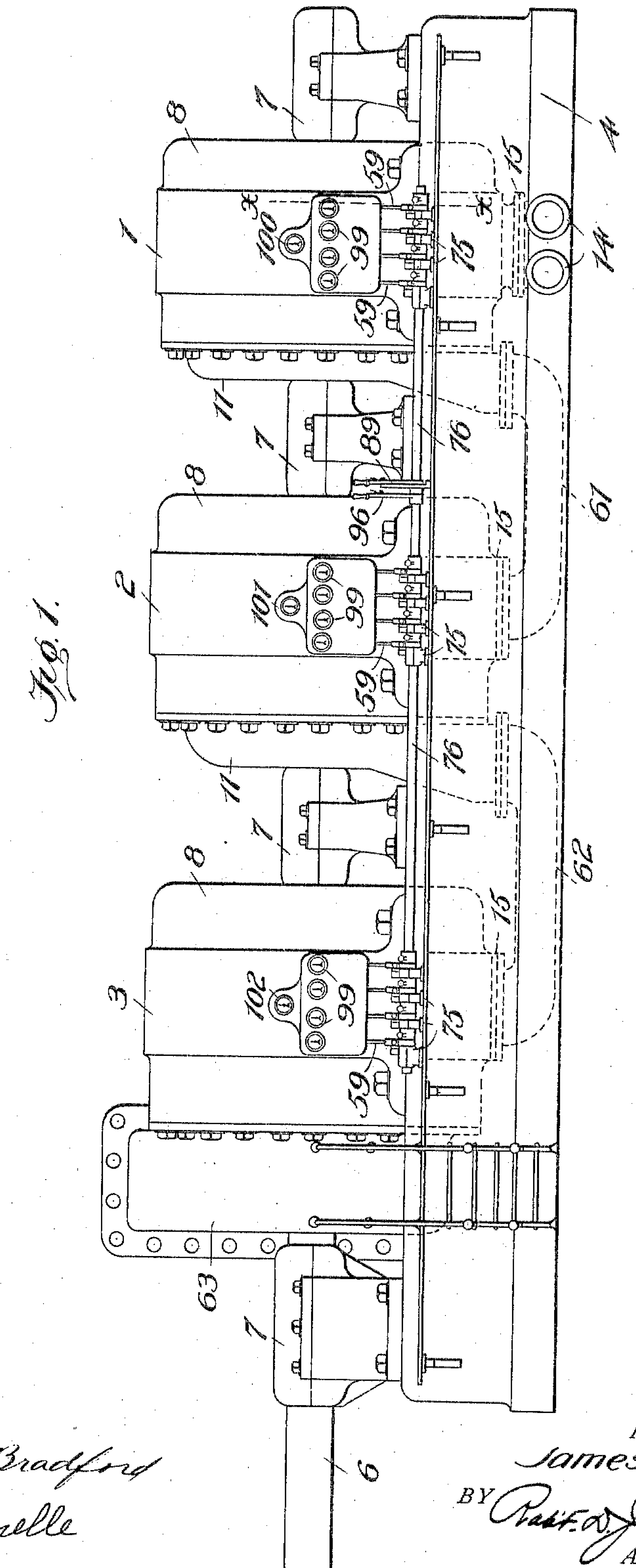
No. 766,922. PATENTED AUG. 9, 1904.

J. WILKINSON.

MARINE TURBINE.

APPLICATION FILED APR. 20, 1904.

NO MODEL. 6 SHEETS—SHEET 1.



WITNESSES:

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NO MODEL. 6 SHEETS—SHEET 2.

Fig. 2.

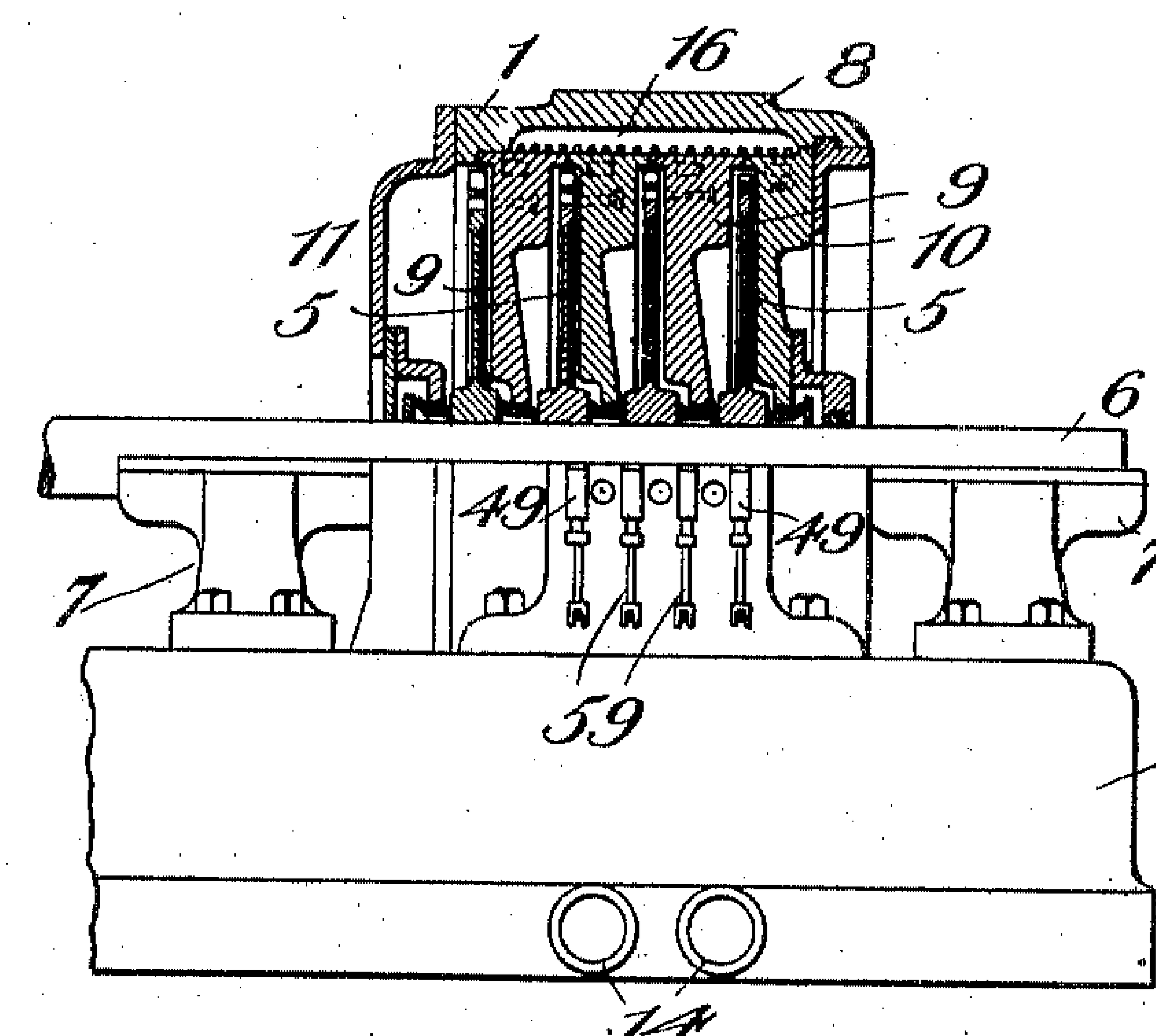


Fig. 4.

