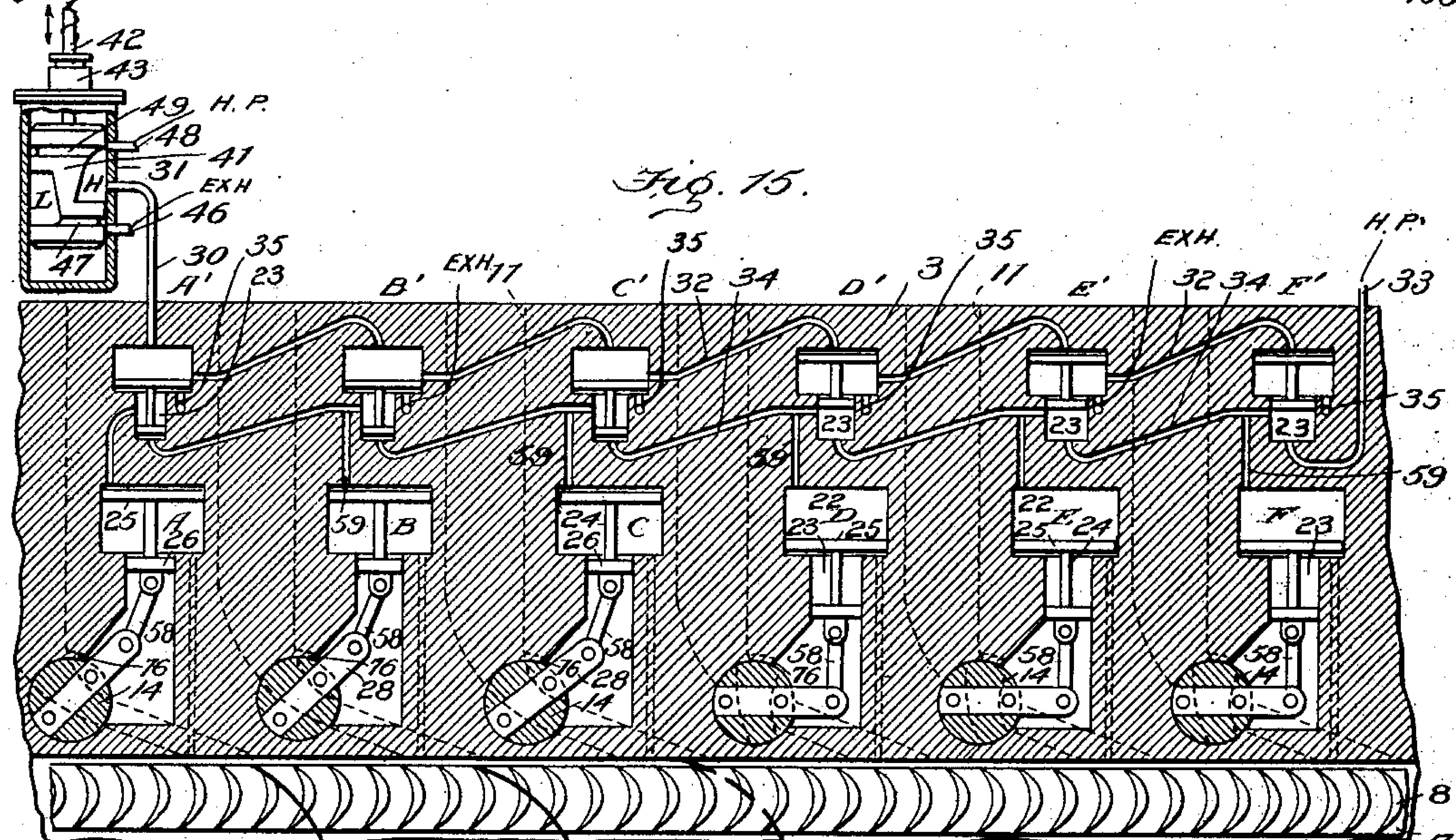


Fig. 17.

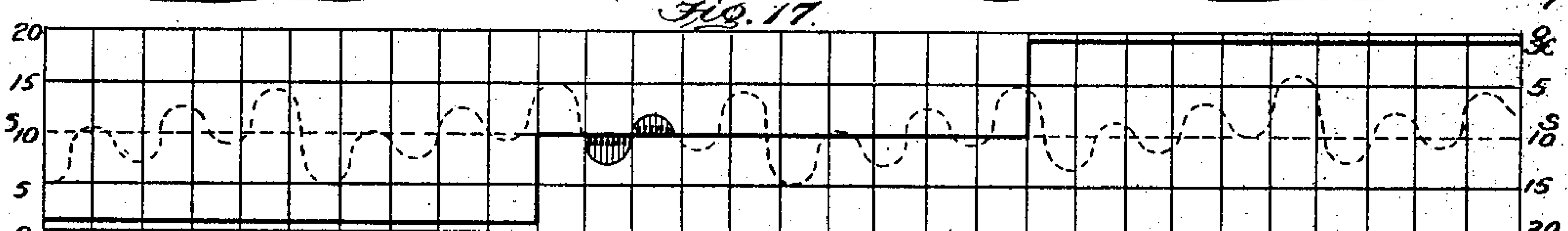
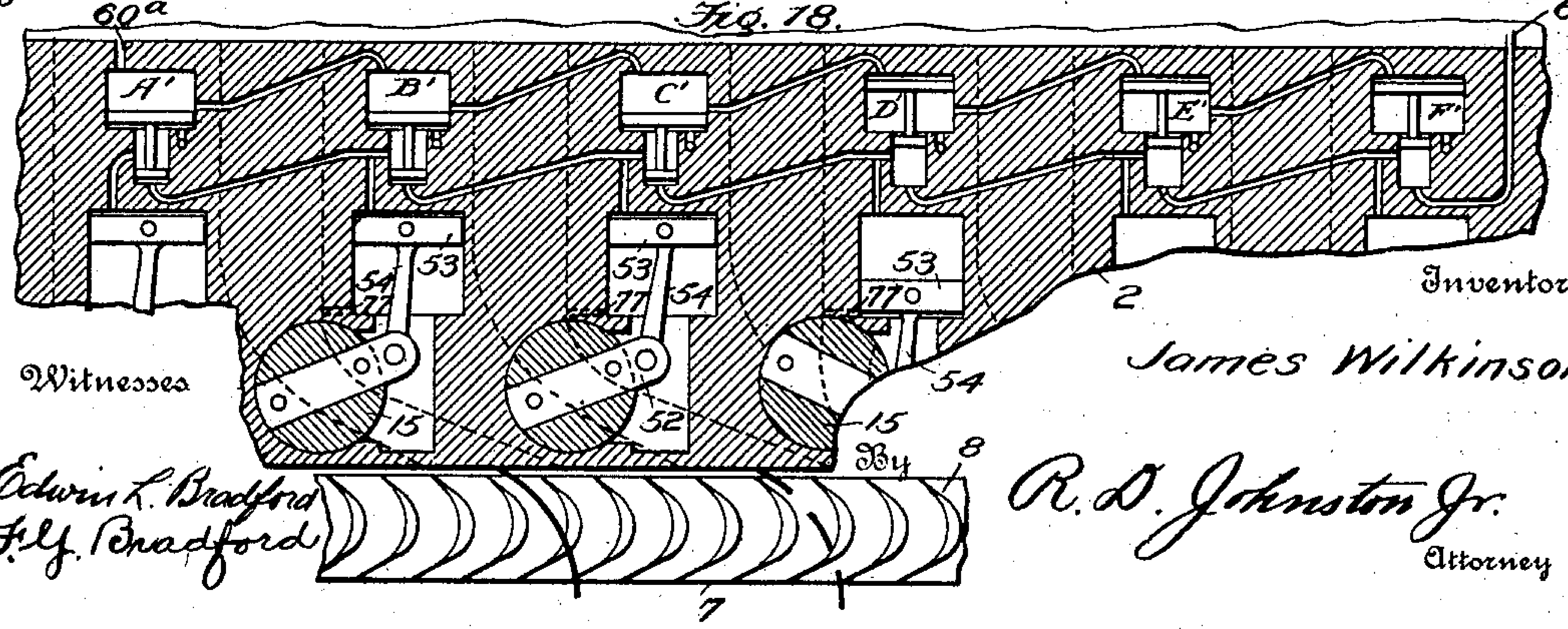


Fig. 18.



Witnesses

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No. 753,772. Patented March 1, 1904.

UNITED STATES PATENT OFFICE.

JAMES WILKINSON, OF BIRMINGHAM, ALABAMA, ASSIGNOR TO WILKINSON STEAM TURBINE COMPANY, A CORPORATION OF ALABAMA.

GOVERNING MECHANISM FOR TURBINES.

SPECIFICATION forming part of Letters Patent No. 753,772, dated March 1, 1904.

Application filed November 10, 1903. Serial No. 180,618. (No model.)

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 new and useful Improvements in Governing Mechanism for Turbines, of which the following is a specification.

This invention relates to improvements in mechanism for governing elastic-fluid turbines, and is particularly designed for use in connection with multiple-nozzle turbines wherein the flow of the fluid is controlled by independent valves disposed in the supply-head of a wheel-compartment and adapted to operate successively to vary the motor-fluid supply.

The object of this invention is to provide a governing mechanism capable of regulating the turbine by a series control of any desired number of valves, which are preferably actuated by the pistons of a row of compound cylinders whose high and low pressure ends are coupled up in series to each other and to a source of high pressure and to a governor-controlled pressure, respectively.

It is a further object to adapt my fluid-pressure-controller means to intermittently actuate the valve or valves nearest the critical point of regulation, so that they will pulsate a part of the motor-fluid supply, and with this object in view I provide means to pulsate the controller fluid and vary the mean potential of the fluid's pressure which controls the number of valves held constantly open or closed. I have shown this governing mechanism in connection with a multiple-stage turbine and adapted to control rows of valves across the several stages; but I do not restrict myself to this control across stages nor do I claim the same herein, as this forms the subject-matter of a separate application for Letters Patent which is now pending.

This invention further 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, in which—

Figure 1 is a side elevation of the turbine-casing, showing an electric generator mounted thereon and the governor device driven from the shaft. Fig. 2 is a similar view with part of the outer shell removed, showing the milled channels in the casing forming passages for the valve-controlling fluid in full lines and the internal governing mechanism in dotted lines. Fig. 3 is a partial vertical transverse section through Fig. 2, showing the supply and stage valves and their operating-pistons in a row across the stages and the connecting passage between the supply and stage cylinders, shown with the calking-strips, whose inner sides are channeled to form part of the fluid-passages, removed. Fig. 4 is an enlarged view of a supply-valve and its actuating mechanism and showing the manner of forming the passages for the valve controlling and actuating fluid. Fig. 5 shows a modification of a portion of the inner casing in which a continuous exhaust-passage connecting the several cylinders is formed in the same manner as the short connecting passages. Fig. 6 comprises detail views of a channeled calking-strip. Fig. 7 illustrates a modified form of controller device and turbine-valve. Figs. 8 to 12 illustrate further modifications of valves and seats therefor. Fig. 13 shows a row of valves coupled up in series parallel. Fig. 14 illustrates a valve directing the flow of the governor-controlled fluid to one of three parallel series of turbine-valves which may be used for turbines having a plurality of concentric rows of working passages. Fig. 15 is a broken-away section taken in a vertical plane through the supply-head of a compound turbine, the supply-valves being controlled in series by the governor device and the stage compartment broken away below the rotor-wheel. Fig. 16 is a diagrammatic chart of the governor's delivery of the valve-actuating pressure. Fig. 17 is a diagrammatic illustration of the action of the stage-pressure in controlling the stage-valves of Fig. 15. Fig. 18 is a view similar to Fig. 15, showing a number of stage-valves serially controlled by stage-pressure.

Similar reference characters refer to the same parts throughout the drawings.

The turbine comprises the outer shell 1, surrounding the casing proper, 2, formed by the interlocked circumferential flanges depending from the supply-head 3 and disposed around the shouldered peripheries of the diaphragm-partitions 4. The inner walls of these flanges are provided with radiating fins 5, which are heated by steam-jackets 6, formed between the shell 1 and casing 2 and surrounding the several wheel-compartments into which the interior of the turbine is divided by partitions 4 and within each of which a rotor-wheel 7, provided with a row of peripheral buckets 8, rotates. These wheels are keyed to the turbine-shaft 9, which is provided with suitable end bearings, and extends through head 3, having mounted thereon an electric generator 10. Fluid-pressure is supplied to a series of nozzle-passages 11 in the head 3 by a pipe 12, leading from any desired source and preferably entering a circular supply-passage (not shown) common to all the nozzles. Similar passages 13 are provided in the partitions 4 in line with passages 11 and buckets 8 to form continuous working passages in which the velocity of the fluid is fractionally abstracted. Circular radially-disposed openings around the head and partitions form seats for rotary supply-valves 14 and stage-valves 15, which are held in place by screw-plugs 16. The passages, valves, and buckets increase in area toward the exhaust end 17 of the turbine to accommodate the increasing volume of the fluid. The exhaust or condenser 17 forms a continuation of the turbine-casing 2, being provided at its upper end with a shoulder 18, which engages the lower shoulder 19 of the shell 1. The upper end of this shell is screw-threaded at 20 to enable the head 3, which has an externally-threaded outer flange 21, to engage the same.