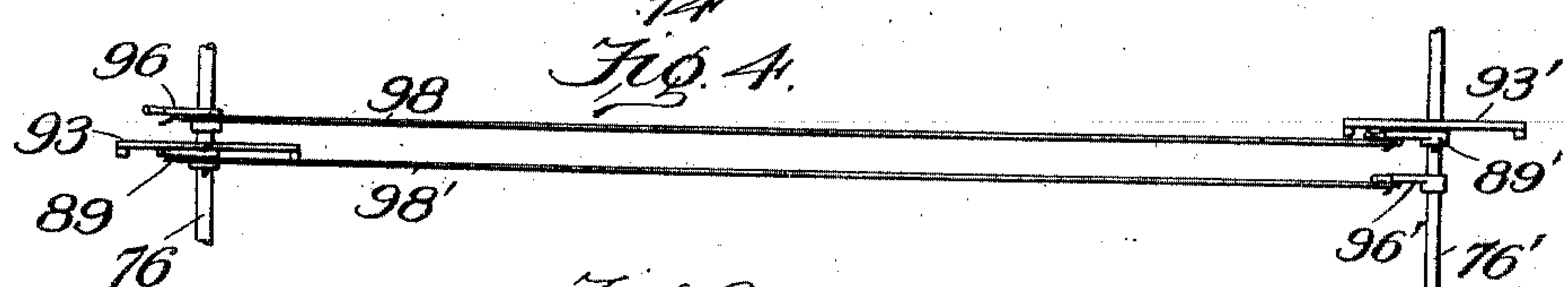
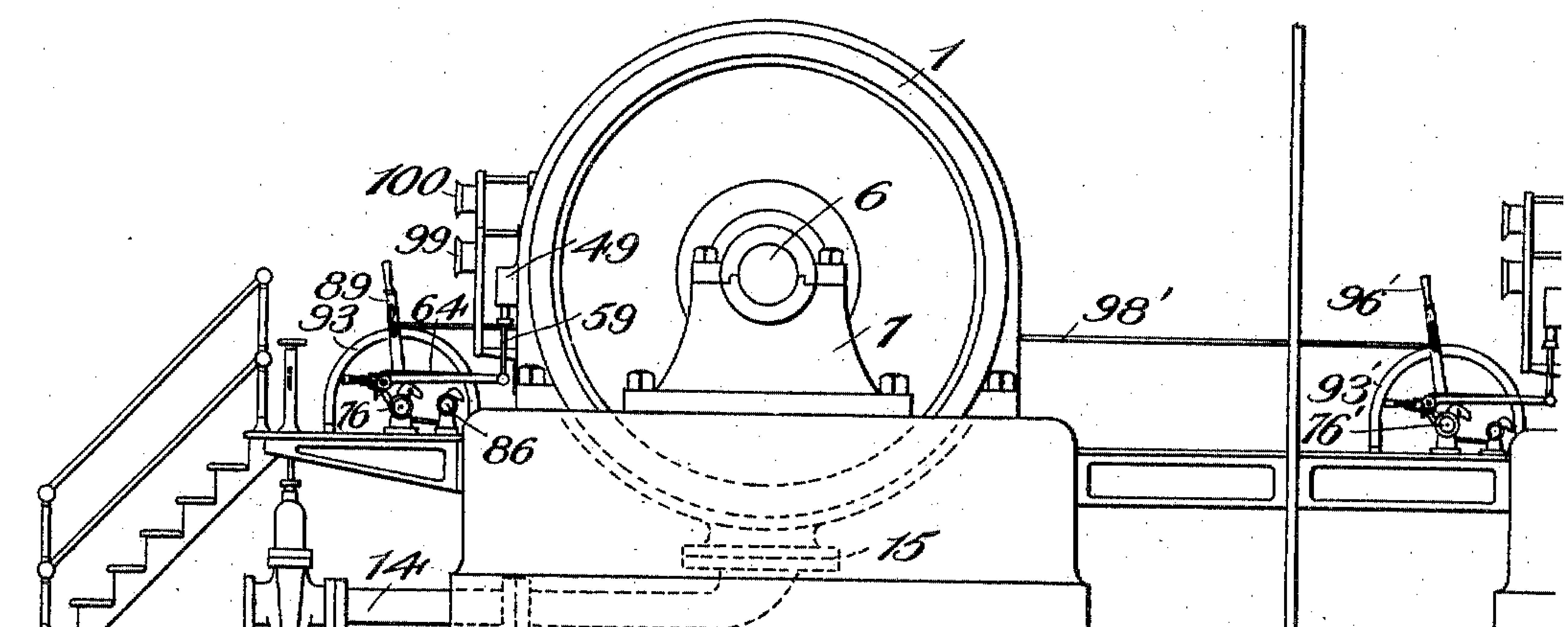


Fig. 3.



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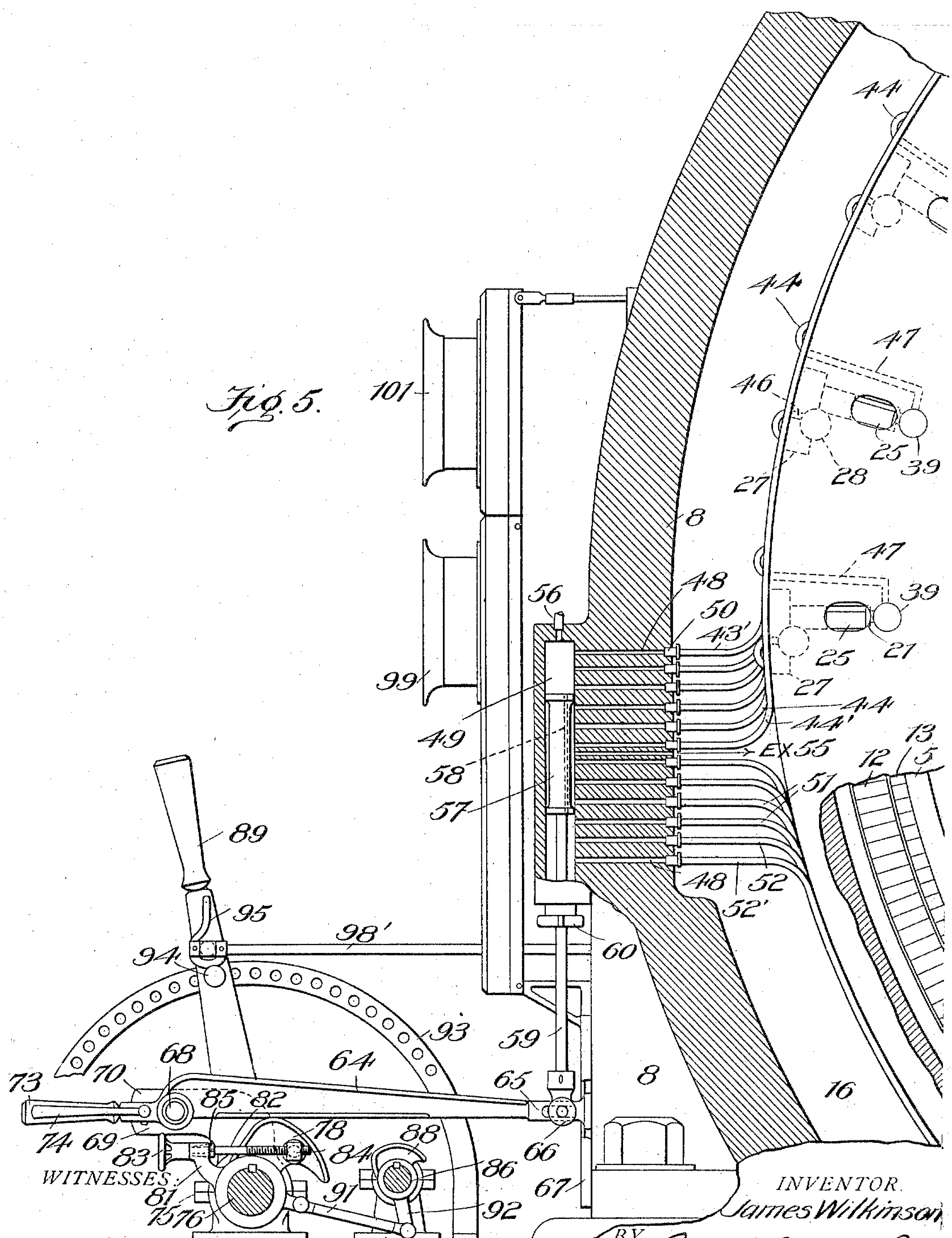
NO MODEL. 6 SHEETS—SHEET 3.

Fig. 5.



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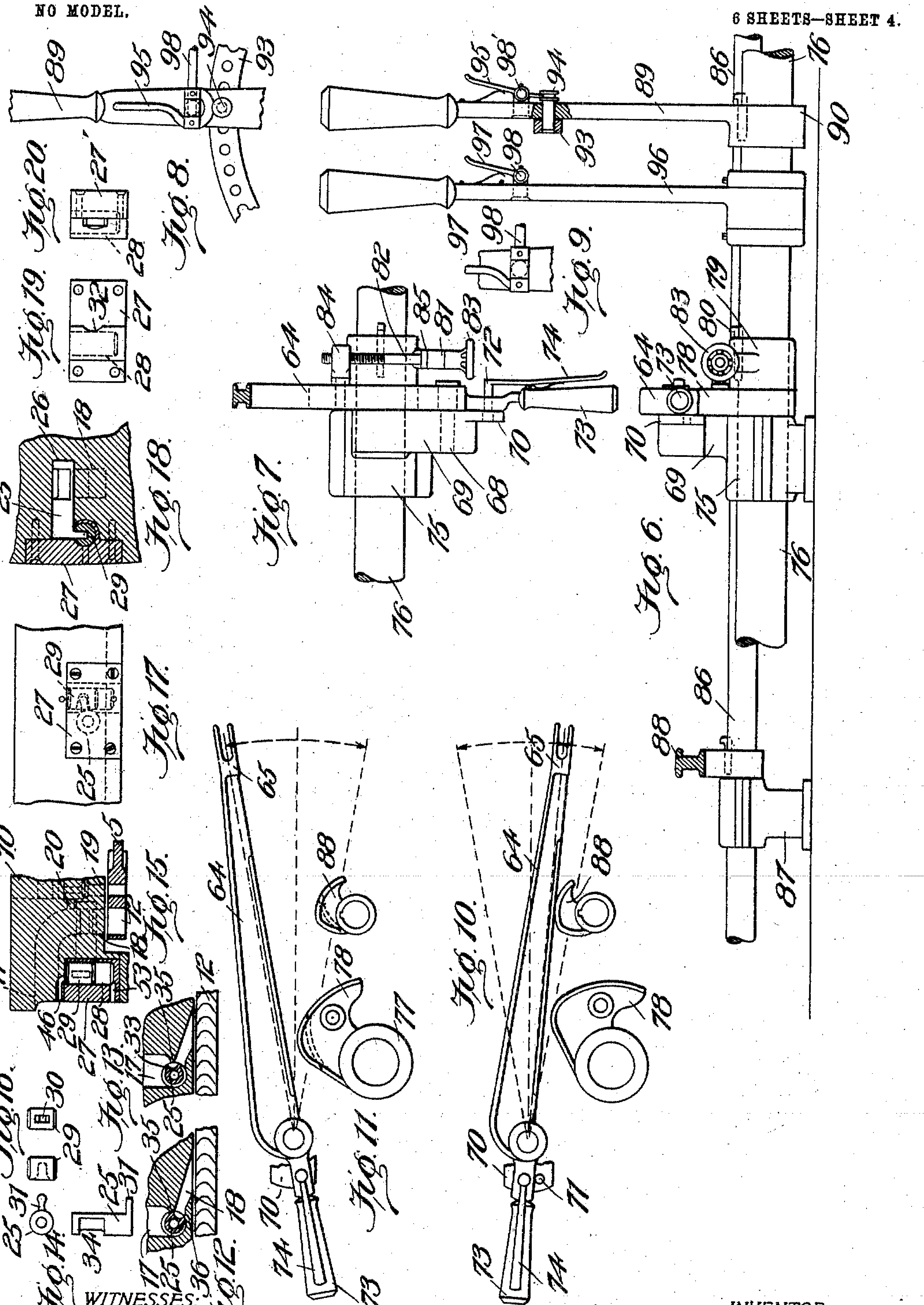
NO MODEL. 6 SHEETS—SHEET 4.



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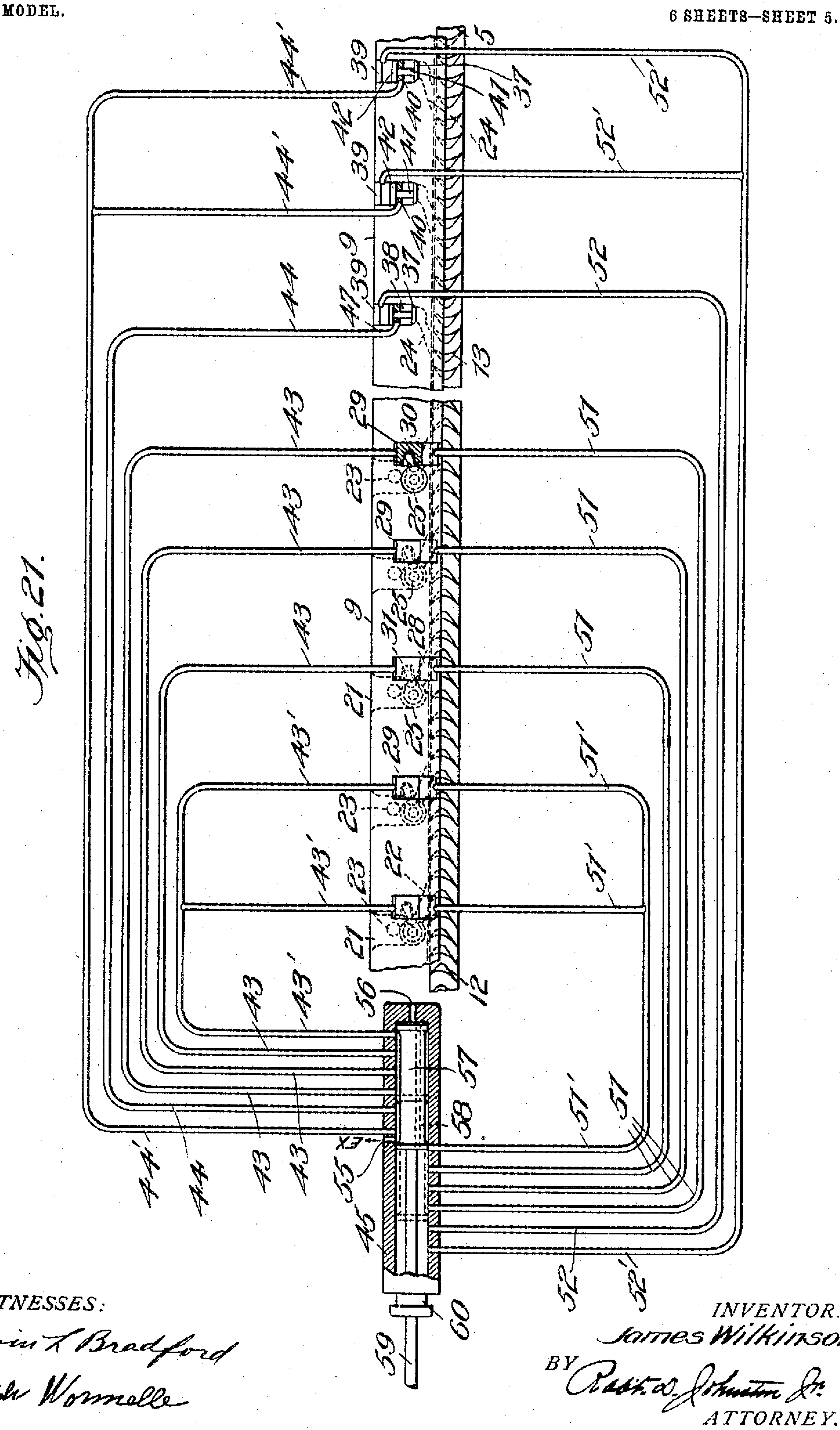
NO MODEL. 6 SHEETS—SHEET 5.