The operating mechanism for the supply-valves 14 comprises pressure-controlled engines whose differential low and high pressure cylinders 22 and 23, respectively, are formed by circular chambers provided in head 3 between the passages 11. A compound piston 24, having low and high pressure heads 25 and 26, respectively, moves in these cylinders subject to a constant high pressure and a variable governed supply of relatively lower pressure. This piston has a stem 27, which extends downwardly through a passage leading from the center of cylinder 23, being suitably packed to prevent the escape of pressure around it. The valves 14 are double-ported and provided with crank-arms 28, secured thereto between the ports and pivotally connected to the lower ends of stems 27, the head being suitably recessed to provide for the opening and closing swing of the cranks. A screw-plug 29 closes the upper ends of cylinders 22. From the top of the first cylinder 22 of a series of differential cylinders (lettered A to E, Fig. 2) a passage 30 leads to the center of a governor-cylinder 31, and a second passage 32 leads from the side of said cylinder 22, above the low-pressure head 25 of piston 24 when lowered and below when raised, to the top of the succeeding low-pressure cylinder of the series. Passages similar to 32 connect the other cylinders 22 of the series together, so that were all the pistons 24 lowered the governor-controller power could pass from cylinder 31 through passages 30 and 32 to all cylinders 22 of the series, which may include all or any desired number of the cylinders in the head. Beginning with the end cylinder of the series a passage 33, Fig. 15, connects its high-pressure cylinder 23 with a constant source of high pressure, such as the boiler, and passages 34 connect the succeeding cylinders 23 in the same manner as passages 32 connect cylinders 22. Between the two heads of each piston 24, which are packed to move pressure-tight within their respective cylinders, I introduce atmospheric or condenser-exhaust pressure through a passage 35, which enters the upper end of the chambers 23 and communicates with a passage 36, common to all the cylinders and formed by an annular groove in the shell, open to the condenser through a passage. (Not shown.) A division-plate 37 (seen more clearly but in a reversed position in Figs. 4 and 7) separates the high and low pressure ends of the compound cylinders. This plate has a central opening 38, proportioned to make a close fit with the stem of piston 24 and has a small escapement-opening 39, Fig. 4. The stem of piston 24 is reduced at 40, so that when raised the atmospheric pressure can pass readily between the cylinders through both 38 and 39 for the purposes hereinafter explained.

Within the governor-chamber 31 I place a rotating longitudinally-shifting piston 41, whose stem 42 extends upwardly through the plug 43, closing the end of the chamber, and is engaged by a small governor 44, driven by a belt 45 from the turbine-shaft 9, which is secured to the head 3 near its periphery. This governor may be of any desired construction and of very small proportions, since it is only required to rotate piston 41 and move it longitudinally responsive to speed variations. This piston, Fig. 2, has inversely-disposed wedge-shaped recesses between its circular ends, forming a chamber L, always open to low or atmospheric pressure through a pipe 46 and a semicircular passage 47 around the piston, and a chamber H, similarly exposed to high or boiler pressure through pipe 48 and passage 49. The source of pressure for both pipes 33 and 48 may be the same; but on account of the differential character of the pistons 24 when the pressures are equal they will move to open valves 14. The high-pressure cylinders 23 increase in size from A throughout the series, so that each successive cylinder requires a relatively greater governed pressure to open the valve controlled thereby. This progressive increase of pressure may be taken at ten pounds, and its object is to insure the valves opening one at a time under a gradually-varying load.

To illustrate the controlling effect of the governor's throttling action upon the variable pressure in its simplest form, I will refer to the controller-piston 50 of Fig. 7 and will describe its effect in connection with the series of cylinders in Fig. 2, which I have been describing. The mean effective value of the governed pressure will be determined by the vertical position of the piston 50 relatively to the pipes 46 and 48, which are so spaced that the piston will have a wiredrawing effect as it moves over them, acting to expose one as it shuts off the other. This throttling action of the piston will produce an increasing or decreasing governed pressure, according as it is shifted by the governor sensitive to the load, which pressure will be admitted to passage 30 and the cylinders. This piston being moved by the governor will before the turbine is started be in its lowest position when the governor may be turned, so that pressure-pipe 48 will be entirely exposed and exhaust-pipe 46 shut off. This governed pressure will be superior in all the cylinders of the series and will move all the pistons 24 to open the supply-valves. As the speed of the turbine increases the piston will rise, throttling the supply and reducing the pressure in chambers 22 until in the last chamber of the series, as E, where the differential is least, it becomes inferior to the constant pressure in cylinder 23, and the piston therein moves upwardly to close its valve 14. There will be no pressure under the heads 26 in the preceding cylinders, for the constant pressure was cut off from the series as long as head 26 in E was below passage 34, and they will each be exposed through passages 34 to the atmospheric pressure existing between the piston-heads in the succeeding chambers. As the piston E moves up the constant pressure passing through 34 begins to act against the governed pressure in cylinder D. When the governed pressure decreases ten pounds and becomes inferior to the constant pressure in D, the piston will rise and the constant pressure will take effect in cylinder C, while head 25 will cut the governed pressure off from E and open the passage 32, leading thereto, to the atmosphere or exhaust-pressure in D. Carrying this action out, it will be seen that the two pressures will oppose each other in but two cylinders of the series which are nearest the critical point of regulation and comprise the piston that will rise next under an increasing load and the one that will move down next if the load falls. In all the cylinders preceding these two only the governed pressure will exist, which locks them down, and in all succeeding cylinders only the constant pressure, which locks them up. The value of the governed pressure determines which the potentially-active cylinders shall be, and as it rises or falls it sweeps the valves controlled by them successively open or closed, according to the load.

To control and operate the stage-valves subject to the governor 44, using the pistons 24 as relay-valves, I provide cylinders 51, boring them down through the diaphragms 4 near the outer ends of the valves 15, at which point said valves are provided with cranks 52, swinging in said cylinders and connected to pistons 53 by links 54. Plugs 55 close the tops of these cylinders. From the center of cylinder 23 of A and from each of the passages 34, leading to the centers of the succeeding cylinders 23, passages 56 lead down across the stages, communicating each with a row of stage-cylinders 51 through by-passages 57, which admit pressure above pistons 53. Pressure from the stages is admitted below the pistons 53 to raise them and open the valves 15 when passages 56 are open to the atmospheric pressure between the heads of pistons 24, which is the case when the pistons are held down to open supply-valves 14. As each supply-valve is closed its operating-piston moves up and admits the constant pressure to passage 34, and therefore to 56, through which it passes to close a series of stage-valves across the turbine and preferably in the line of the fluid's flow by moving pistons 53 down against the stage-pressure. In this manner by using pistons 24 as relay-valves to control the constant pressure, which acts as a stage-valve-closing power, it is evident that when the latter power closes a supply-valve it will simultaneously close a corresponding row of valves across the stages, and when a supply-valve is opened its piston 24 will move down, cutting pressure off from 56 and opening it to exhaust-pressure, so that a row of stage-valves will be opened by the stage-pressure beneath their pistons. In this manner the governor controls both the supply and stage valves and governs the volume of fluid admitted to and discharged from each wheel-compartment; but, as has been heretofore stated, this governor control across the stages illustrates an application of my invention which is not made the subject-matter of claims herein. To adapt this mechanism to pulsate a portion of the fluid-supply to the turbine to compensate variations in load intermediate stated points of regulation, (in this case ten pounds,) at which another valve will be opened or closed, I use the controller-piston 41, Figs. 2 and 15, formed with a pressure-chamber H and an exhaust-chamber L. As the piston rotates one or the other of these chambers will be in communication with passage 30 and will deliver thereto impulses of pressure, which will be communicated to the series of cylinder A, &c. It will be noted that this piston has the same throttling effect as 50, with this distinction, that it produces an increased exhaust to chamber L and a restricted supply to chamber H, or vice versa, according to the piston's movement.