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NO MODEL. 6 SHEETS—SHEET 6.

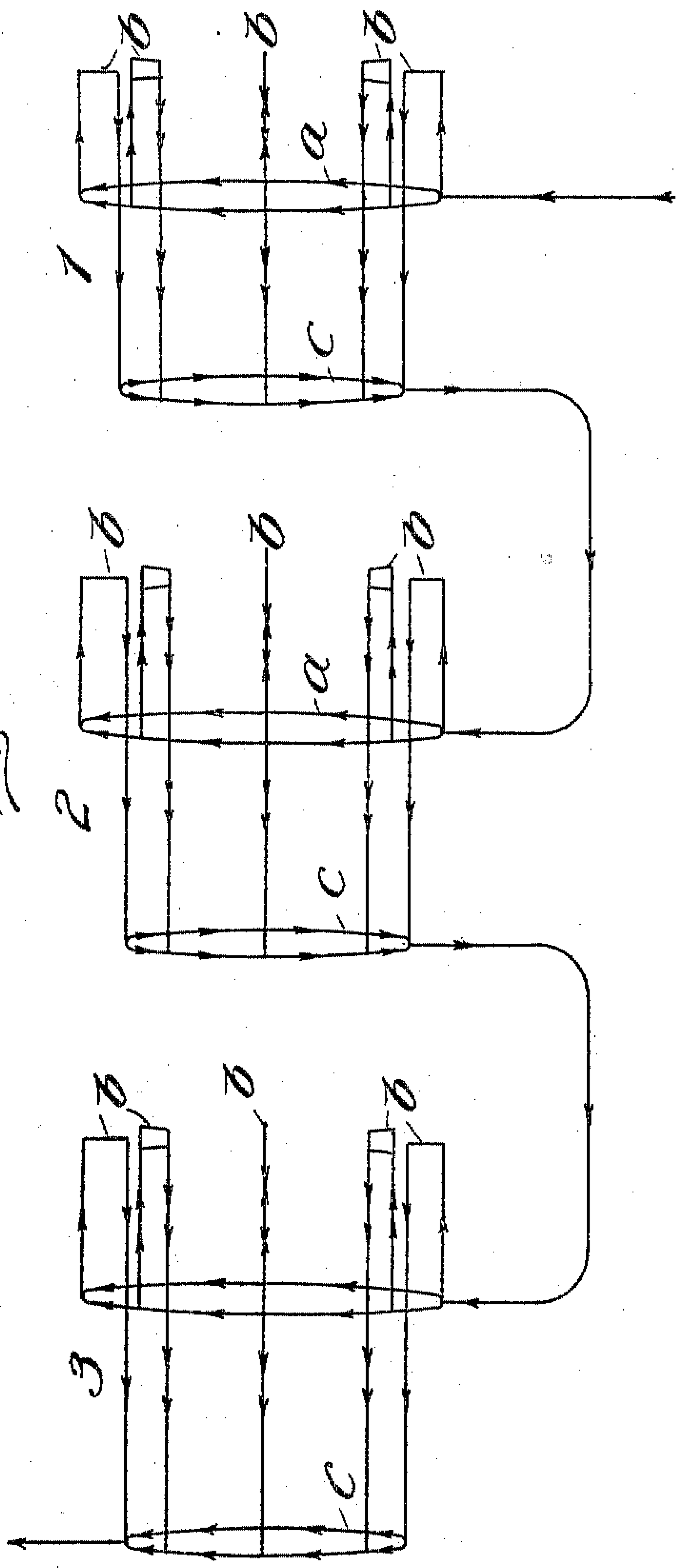

Fig. 22.

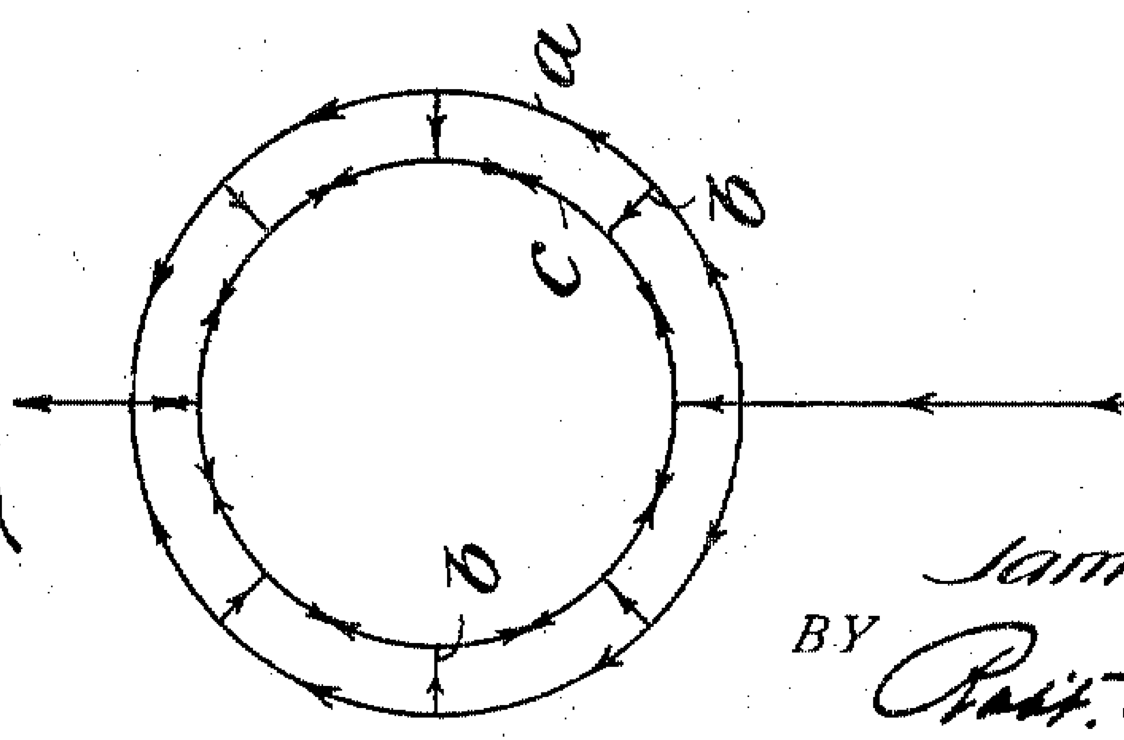

Fig. 23.

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No. 766,922. Patented August 9, 1904.

UNITED STATES PATENT OFFICE.

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

MARINE TURBINE.

SPECIFICATION forming part of Letters Patent No. 766,922, dated August 9, 1904.

Application filed April 20, 1904. Serial No. 204,113. (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 Marine Turbines, of which the following is a specification.

My invention pertains to elastic-fluid turbines and means to control the supply of motor fluid and its flow through the working passage.

In a pending application I referred to the great adaptability of a turbine provided with means to regulate both the volume of the motor-fluid supply and the dimensions of its working passage. It is the principal object of my present invention to apply this method of regulation to a multiple-stage impact-turbine of the type particularly designed for marine propulsion and which will therefore be subjected to varying conditions of speed and load. To this end I provide an independent controller device for the valve or valves which serve to vary the cross-sectional area of the motor-fluid passages discharging into each wheel compartment or stage, which passages, disposed successively across the stages, constitute the working passage for the motor fluid. My preferred means for controlling the actuation of the several controller devices comprise a cam-shaft operated by a hand-lever and carrying a plurality of cam-surfaces, one for each device, which may be relatively adjusted or of different configuration with a view to varying the proportions of the working passage in an infinite variety of ways. Thus each movement of the cam-shaft will simultaneously set the valves throughout the stages in determined positions calculated to vary the extent and cross-sectional area of the working passage in accordance with differing conditions of speed and load. This secures the widest range of control not only for the volume of the motor fluid as proportioned to the load, but also of the working passage to increase the adaptability of the turbine-motor to operate with high efficiency under varying conditions of speed and load. At the same time the controller mechanism may be adjusted by test with pressure-indicating means for each compartment under different conditions, so that throughout its movements it will produce the most desirable results in economy and efficiency.

My invention further embodies improvements in the construction of the turbine and in the arrangement of the valves and their controller mechanism designed with a view to simplifying and reducing the cost of manufacture.

My invention in its preferred form, to which, however, I do not desire to limit myself, consists in the construction and arrangement of parts hereinafter described and illustrated in the accompanying drawings, which constitute a part of this application, and in which—

Figure 1 is a side elevation of a compound turbine divided into three four-stage turbines connected up in series and controlled by a common cam-shaft. Fig. 2 is a similar view of one of the turbines, partly in section. Fig. 3 is an end view of Fig. 1 and illustrates a part of a second compound turbine which cooperates with the turbine shown. Fig. 4 illustrates a means for controlling both turbines simultaneously. Fig. 5 is an enlarged transverse sectional view taken on the line x x, Fig. 1. Fig. 6 is a detail view of the operating-levers for the cam-shafts and the means for securing the cams and cam-levers thereon. Fig. 7 is a top plan view of a cam-lever mounted on a controller-shaft. Figs. 8 and 9 are detail views of the hand-levers for operating the locking-pins which hold the levers which move the controller-shaft in set positions. Fig. 10 shows the cam-lever riding on a small cam which controls the reversing action of the turbine. Fig. 11 shows the cam-lever locked in its raised position independently of the cams, which are here shown with dotted lines indicating possible variations in configuration. Figs. 12, 13, and 14 show the rotary motor fluid-valve in its operating position and in detail. Figs. 15, 16, 17, 18, 19, and 20 are detail views of the fluid-motor for actuating the rotary valve. Fig. 21 is a view showing a modification of the manner of conducting valve-actuating fluid by pipes to the forward and reversing nozzles and of controlling the admission and exhausting of pressure from said pipes. Figs. 22 and 23 are diagrammatic views of the travel of the motor fluid throughout the several turbines in series.

Similar reference-numerals refer to similar parts throughout.

As embodied in a multiple-stage impact-turbine designed for marine propulsion my invention comprises a series of turbines 1, 2, and 3, mounted upon a common bed-plate 4 and provided each with a plurality of rotor-wheels 5, keyed to a common shaft 6, which is supported in suitable bearings 7, disposed at each end of said bed-plate and between the several turbines. Each of these turbines comprises an outer shell 8, surrounding the inner casing, which is formed by the abutting flanged peripheries of diaphragm-partitions 9, disposed and held in place between the supply-head 10 and a shoulder in the shell. An exhaust-passage casing 11 is suitably connected to the outer shell. These diaphragm-partitions subdivide the interior of the several turbines into stage compartments, within each of which a rotor-wheel 5 is disposed and provided with peripheral rows of reversely-disposed buckets 12 and 13. Motor fluid is supplied to the turbine 1 through conduits 14, leading from a suitable source of supply through the bottom of the bed-plate and entering the shell 8 through a port 15. This port opens into an annular superheating-chamber 16, formed between the inner casing and the shell, preferably by grooving out the latter, and from this chamber the fluid is admitted through a passage 17 (shown in dotted lines, Fig. 15) to the supply-nozzles 18, leading through the head 10 and to an inner row of nozzles 19. These nozzles are arranged in two circular rows at different distances from the shaft-center, those of each row being disposed in opposite oblique directions and adapted to discharge motor fluid against one or the other of the rows of revolving buckets 12 and 13 in the first compartment. A branch passage 20 from each nozzle 18 admits motor fluid to the nozzle-passages 19. I provide each diaphragm-partition 9 with an enlarged motor-fluid-inlet opening 21, disposed above a nozzle-passage 22, leading through the diaphragm and discharging motor fluid against the forward driving-buckets 12. Ports 23 (shown in dotted lines, Fig. 21, and corresponding with branch passages 20) admit the motor fluid to reversely-disposed nozzle-passages 24, which discharge it against the reversing buckets 13. The succeeding nozzle-passages with the interposed rows of revolving buckets constitute working passages, or, more properly, the working passage for the motor fluid, which will increase in cross-sectional area as the motor fluid expands. I control the flow of motor fluid through these several nozzle-passages by means of independent motors which actuate valves adapted to definitely open and close the nozzle-passages without assuming intermediate operating positions. For the forward driving-nozzles 18 and 22 I provide a semirotary valve 25. (Shown in detail in Fig. 14 and in its two operating positions in Figs. 12 and 13.) This valve is disposed in a seat 26, Fig. 18, which is preferably bored into the periphery of the head or diaphragm in a radial direction. It is my purpose to provide a very simple and compact fluid-motor for operating this valve, and accordingly I insert in a recess in the periphery of the head or diaphragm a block 27, which is provided with a chamber 28, constituting a cylinder which is closed at its upper end by the head or diaphragm cut away to form a beveled seat. I provide a similar beveled seat in the block for the lower end of the cylinder within which is disposed the piston 29, moving substantially pressure-tight therein and provided with beveled ends and a flaring recess in its side. It will be noted in Fig. 18 that the valve-chamber 26 is bored inwardly from the recessed portion into which the block 27 is inserted, so that the latter serves both as a bearing-block for the outer end of the valve and as a closure for its seat. The valve 25 has an integral stem or tongue 31 at its outer end which passes through an opening 32 in the side wall of cylinder 28 and enters the recess 30 in the piston. It will be noted by reference to Figs. 17 and 21 that this arrangement provides for certain amount of lost motion between the piston and stem 31, which enables the former to engage the crank with a slight tap to render the valve's opening and closing movements more positive. My present form of rotary valve is particularly designed to compensate slight variations in its open position, due to this lost motion, without affecting the volume of fluid delivered by the passage 21 to the nozzle 22. This valve 25 is an improvement upon the rotary valves shown and described in my prior patents and comprises a hollow body portion and two parallel lips 33, which connect the cylindrical ends of the valve and open and close two ports, one of which is formed between the reduced portion 34 of the valve and one wall of the supply-passage for the nozzle and the other of which is formed between the admission edge 35 of the nozzle 22 and the two lips 33. In this manner when the valve is open, as shown in Fig. 13, any slight displacement due to lost motion will not affect the cross-sectional area of the opening. The valve is shown closed in Fig. 12, and it will be noted that the admission edges 35 and 36 for the nozzle-passages are so constructed that the valve overlaps them and will definitely close the passage irrespective of its position due to the lost motion. The passage leading through the valve serves to stiffen it and to conduct lubricant to its inner end.