These chambers maintain their respective pressures distinct, there being no direct communication between them. The throttling action of piston 41 governs the mean effective pressures of the impulses, upon the principle that any head of pressure may be maintained in a vessel or conduit by admitting thereto and exhausting therefrom calculated amounts of fluid-pressure. The supply of pressure into and out of passage 30 is determined principally by the relative areas of the exhaust and supply pipes exposed, and the magnitude of the rise and fall of the pressure is controlled by the rapidity of the piston's rotation—*i. e.*, if the piston rotates slowly, giving the passages 30 32 and cylinders 22 full time to raise their pressure to that of chamber H and of the exhaust in chamber L, a sine wave of pressure will be produced in said pipes equal in value to the full difference in pressures between chambers H and L. If the governor-piston be rotated more rapidly, time will not be given for the complete charging or exhausting of said passages, and a sine wave will be produced of less relative variation, so that under a rapid rotation the sine wave will represent but small pressure variations, while the mean effective value remains always dependent upon the endwise shifting of the piston 41. The mean effective value of the pulsatory supply of governed pressure determines, as in the case of a constant supply, which the potentially-active cylinders shall be, and acts to intermittently oscillate an intermediate active piston, while the pistons on either side will be alternately and intermittently exposed to both pressures, and therefore potentially active, as the piston moves up and down. But two of the three cylinders are potentially active at the same time, for the oscillating piston acts as a double-pressure relay-valve, which shuts one of the pressures off from one cylinder when both are admitted to the other cylinder. It is only by oscillating the piston for varying intervals that it is able to respond to intermediate variations in load between points of regulation; otherwise it would remain open or closed until there had been a rise or fall of full ten pounds in the governed pressure. In the latter case the real point of regulation will be between two valves, while with the pulsatory control one valve represents the critical point, and, by varying the duration of the impulses it delivers, all load variations calculated to effect a variation of less than ten pounds of the governed pressure will be compensated by it. The duration of the impulses is determined by the relative value of the sine wave of pressure to the equilibrium-pressure between the governed and constant sources. This is shown in the chart, Fig. 16, where the dotted wave-line represents the increasing mean effective value of the pulsations, rising from twenty to eighty pounds, while the relative distance of the waves, representing pulsations above and below the horizontal pressure-lines, determines their sine value, here about ten pounds. The chart is divided into sections A to F, corresponding with the cylinders of the same letters, so that as the mean effective value of the pulsations increases ten pounds the wave enters the succeeding section of the chart and the succeeding valve will be opened by the increase of pressure in cylinder 22, which action can be followed by the line *e e*. The horizontal pressure-lines when read from the left indicate the values of the governed pressures and when read from the right indicate the pressure values of the boiler-pressure. The line of equilibrium between these two pressures, as represented in cylinders C and D, is shown by the line *x x*, and the full-line wave represents the degree to which the pulsations effected by the action of piston 41 causes the pressure in cylinder 22 of D to rise above and then fall below that of cylinder 23. The horizontal distance between the points of intersection of the wave-line with the pressure indicates the time duration of the impulses and is determined by the relative value of the sine wave of pressure to the equilibrium-pressure line of the several valves. In this showing the pulsation of the valve will admit and cut off pressure to the turbine for equal portions of each revolution of the piston 41. Unless the load is full on or off one of these valves will always be oscillating to admit impulses of pressure to the first stage of uniform volume and velocity, but which vary in duration in accordance with the varying value of the sine waves delivered to its cylinder. The valves will be successively oscillated as the load rises or falls.

The value of having all the pistons but those potentially active locked against movement will be obvious in connection with this method of pulsating the governed supply of pressure. As cylinders are added to or cut off from the governor's control the length of the active passage and its capacity will vary. To compensate the effect of this upon the governor's action, the chambers H and L are wedge-shaped and inversely disposed, so that the shifting of the piston will have the effect of varying the relative of duration of exposure of passage 30 to the chamber-pressures.

If the stage-valves be connected up with the supply-cylinders in the manner hereinbefore described, this combined constant and pulsatory flow of the fluid will be effected throughout the whole turbine.

In Fig. 15 I utilize the constant pressure as a relay-power to actuate the pistons 24, whose high-pressure heads 26 are connected to the cranks of valves 14 by intermediate links 58. The admission of the controlling-pressure to the engine-cylinders is effected subject to the action of a series of differential relay-valves A′ to F′, which are connected to each other and to the governed, constant, and atmospheric sources of pressure in the same manner as the cylinders in Fig. 2. These relay-valves move in high and low pressure cylinders 22 and 23, respectively, and have heads 25 and 26, connected by stems 24, all as shown and described in connection with similar parts in Figs. 2 and 3, the only difference being that they act as valves merely because they are not operatively connected to the valves 14. The action of these relay-valves upon the supply-valves will be identical with the action of the supply-pistons when acting as relay-valves to control the operation of the stage-valves, for passages 59, corresponding to 56, lead from the center of the high-pressure chambers of the controller-cylinders to the upper ends of the engine-cylinders and alternately open the latter to the high constant pressure or to the atmosphere, subject to the action of the governor-controlled pressure upon their respective controller relay-valves. In the former figures the turbine-valves were directly operated by the governed pressure, whereas in this figure the use of a relay-actuated power makes this control indirect.

In Fig. 18 I illustrate an apparatus for automatically actuating the stage-valves subject to the control of stage-pressure. Here the construction and arrangement of parts are substantially the same as in Fig. 15, a high constant pressure being admitted by a pipe 60 to one end of a series of differential relay-valves A′ to F′, while the stage-pressure existing in the wheel-compartment above the diaphragm is admited at the other end of the series through passage 60^a as a substitute for the governed supply. The volume of the stage-pressure above the diaphragm 4 being sensitive to the action of the supply-valves controlled by the governed pressure, the stage-valves will be indirectly sensitive to the action of the governor. In the same manner a succeeding stage-pressure responds to the action of the preceding stage-valves. In this figure the controller-valves need not have their differential heads of increasing proportions throughout the series, as is the case in Fig. 15.