I control the flow of motor fluid through the reversing nozzles 24 by means of reciprocating puppet-valves 37, which move in chambers 38, bored downwardly through the supply-head or diaphragm and closed at their upper ends by plugs 39. I insert a block 40 in each of these chambers and pass centrally therethrough the stem 41 for operating the valve 37. This stem is connected to a piston 42, which moves in the upper end of the chamber as a cylinder. The passages 20 and 23 enter these chambers 38 below the blocks 40 and accordingly admit pressure around the valve and into the nozzle when the piston is moved to its "valve-open" position. I prefer to use these puppet-valves for the inner row of nozzles, since their motors require but little metal to be cut out of the diaphragms or head to provide for their reception, and accordingly do not weaken those parts materially. By placing the major part of the cut-away portions for cylinders 28 in the abutting portions of the diaphragms my construction is further strengthened, since they will be practically located in the strongest part of the inner casing where the diaphragms are exposed to the least pressure strain. This manner of inserting the cylinders is also simpler and more economical than where they are formed in the body of the diaphragm.

The fluid-pressure-controller mechanism for the several valves controlling the admission of motor fluid to a stage or wheel compartment is shown more fully in Figs. 5 and 21, where it will be noted that a plurality of separate pipes 43 and 44 lead, respectively, from one end of a controller-cylinder 45 to passages 46, leading to the upper ends of a row of cylinders 28, and to passages 47, entering the lower end of the row of cylinders for the pistons 42. These several pipes may either lead directly from a cylinder 45, as shown in Fig. 21, or they may connect with passages 48, leading through the shell 8 and entering a chamber 49, corresponding to 45, but here shown integral with the shell. Suitable packing-glands 50 may be used to secure a pressure-tight connection between the pipes and the passages 48. This controlling apparatus is duplicated for the valves of each stage throughout the several turbines. These pipes 43 and 44 are disposed in the annular supply-chamber 16 and lie upon the inner casing, as will be seen in Figs. 2 and 5, each pipe at its inner end entering one of the passages 47, which are bored through the periphery of the head or diaphragm and which would otherwise open into the chamber 16. Similar pipes 51 and 52, corresponding to pipes 43 and 44, lead from the other end of the controller-chamber 45 or 49 around through the chamber 16 and enter the lower ends of the cylinders 28 and the upper ends of the cylinders in which the pistons 42 move. The pipes 51 enter passages 53, leading through the blocks 27, and pipes 52 lead through passages 54 in the heads or diaphragms to the upper ends of the cylinders for pistons 42. It will be noted in Fig. 21 that the passages 47 lead partly through the blocks 40 and open upwardly into the cylinders above it. The pipes 51 and 52 will be adapted to control the same number of valves as pipes 43 and 44, to which they correspond. As shown in Fig. 5, each pair of pipes 43 and 51 control a plurality of valves 25, which open and close simultaneously. The pipes may each control only one valve or, according to Fig. 21, one or more of them, as 43′ 51′, and 44′ 52′ may control a group of valves. Any of the pipes may be used to control the group of valves, and this arrangement may be advantageously adapted for the purpose of delivering extra supply of motor fluid to the turbine as it starts either its forward or reverse driving motion. This gives a good starting torque without increasing the value of the subsequent points of regulation which would affect the economy of operation. Between the two sets of pipes I provide an exhaust-opening 55, which in Fig. 5 is shown entering the chamber 16, which construction is preferable when the pressure in chamber 16 is below that of the motor-fluid supply, which enters the upper end of the cylinder through a passage 56. This will be the case in the turbines 2 and 3, to which the previous description of details apply and in which the several nozzles and rotating buckets will be of relatively and successively greater proportions in view of the expanded condition in which the motor fluid is supplied to them from the turbine or turbines preceding them in the series. In connection with turbine 1, however, the motor fluid at high pressure exists in passage 16, and therefore it will be necessary to lead the exhaust from passage 55, Fig. 21, to one of the low-pressure turbines or to exhaust it into a supply-nozzle by an ejector action in the manner described in a pending application. A piston-valve 57, which is reduced between its end portions, fits substantially pressure-tight within the cylinder 45 or 49 and is provided with a transverse passage 58, which opens communication between both ends of the cylinder. A stem 59 for actuating the piston-valve 57 enters one end of the controller-cylinder through a packing-gland 60 and is connected at its outer end to an operating mechanism hereinafter described. It will be seen by reference to Fig. 21 that the exhaust-opening 55 is so placed that it will always be in communication with the chamber formed between the two heads of the piston-valve 57, which chamber accordingly constitutes an exhaust-passage through which the valve-actuating fluid supplied through port 56 at an end of the cylinder escapes from the pipes leading to the valve-motors as the movement of the piston-valve opens them to said chamber. Thus, as shown in Fig. 21, the high pressure through port 56 and passage 58 enters all of the pipes 51 and 52, and it will be noted that this will have the effect of opening all of the valves 25 and admitting motor fluid to the forward driving-nozzles 22, while it closes the valves 37 and cuts off motor fluid from the reversing-nozzles 24. The passages 44 and 52, controlling these valves 57, occupy the same relative position in each group of valves, so that the high pressure will be maintained in passages 52 and hold them closed until piston-valve 57 will have moved to the position shown in dotted lines, Fig. 21, when the high pressure will enter the passages 43 of the series, closing the forward driving-nozzles. In this position all of the turbine-valves will be closed, and this accordingly represents the position of the piston-valve when the load is off or the turbine inactive. If the piston be moved farther to the left from its latter position, it will expose one of the passages 52 to the exhaust-pressure and will simultaneously open a passage 44 to the high pressure, so that the pressure being withdrawn from above one or more pistons 40 and admitted below it or them one or more of the valves 37, as the case may be, will be opened and the motor fluid admitted to nozzles 24 to reverse the turbine, while all of the forward driving-nozzles are maintained closed, due to the high pressure in passages 43. If, however, the piston-valve be moved to the right from the position shown in dotted lines in Fig. 21, the high pressure will be maintained in pipes 52 which close the reversing-valves 37 and will be successively admitted to the passages 51 to successively open the valves 25, and it will continue to open these valves and to successively exhaust the pressure from passages 43 until it assumes the full-line position, when all of the forward driving-nozzles will be held open and the reversing-nozzles closed. It will thus be seen that it is not possible for the forward and reverse passages to be open at the same time, though I am able to control both from the same controller-casing and by means of the same piston-valve. Any desired number of these passages may be used, and they may, as before stated, control the valves separately or in groups of any desired number in which the several valves of each group move simultaneously and may be disposed around the head or diaphragm in any desired manner.