When pressure is admitted by the valves 7 to the first stage, which I shall treat as that disposed above diaphragm 4, it accumulates therein until it rises above the desired stage-pressure, when it will act upon the piston in cylinder A′ to move it down and open the stage-valve controlled thereby. If one valve will not carry off the excess of stage-pressure, it will continue to open up successive valves by rising superior to the high pressure in cylinders B′ C′, &c., and moving their pistons down until sufficient stage-valves are open to maintain the stage-pressure normal. The normal line of stage-pressure is represented by *s s* in Fig. 17 and the line of equilibrium-pressure by *x x*, as in Fig. 16. The full-line portion of the wave-line indicates a pulsation to correspond with that of the supply-valve which will be delivered by the stage-valve to a succeeding stage.

In Fig. 4 I illustrate a modified construction of the compound differential cylinder and piston 24. Here the low-pressure chamber 22 is formed by a shell 61, inserted in a chamber bored in the head, and is provided with a packing-chamber 62 for the stem 27 of the piston, which connects with the valve 14 by an intermediate link 63. A circular division-plate 37 is seated on shell 61 and acts to divide cylinder 22 from the high-pressure cylinder 23, formed by a chamber bored in the screw-plug 64, which closes the opening through which shell 61 was inserted. This plate is held in position by the plug and is formed with an escapement-opening 39 and a central opening 38, through which the stem of the piston 24 passes. The reduced portion 40 of this stem is shown disposed within this opening 38, and it will be noted that the chamber 23 below the head 26 will be in communication through 38 and 39 with the exhaust-pressure maintained above head 25 in cylinder 23 by passage 35. To better understand this figure, reference may be had to Fig. 9, which illustrates its relation with the other cylinders of the series. From this it will be seen the upper of passages 34, which are shown disposed on the same side of the cylinder, leads to the cylinder to the right and the lower passage to the cylinder to the left, and the same is true of passages 32. As the head 25 of piston 24 moves above upper passage 32 the flow of pressure thereinto would affect its rising movement if it were not compensated by holding the pressure which flows back from lower passage 34 when head 26 passes above it and opens it to the exhaust-pressure between said heads in cylinder 23 long enough to cause it to act beneath piston 26. The stem of the piston prevents the escape of this pressure except through 39 until it reaches nearly the end of its stroke, when 40 permits its free escape through 38 and 35 to the exhaust. In this showing the cylinder ends and piston-heads are beveled to insure a more positive action. This also illustrates the preferable manner of forming the passages—*i. e.*, by first drilling holes from the outside directly to the desired points in the several cylinders of the series and then milling a grooved channel in the outer wall of the casing between the two holes which it is desired to connect, in the manner shown in Fig. 5. In Fig. 4 these holes are drilled through the plug 64, plate 37, and shell 61. This grooved channel 64 is closed by a similarly-grooved calking-strip 65, which is brazed or welded in place and is further secured by the outer shell 1, which fits closely against the inner casing.

In Fig. 5 I form the continuous exhaust-passage 36 by a grooved channel and a circular grooved calking-strip 66.

In Figs. 7 to 12 I show a series of broken views of different kinds of supply or, if desired, stage valves, which the governed pressure lifts by being introduced in the lower ends of the cylinders 22, which are disposed below cylinders 23. In Fig. 7 I show a single-seat puppet-valve, in Fig. 8 a balanced puppet-valve, in Fig. 9 a piston-valve, in Fig. 10 my preferred form of rotating valve, in Fig. 11 a sliding gate-valve, and in Fig. 12 a swinging gate-valve, any of which may be used.

I have stated that the entire series of supply and stage valves may be controlled from one governor-cylinder; but they may be subdivided and controlled in series by two or more governor-cylinders coupled up to operate simultaneously.

In Fig. 13 is illustrated a method of arranging and controlling the valves of a row in series parallel. Here the passages 30 and 33 may continue around the casing, each having branches which lead to separate series of valves, as A B C and D E F, connected up in the usual manner. The advantage of this is to multiply the number of valves supplying fluid to the turbine when the corresponding cylinders of the several series are of the same differential. If the succeeding cylinders throughout the row progressively vary in differential, this method of piping will increase the accuracy of the governor's control through a long series by avoiding the necessity for the governed-pressure pulsations passing through any but a few intervening low-pressure chambers. Two pipes 30 could be led from chamber 31 in opposite directions around the row of cylinders to shorten the length of the passages, and, if desired, the governed pressure could be piped to the stage-valves to actuate them directly. In this figure the chambers H and L in the governor-cylinder 31 are formed by a continuous flange 67 in the form of a conical helix around piston 68.

In Fig. 14 I show method of controlling a turbine having three series of concentric fluid-passages and independent serially-connected rows of cylinders controlling the valves in the several passages. I lead the governed pressure in passage 30 to a valve-chamber 69, open to the atmospheric pressure in pipe 70 through ports 71, and having passages 72, 73, and 74, leading, respectively, to the outer, intermediate, and inner rows of cylinders A, &c. A valve 75 in chamber 69 is adapted to direct the governed pressure to but one of the rows at a time, while the other two passages will be opened to the exhaust-pressure in pipe 70 through one or both ports 71. The constant pressure in pipe 33 branches to each row and acts to close all the valves of the rows which are exposed to the exhaust-pressure and to oppose the governed pressure in the other row. This construction is particularly adapted for marine turbines which will be capable of operating to drive forward or reverse and also to maintain a cruising speed, and constitutes the subject-matter of a separate pending application.

In Fig. 3 I show the rims of the rotor-wheels 7 provided with two similarly-disposed undercut annular shoulders 76 in the same circumferential plane, and the base-blocks of the buckets 8 have reversely-disposed similarly-undercut shoulders 77, which when inserted between shoulders 76 may be moved sidewise to lock with said latter shoulders. To secure the buckets in place, I may insert locking strips or blocks 78, Fig. 4, or I may effect a tighter joint by filling the cavity with molten type-metal 79, Fig. 3, through a passage 80, provided therefor through the rim. It is only necessary to use this passage for locking the last bucket in, for the metal may be simply poured into the cavity from above as the buckets are assembled. To further strengthen this connection, I may braze or weld the base-block to the rim at 81 or may provide the latter with a calking-lip and force it against the base-block to lock it against sidewise movement.

Beneath the center of supply-valves 14 I use a transverse wedge-shaped center support 82, (shown only in Fig. 4,) which continues to the delivery end of said nozzle, serving as a partition to divide the nozzle and form two passage-ways, with which the two ports of the valve 14 are in alinement. In this figure it will be noted that bevel valve-seats 83 and 84 are provided at each end of the cylinders 22 and 23, respectively. The piston-heads 25 and 26 have bevel portions 85 and 86 on each side, which seat pressure-tight against the bevel-seats 83 and 84. By this arrangement the possibility of leakage of pressure around the piston is avoided in the simplest manner, and the use of packing is to a large extent dispensed with. By this construction when the piston is moved from its seat the increased area exposed to the pressure will cause it to move a full stroke.

The modification and adaptations of which the principles hereinbefore disclosed are capable are too numerous to be further specified; but it is to be understood that I do not here limit myself to any particular construction or arrangements of parts, but desire to cover any means for effecting a series as contradistinguished from a parallel control of the turbine-valves.

If the stage expansion of the elastic-fluid pressure be effected in separate casings, they may be connected up in the same manner as in Fig. 2, or a branch pipe 30 may lead to each stage series of valve-actuating cylinders. This series control of valves is equally applicable to a row of valves supplying pressure to the initial or to a subsequent stage or wheel compartment, and when a separate controller means is used for each row of valves for a stage their action will give the same control for the valves of the several rows. I do not, therefore, desire to limit myself herein to the series control of the supply-valves for any particular stage or wheel compartment of a turbine operating to fractionally convert the pressure of the motor fluid into velocity.

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

1. In a motor, a governing mechanism comprising a plurality of valves coupled in series, and a governor-controlled power means of varying potential for serially controlling said valves.

2. In a motor, a governing mechanism, a plurality of valves, means to serially transmit an actuating power of varying potential to said valves, and means to vary said power.

3. In a governing mechanism for motors, a plurality of valves, means to serially transmit an actuating power from one valve to another, and means to vary the effective extent of said power through the series.

4. In a governing mechanism for motors, a plurality of valves, a governed actuating power, means serially transmitting said power from one valve to another, and means to vary the effective extent in said series of said power in accordance with its potential.

5. In a governing mechanism for motors, a plurality of valves coupled up in series, means to deliver a varying actuating power to a varying number of said valves, and means to vary the actuating power.

6. In a governing mechanism for motors, a plurality of pressure-controlled valves, passages serially connecting said valves and constituting a portion of a pressure-controlling passage, the extent of which is varied by the valves under its control.

7. In a governing mechanism for motors, a plurality of valves, motors to operate said valves which are coupled up in series, and means transmitting a governed actuating power to the initial motor of the series from which it passes to one or more of the other motors of said series to successively operate them.

8. In a governing mechanism for motors, a plurality of motor-fluid valves, cylinders, piston-valves therein, controlling means to operate said motor-fluid valves, means to admit a governor-controlled pressure to said cylinders to move said pistons, and means to hold said pistons against movement whose relative value varies between the several cylinders.

9. In a governing mechanism for motors, a plurality of valves, a plurality of motors connected to said valves, and a governor controlling the admission of an actuating pressure of varying potential to said motors.

10. In a governing mechanism for motors, a valve interrupting the flow of fluid-pressure through a nozzle, a governor controlling the intermittent delivery of an actuating power to said valve and varying the potential of the power in accordance with the load.

11. In a governing mechanism for motors, a plurality of valves, means to transmit an actuating power to said valves, means to hold said valves against movement by said power which vary relatively in strength, and a governor to vary the potential of the actuating power.

12. In a governing mechanism for motors, a plurality of valves, means to operate said valves, means transmitting a governed motive power serially from one to the other of said operating means, and means to serially counteract said governed power in a reverse direction as it varies in potential.

13. In a governing mechanism for motors, a plurality of valves, fluid-pressure-operating means for said valves, means to serially transmit a governed and an opposing constant pressure to a part of said operating means, which are operated by relatively different variations in the potential of the governed pressure.

14. In a governing mechanism for motors, a plurality of valves, a controlling-cylinder and an actuating-piston for each valve, said cylinders being serially coupled up to each other, means introducing a governed and an opposing constant pressure to opposite ends of said series, and intercepting said pressures in the line of their flow beyond the cylinder or cylinders wherein the said pressures most nearly counterbalance each other.

15. In a governing mechanism for motors, a plurality of valves coupled up in series, and means to deliver actuating fluid in pulsatory blasts of varying value to part of said valves, while the rest are held open or closed.

16. In a governing mechanism for motors, a plurality of valves, means to operate said valves coupled up in series, and a governing means delivering a pulsatory actuating power of varying mean value to part of said valve-operating means, while the rest are maintained open or closed according to said mean value.

17. In a governing mechanism for motors, an engine controlling a row of valves which control the flow of fluid-pressure through nozzles, said engine comprising a cylinder whose ends are exposed to a governed variable and a constant pressure, a piston movable between said pressures and recessed to form between its ends a low-pressure chamber continually open to an exhaust-pressure, a connection from said piston to a valve and a conduit from said cylinder leading to said other valves and conducting pressure thereto to operate them when said piston assumes a determined position.

18. In a turbine, a nozzle-passage divided by a partition, and a multiported rotary valve disposed in said nozzle and acting to interrupt the flow of fluid therethrough.

19. In a turbine, a divided nozzle-passage,

a rotary valve seated in the nozzle-bearing portion and having a port in line with each of the passages formed as divisions of said nozzle, and acting to open or close them to the motor fluid.

20. In an elastic-fluid turbine, a motor-fluid passage, a multiported rotary valve therefor, and means to operate said valve connected thereto between two of its ports.

21. In a turbine, motor-fluid passages and valves, and fluid-pressure motors to actuate said valves having cylinders formed by chambers in a stationary portion of the turbine, and plugs closing said chambers and forming heads for said cylinders.

22. In a turbine, a fluid-pressure motor to actuate a turbine-valve comprising a cylinder formed as a chamber in the supply-head to a wheel-compartment, and a detachable head for said cylinder which is screwed into an end of said chamber.

23. In a turbine, a nozzle-passage, a fluid-actuated valve therefor, and governing means for said valve comprising a chamber communicating with a high pressure and an exhaust, a movable piston therein which throttles the pressure and exhaust openings to create therein a pressure of varying value, and means to conduct this pressure to actuate said valve.

24. In a turbine, a nozzle, a valve therefor, and a motor to actuate said valve comprising a compound cylinder, a compound piston whose heads are connected by a stem, passages admitting a governed pressure to one end of said cylinder, a substantially constant pressure to the other end, and an exhaust-pressure near the center and between said piston-heads.

25. In a governing mechanism for motors, a plurality of supply-valves serially connected up, a controller means, and a single connection between said series and said controller means.

26. In a governing mechanism for motors, a plurality of fluid-pressure-actuated supply-valves, passages leading from valve to valve to serially connect them, a source of actuating fluid-pressure, a passage leading from said source of pressure to the initial valve of said series.