It is my purpose to provide four stages or wheel-compartments in each of the turbines 1, 2, and 3, and I conduct the motor fluid from the exhaust-passage casing 11 of the first turbine of the series through a passage 61 to the supply-port 15, opening into the superheating-chamber in the shell of the second turbine at a point near its central portion, and a passage 62 connects in the same manner this latter turbine with the last turbine of the series, from which the motor fluid is exhausted into an enlarged exhaust or condenser chamber 63. This manner of connecting the several turbines enables me to set them closely together. In Fig. 22 I illustrate by diagram the flow of the fluid through the several turbines, the arrow-heads indicating the direction of its flow. It will be noted that the fluid flows upwardly around the turbine 1 and then after passing through the working passages flows downwardly and through the connecting-passage to the second turbine 2, through which it takes the same course, and finally enters the last turbine 3 of the series, from which it will be noted that the pressure exhausts upwardly from the last wheel-compartment. In Fig. 23 the arrow-heads on the circle *a* indicate the flow of fluid through the chamber 16. The transverse lines *b* indicate its diversion into the working passages and the arrow-heads on the circle *c* its flow through the exhaust-chamber, it being noted the double heads here indicate the reverse direction of the flow between the last and preceding turbines of the series. It is my object to control the valves for the several stages independently throughout the series of turbines, and accordingly I provide, as shown in Figs. 2 and 5, an independent controller mechanism for each row of valves. There will therefore be twelve controller-chambers 49 and twelve stems 59, which control the piston-valves for these cylinders. My operating mechanism for these several piston-valves comprises a plurality of levers 64, each of which is bifurcated at one end and adapted to engage a cross-head pin 66, to which the stem 59 is connected and which is vertically movable in suitable guides 67, secured to the shell 8. Near their outer ends these levers are pivoted at 68 to standards 69, each of which has integral therewith a flange 70, provided with an aperture 71, in which a pin 72 enters when the lever is swung upwardly its full throw by the handle 73, connected to or formed integral therewith. A pivoted spring-pressed lever 74 normally presses the pin 72 against the flange 70, so that when the pin is opposite the opening 72 it automatically enters it and locks the lever in position. The several standards 69 are preferably formed integral with the upper section of the several bearings 75 for the longitudinal controller-shaft 76, which extends along the bed-plate 4 to a point opposite the several turbines of the series. Adjacent to each bearing 75 I mount a loose collar 77 upon the shaft 76, which carries a cammed surface 78, disposed beneath the lever 64, which is adapted to engage and rest thereon. This loose collar 77 is disposed between the bearing 75 and a collar 79, also mounted on shaft 76 and which is fixed thereon by a key 80. This collar carries an arm 81, in which I form a flaring opening through which a rod 82 passes. This rod turns freely in the arm 81, being provided at its outer end with a handle 83 and at its opposite end with screw-threads which are adapted to engage the threaded opening in a pin or block 84, pivotally connected to a cam 78. A collar 85 is keyed to the rod 82 and serves as a stop to enable the cam to be adjusted by turning this rod by its handle 83. In this manner I secure a firm and positive connection for the several cams, so that they move with the shaft 76, and at the same time they are relatively adjustable, so that they may be set to cause the several levers 64 to actuate their respective controller-piston valves in any desired manner to gain different effects. In addition to this adjustment of the cams their relative configuration may be varied to increase the variety of the differential control of the cross-sectional area of the working passage between the several stages, or the several cam-surfaces may be fixed to or formed integral with the shaft, in which case their variation in configuration will be wholly relied upon to effect the differential control of the stage-valves. The dotted lines on the cam shown in Fig. 11 illustrate possible changes in conformation.

I provide a counter-shaft 86, which extends parallel with the shaft 76 and is suitably mounted in bearings 87, secured to the bed-plate 4. This shaft 86 carries a set of secondary controller-cams 88, which are rigidly keyed thereto and disposed opposite to and at a point below the cams 78, so that they receive the levers 64 when lowered thereon by the latter cams, as seen in Fig. 10.

I provide a suitable operating-lever 89, which is rigidly keyed to the shaft 76 and provided with a collar 90, which surrounds the shaft and is connected by a link 91 with a lever 92. This lever is connected to a collar, preferably that of one of the cams 88, which is keyed to shaft 86, and by means of which this latter shaft is operated simultaneously with the main shaft 76. By means of a quadrant 93 and a pin 94, carried by the arm 89 and controlled by a spring-pressed handle 95, the lever 89 may be locked in any desirable position to hold all of the controlling means for the several rows of valves in a fixed position. Where I provide a battery of turbines, as partly shown in Fig. 3, it will be of advantage to enable both to be controlled from the same point, and I accordingly provide an auxiliary lever 96, mounted loosely on shaft 76 and provided with a handle 97, which operates a rod 98, Fig. 4, which connects with the handle 95′, carried by the lever 89′, which is keyed to the other shaft, 76′. By means of this rod 98 the pin 94′ may be moved out of engagement with the quadrant 93′ and the lever 89′ operated by lever 96. I can thus control the position of the shaft 76′ while operating shaft 76 by means of lever 89. In the same manner rod 98′ and lever 96′ may be used to operate the shaft 76.

Referring to Figs. 10 and 11, the upper surface of the cams 78 and 88 are preferably struck on the arc of a circle from the shaft centers, so that a lost-motion connection is thus provided between the several cams and their respective levers 64. This is essential to provide for the successive operation of the levers 64 when controlling the supply of motor fluid to the forward driving working passages. It is also necessary that the cams 88 should be provided with similar lost-motion surfaces; otherwise as the levers 64 are successively lowered upon them by cams 78 they might not all be sustained at an intermediate position when their controller-piston valves 57 will occupy the position shown in dotted lines, Fig. 21, and all of the turbine-valves be closed preliminary to the admission of motor fluid for the reversing-passages. This admission will then be successively controlled by the relative position or variation in contour between the several cams 88.

In connection with marine turbines, where the load and speed may vary proportionately, it is essential to an economical operation of the turbine that these variations in speed be compensated by a corresponding variation in the proportion or the extent of the working passage. Instead of varying the actual length of the working passage, which involves serious disadvantages in the difficulty to control and the cost of construction, it is my purpose to vary the effective extent of the working passage, throughout which the motor fluid does useful work. It will be evident that if I provide thirty nozzle-passages of a given horse-power capacity each for the twelve stages shown and the cam-shaft be set to open three nozzles, or ten per cent. of the full supply to each stage, the turbine will act with ten per cent. of its full capacity at low speed. If it be desired to simultaneously increase the speed and power, the cams may be set or formed so that they will admit fifty per cent. of the capacity of the first-stage nozzles, fifty-five per cent. of the second, &c., when the nozzles of the last two stages will be fully opened. This will give a greater drop of pressure to each stage and a consequent increase of velocity of the fluid per stage, which permits of a consequent increase in the speed of rotation of the buckets without loss of economy. This has the effect of practically cutting two rows of buckets out of service, for it causes the exhaust or condenser pressure to move up into the last two stages, thus shortening the effective extent of the fluid's working passage and permitting the speed to be increased about one-sixth. A continued movement of the cam may further permit an increase of speed by throwing open all nozzles for the last three or more stages; but beyond a certain point the speed can be increased only at the expense of the power of the turbine, as it will be necessary to reduce the volume of fluid admitted to the first stage to secure the relatively large increase in proportions requisite to secure a high speed by means of a short working passage. The cams may be formed or set to produce any desired differential in the operation of the stage-valves, and by making them adjustable and providing a pressure-gage 99 for each stage, a boiler-pressure gage 100 for turbine 1, a speed-indicator 101 for turbine 2, and a vacuum-gage 102 for turbine 3 the action of the fluid within the turbine may be closely watched, and when necessary one or more of the cams be adjusted to keep the turbine operating at highest efficiency. Variation in speed may also be effected by locking one or more of the intermediate levers 64 in their open position, thus opening all of the nozzles for the stage it controls. When a number of nozzles for the preceding and succeeding stages are closed, this intermediate stage will be practically cut out of active service and will constitute a continuation of the preceding stage, through which the pressure will flow without acting to drive the rotating buckets therein. In this manner the whole of turbine 2 may be cut out of service, when, with conduits 61 and 62, it will form the communicating passage between turbines 1 and 3.

In applying my invention to other forms of turbine than marine, where a substantially constant speed is desirable, the cams will be set to successively actuate the stage-valves to maintain the proportions of the working passage while increasing or diminishing the volume of motor fluid. Also the intermediate means for operating the stage-valves may be dispensed with and the valves operated directly without materially departing from my invention. In the same manner the cam-shaft may comprise a single cam-surface of varying cross-sectional contour or a single surface for the valves of each shell, and, if desired, the surfaces may be independently operated. Though I prefer to shift the cam-shaft and control the valves manually, yet I do not desire to limit myself to this feature, since the controller-shaft may be actuated in any other well-known manner common in this art.