27. In a turbine, a plurality of motor-fluid valves, pressure-controlled actuating means therefor, and passages to conduct the actuating pressure from one valve to another, formed in the turbine-casing.

28. In a turbine, fluid-actuated supply-valves, and passages to conduct the actuating fluid from one valve to another which leads through the turbine-casing.

29. In a turbine, fluid-actuated supply-valves, and passages to conduct the actuating fluid from one valve to another which are disposed inside of the outer casing.

30. In a turbine, fluid-pressure-controlled means to actuate motor-fluid valves, and fluid-conducting passages formed by channels in the turbine-casing and means closing said channels while leaving an inner passage-way for the fluid.

31. In a turbine, two or more fluid-actuated valves seated in a valve-bearing portion, openings leading through the casing to conduct actuating fluid to said valves, a channel in said casing between said openings, and filler-strips to close said channel and leave an inner passage-way connecting said openings.

32. In a turbine, a plurality of fluid-actuated valves, and means to conduct an actuating pressure to said valves comprising a series of holes drilled through the casing to said valves, and a channel in said casing connecting said holes and a calking-strip for said channel leaving a closed way connecting said several openings.

33. In a turbine, a plurality of valve motor-cylinders disposed in a compartment-head portion, openings leading through the casing to said cylinders, a channel connecting the outer ends of said openings, and locking-strips closing the open side of said channel and forming with the inner side thereof a passage-way common to said openings.

34. In a turbine, a series of valve-actuating motors, each of which comprises a constant and a variable pressure cylinder, a division-wall between said cylinders, a piston-head within each cylinder connected by a stem having a reduced portion near one head and passing through an opening in said wall, an exhausting-passage opening into the cylinder near whose piston-head said stem is reduced, and passages leading from the sides and ends of said cylinders to adjacent cylinders.

35. In a turbine, a series of moters for actuating motor-fluid valves comprising compound cylinders, compound pistons whose heads are connected by stems having reduced portions, and suitably-apertured division-walls between the ends of each compound cylinder.

36. In a turbine, a nozzle, a valve therefor, a fluid-pressure motor seated in said nozzle-bearing portion and having its cylinder formed by a casing inserted in said portion, and a stem for operating said valves leading through the inner end of said casing.

37. In a turbine, a plurality of motor-fluid valves, motors for actuating said valves each comprising constant and variable pressure cylinders and a compound piston having heads movable in said cylinders and operatively connected to said valve, a pressure-supply passage entering the ends of said cylinders and pressure-conducting passages leading from the sides of said cylinders, and an exhaust-passage opening into both said chambers between said piston-heads.

38. In a turbine, a motor for operating a

turbine-valve, a compound piston having heads moving in two cylinders, said heads being connected by a stem having a reduced portion, said stem passing through an opening in a division-wall, and acting as a valve to close said opening.

39. In a turbine, nozzle-passages, rotary valves therefor, and reciprocating motors operating said rotary valves.

40. In a turbine, nozzle-passages, rotary valves therefor, and a reciprocating motor actuating one or more of said valves, and controlling pressure to actuate said other valves.

41. In a turbine, a plurality of pressure-actuated valves, and a governor therefor comprising a cylinder to which a high and low pressure is admitted, and means movable within said cylinder and acting to create a third variable pressure, out of said first-mentioned pressures, which controls the action of said valves.

42. In a turbine, a motor for operating a turbine-valve, a compound piston having heads moving in two cylinders, an apertured partition between said cylinders, means between said piston-heads which are adapted to act as a valve to open or close an aperture in said partition.

43. In a motor, a governing mechanism comprising a controller power means, a plurality of valves, adapted to be independently actuated by said power means, which are serially coupled up and have a common connection with said power means by which they are successively actuated.

44. In a governing mechanism for motors, a plurality of fluid-actuated valves, separate fluid-conducting passages leading from valve to valve which passages are successively opened to the actuating fluid by the movement of the valves from which they severally lead.

45. In a governing mechanism for motors, a plurality of valves, a plurality of fluid-pressure motors actuating said valves, passages leading from one motor to another which are successively opened to the actuating fluid, delivered to the initial motor of a series, by the movement of the motors which precede said passages in the line of the fluid's flow.

46. In a governing mechanism for turbines, a plurality of independent fluid-actuated turbine-valves, a source of governed valve-controlling fluid, and a passage conducting said fluid to a plurality of independently-acting valves.

47. In a governing mechanism for turbines, fluid-pressure motors, fluid-conduits leading from one to another of said motors, motor-fluid-supply valves, and piston-valves in said motors connected to said valves and controlling the admission of pressure to said conduits.

48. In a governing mechanism for turbines, a plurality of valve-actuating motors comprising cylinders, passages leading therefrom to a governed source of fluid-pressure, to an exhaust-pressure, and to one or more adjacent motors, and piston-valves in said cylinders acting to expose the passages leading to adjacent motors to either the governed or exhaust pressures.

49. In a governing mechanism for motors, a plurality of valve-actuating pistons exposed to a constant power and to a governed-pressure means of varying potential, the proportions of said pistons being relatively varied to cause them to operate successively as the potential of said governed-pressure means varies.

50. In a governing mechanism for motors, a plurality of valves, a plurality of differential valve-actuating pistons exposed to a constant and a variable governed pressure, and each of said pistons being designed to move responsive to a predetermined differential between said pressures.

51. In a governing mechanism for motors, a plurality of valves, a plurality of valve-actuating pistons of relatively varying proportions which are exposed to a substantially constant power, and means serially transmitting a power of varying potential to one or more of said pistons.

52. In a motor, a plurality of fluid-pressure-actuated valves, and means to control the pressure of the valve-actuating fluid, comprising a cylinder, fluid inlet and outlet passages, and a governor-actuated throttling-piston which varies the potential of said actuating fluid.

53. In a motor, a plurality of fluid-pressure-actuated valves, and a controller means therefor comprising a cylinder, fluid-conduits leading from said cylinder to a high and exhaust pressure, and a rotating cut-away piston therein, which intermittently delivers to a passage the valve-actuating fluid.

54. In a motor, a fluid-pressure-actuated valve, a cylinder exposed to a high and an exhaust pressure, a rotating governor-shifted controller device therein, which forms with the side of said cylinder two separate rotating chambers each of which is in exclusive communication with one of said pressures, and a passage for the valve-actuating fluid which is alternately exposed to the chamber-pressures.

55. In a motor, fluid-pressure-actuated valves, and a controller means for the valve-actuating fluid, comprising a cylinder, a rotating piston therein cut away to form with the sides of said cylinder two reversely-disposed wedge-shaped chambers, means to maintain in one chamber fluid under a varying high pressure and in the other an exhaust-pressure, and a passage for the valve-actuating fluid, which is alternately exposed to said chambers.

56. In a turbine, a valve-actuating motor

comprising a cylinder formed with a beveled valve-seat at one end, and a piston-valve movable therein and beveled to seat pressure-tight against said seat.

57. In a turbine, a valve-actuating motor comprising a cylinder having side and end ports, and provided with beveled seats at each end, and a piston acting as a valve and having beveled ends engaging said seats.

58. In a turbine, a valve-actuating motor comprising two cylinders, a plurality of ports therein, a compound piston acting as a valve and having a head in each cylinder, beveled valve-seats at each end of said cylinders and beveled portions of said heads adapted to engage said seats.

59. In a governing mechanism for motors, a plurality of valves, passages to serially conduct actuating fluid from valve to valve, means to lock part of said valves at one end of their stroke, while the valve or valves at the critical point of regulation are left free to move subject to the control of said actuating fluid.

60. In a governing mechanism for motors, a plurality of valve-actuating means, means transmitting a governed fluid-pressure serially from one to the other of said actuating means, means to serially transmit an opposing pressure from one to the other of said actuating means and in a reverse direction to said governed fluid-pressure, and means to lock all but the valve or valves nearest the crititical point of regulation in a definite position by cutting one or the other of said opposing pressures off from their actuating means.

61. In a turbine a plurality of motor-fluid stage-valves, motors for actuating said valves seated in chambers formed in the valve-bearing portion.

62. In an elastic-fluid turbine, an induction-nozzle, a fluid-actuated rotary valve therefor, a passage for the valve-actuating fluid, and governed means to control the fluid to actuate said valve.

63. In an elastic-fluid turbine, an induction-nozzle, a rotary fluid-actuated valve therefor, and governor-controlled means to actuate the valve without stationary intermediate operating positions.

64. In a turbine, a supply-passage, a rotary fluid-actuated supply-valve therefor seated in that portion of the turbine in which said passage is disposed, and passages conducting actuating fluid through said portion to move said valve under control of a governor device.

65. In a turbine, a supply end portion through which induction-nozzles pass, valves for said nozzles having actuating-stems disposed within chambers formed in said end portion, and means to operate said stems.

66. In a turbine, a supply end portion through which induction-nozzles pass, rotary valves for said nozzles seated in said end portion, chambers within which actuating means for said valves extend, and passages to admit fluid-pressure to operate said means.

67. In a turbine, a plurality of motor-fluid valves, and motors for actuating said valves seated in chambers formed in the valve-bearing portion.

68. In an elastic-fluid turbine having nozzle-passages and valves therefor, a governing mechanism comprising a governor, means for operating said valves, and a controller device moved by said governor, which actuates part of said valve-operating means intermittently according to slight variations in the load.

69. In an elastic-fluid turbine, a plurality of induction-nozzles, means to open and close said nozzles, and a regulating mechanism maintaining a continuous control over all said means and intermittently actuating a part of them.

70. In an elastic-fluid turbine, a plurality of induction-nozzles, means to open and close said nozzles, a rotating controller device constructed to intermittently operate a part of said means during portions of its cycles of action, and means to rotate said device and adjust it and said nozzle-opening means relatively to each other.

71. In a governing mechanism for turbines, a plurality of valve-controlled fluid-admission passages, valve-operating means, and a governing device for controlling said means which moves in accordance with variations in the load and intermittently operates a part of said means while maintaining the rest passively under control.

72. In an elastic-fluid turbine, a governor or regulating mechanism adapted to admit contemporaneously constant and pulsatory blasts of elastic fluid, which are proportioned to the load and used to develop mechanical power.

73. In an elastic-fluid turbine, a governing mechanism for controlling the admission of fluid-pressure to a plurality of nozzles comprising means for admitting a constant supply of fluid according to the load and a pulsatory supply varying in proportion to slight variations in the load.

74. In an elastic-fluid turbine, a governing mechanism for controlling the admission of fluid-pressure to a plurality of nozzles, comprising means for admitting blasts uniform in volume to said nozzles and means to maintain a part of them open according to the load and part pulsatory according to slight variations in the load.

75. In an elastic-fluid turbine, a plurality of nozzle-passages, valves controlling the admission of pressure thereto, and a governing mechanism which oscillates a part of said valves to admit pulsations of fluid-pressure which vary in duration with variations in speed, while it maintains the rest of said passages open or closed according to the load.

76. In an elastic-fluid turbine, a plurality of nozzles, a valve for each nozzle, and means

controlled sensitive to the speed of the turbine, for progressively oscillating a part of said valves while it leaves the rest open or closed according to the load.

77. In an elastic-fluid turbine, a plurality of induction-nozzles, valves for said nozzles, and speed-governing mechanism for sweeping said valves open or closed as the load is thrown on or off, and for oscillating a part of said valves during a constant or slowly-changing load.

78. In a governing mechanism for turbines, a plurality of fluid-actuated supply-valves, and a fluid-pressure-controlling means for said valves to deliver a varying volume of motor fluid to the turbine under varying loads and to pulsate part of said supply to compensate slight variations in the load.

79. In a turbine, a plurality of fluid-supply passages, and a fluid-pressure-governing means to regulate the flow of fluid through said passages, pulsating it in a part of said passages to compensate slight variations in load.

80. In a governing mechanism for motors, a plurality of nozzle-passages, valves therefor, and fluid-pressure means to intermittently actuate part of said valves to pulsate the fluid-pressure delivered by them to the motor, while the other valves are held open or closed.

81. In a turbine, a plurality of motor-fluid-supply passages and valves therefor, in combination with a fluid-pressure-governing mechanism for said valves which intermittently opens one or more of said valves for periods of varying duration, while the rest of said valves are held open or closed.

82. In a governing mechanism for turbines, a plurality of supply-valves, a governor-controlled power means for operating one of said valves, and means under the control of said valve to transmit said operating power to one or more of the other of said valves.

83. In a governing mechanism for turbines, a plurality of independent fluid-actuated supply-valves, and a fluid-pressure-controlling means, for successively operating said valves, adapted to expose but two of them at a time to opposing actuating pressures.

84. In a governing mechanism for motors, a plurality of valves, passages to serially conduct actuating fluid from valve to valve, means to control the successive actuation of said valves and to lock all but the valve nearest the critical point of regulation against movement.

85. In a governing mechanism for motors, a plurality of valves which are opened or closed by fluid-pressure, and a fluid-pressure-governing means to control the successive actuation of said valves and to lock all but the valves nearest the critical point of regulation against movement.

86. In a governing mechanism for turbines, a series of supply-valves, and a fluid-pressure-controlling means for said valves which exposes a part only of said valves to two actuating pressures at a time, the rest of said valves being exposed to one or the other of said actuating pressures according to their position in the series relative to the valves exposed to both pressures.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

JAMES WILKINSON.

Witnesses:
J. J. D. HALL,
H. M. HARTON.