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

1. In a turbine wherein the motor fluid is successively discharged against rows of revolving buckets, the combination therewith of independent means to vary the flow of motor fluid at different points in its passage through the turbine, with means to simultaneously effect a variable control of each of said first-mentioned means.

2. In a multiple-stage turbine, independent means to vary the cross-sectional area of the admission opening or openings for motor fluid to each stage, and a controller means comprising a plurality of irregular surfaces which engage and simultaneously actuate said first-mentioned means.

3. In a multiple-stage turbine, a working passage leading therethrough and formed by succeeding nozzle-passages and interposed rotating buckets, valves at different points in the working passage, and means to simultaneously produce a differential opening or closing movement of said valves, to vary the proportions of the working passage.

4. In a multiple-stage turbine, stage-valves, and a cam means to effect a relative differential operation of the valve or valves for each stage to vary the proportions of the working passage.

5. In a turbine in which the motor fluid is successively directed against rows of rotating buckets in its progress through its working passage, valve means to vary the cross-sectional area of said working passage at different points, and a controller means designed to simultaneously effect a differential movement of said several valve means.

6. In a turbine in which the motor fluid is successively directed against rows of rotating buckets in its progress through its working passage, independent valve means to vary the cross-sectional area of said working passage at different points and a controller means for said valve means comprising a plurality of cam-surfaces.

7. In a turbine in which the motor fluid is successively discharged against rotating elements in separate compartments, means to vary the cross-sectional area of the inlet-opening to said compartments, and a controller means to effect a relatively varying opening or closing of the inlet-opening for the several compartments.

8. In a multiple-stage turbine, one or more valves controlling the volume of fluid admitted to the several stages, a controller means for the valve or valves of each stage, and an actuating device provided with a plurality of cam-surfaces of varying contour which independently actuate said means.

9. In a turbine in which the motor fluid successively impinges against rows of revolving buckets, means to vary the fluid's flow through the turbine between rows of buckets, and an element having an irregular surface of varying cross-sectional contour which controls the operation of said means.

10. In a multiple-stage turbine, stage-valves, a controller device for the valve or valves of each stage, and a series of adjustable cams for actuating said controller devices.

11. In a turbine operating by stage expansion, valves controlling the supply of motor fluid to the several stages, independent means

to operate the valve or valves for each stage, and a controller device comprising a plurality of adjustable cams of varying contour which operate said means.

12. In a turbine wherein the motor fluid is successively directed against rotating elements as it flows through the working passage, valve means to close or vary the cross-sectional area of the working passage at different points, and controller means which are adapted to simultaneously operate said valve means to produce varying relative proportions of the working passage under varying conditions of speed or load.

13. In a turbine, a plurality of motor-fluid valves, means to actuate them singly or in groups, and a controller device for said means comprising a cam-surface designed to effect a relatively varying opening or closing movement of said valves throughout its range of travel.

14. In a multiple-stage turbine, supply and stage valves, a separate fluid-controller means for the supply and for the valve or valves of each stage, and mechanical means to actuate said controller means.

15. In a multiple-stage turbine, a plurality of motor-fluid-supply valves for a stage, a controller device to cause a successive operation of said valves, and a cam to actuate said controller device and control the operation of said valves.

16. In a multiple-stage turbine, supply and stage valves, cams to independently control the operation of the valve or valves admitting motor fluid to each of the several stages, said cams being mounted on a common shaft and means to actuate said shaft.

17. In a controller mechanism for the valves of a multiple-stage turbine, the combination with means to simultaneously control said valves, of means to lock the valve or valves controlling the supply of motor fluid to a stage in an open position independently of said controller mechanism.

18. In a controller mechanism for the valves of a multiple-stage turbine, the combination with independent controller means for groups of valves, of a controller-cam shaft which effects a relatively differing actuation of the controller means.

19. In a controller mechanism for the valves of a multiple-stage turbine, means to operate the valves controlling the admission of motor fluid to a stage, a lever for actuating said means, and a cam for actuating said lever with a lost-motion effect.

20. In a controller mechanism for the valves of a multiple-stage turbine, a plurality of levers each controlling the operation of the valve or valves which admit motor fluid to a stage, a controller-cam shaft, and a lost-motion connection between said shaft and the several levers.

21. In a multiple-stage turbine, a plurality of valves controlling the admission of motor fluid to each stage, an independent controlling means for the valves of each stage, a lever for each controlling means, and a cam-shaft to actuate all said levers.

22. In a turbine, valve means to control the admission of motor fluid to a wheel-compartment, a lever which controls through suitable means the operation of said valve means, a cam which normally engages and shifts the position of said lever, and means to lock the lever out of engagement with said cam.

23. In a controller mechanism for turbine-valves, a plurality of devices controlling the operation of independent groups of valves, a cam-shaft upon which said devices normally rest and by which they are actuated, and means independent of said cam-shaft to set each of said devices to maintain all of the valves under its control open.

24. In a multiple-stage turbine, valve means controlling the supply of motor fluid to each stage, a fluid-pressure-controller means for each valve means comprising a controller-valve and a lever for actuating said valve, in combination with a cam-shaft upon which all said levers normally rest and by means of which they are independently actuated.

25. In a turbine, a plurality of fluid-actuated valves which admit motor fluid to a stage, conduits for an actuating fluid leading to said valves, a controller-valve for successively admitting fluid to said conduits to operate said valves, a stem for said valve, and a cam which controls the actuation of said stem.

26. In a multiple-stage turbine, an independent fluid-controller mechanism for the valves which control the admission of motor fluid to each stage, said controller mechanism comprising each, a cylinder, a plurality of conduits leading therefrom to one or more valves to admit fluid-pressure to actuate them, a controller-valve in said cylinder, a stem therefor, and a pivoted lever connected to said stem, in combination with a cam-shaft for shifting said levers.

27. In an elastic-fluid turbine provided with succeeding passages which direct motor fluid against movable buckets, the combination therewith of means to simultaneously effect a varying opening of the succeeding passages to vary the point of effective expansion of the motor fluid in a working passage of unvarying length.

28. In an elastic-fluid turbine wherein the motor fluid is successively directed by nozzle-passages against movable buckets in communicating stage-compartments, the combination therewith of means to vary the cross-sectional area of the nozzle-admission opening for each stage, and a controller mechanism to simultaneously effect a relatively differing actuation of said means to vary the extent of the

fluid's active agency in the working passage and cause the exhaust or condenser pressure to exist in one or more of said compartments.

29. In a reversing-turbine, forward and reverse driving nozzles, valves therefor, and means to control the independent operation of said valves and, upon reversal to open a plurality of said valves simultaneously and the remainder of them successively as the load varies, for the purposes described.

30. In a reversing-turbine, forward and reversing nozzles for stage-compartments, cam-surfaces to actuate means to open or close said forward nozzles, and independent cam-surfaces to actuate means to open or close said reversing-nozzles.

31. In a multiple-stage reversing-turbine, forward and reversing nozzles for the stages, in combination with a controller means adapted to control the forward-driving nozzles of the several stages while maintaining the reversing-nozzles closed, to close all said nozzles, and to control the reversing-nozzles of the several stages while maintaining the forward-driving nozzles closed.

32. In a reversing-turbine having a plurality of wheel-compartments and reversely-disposed nozzles opening therein, means to control the admission of motor fluid to said compartments, and actuating means having a lost-motion connection with said first-mentioned means which closes all nozzles disposed in one direction before opening up the reversely-disposed nozzles.

33. In a reversing-turbine, forward and reverse driving nozzles for separate wheel compartments or stages, and means to effect a relatively variable control of the forward or reverse nozzles throughout the several stages simultaneously.

34. In a multiple-stage reversing-turbine, means to control the forward-driving nozzles of the several stages independently, means to control the reverse-driving nozzles of the several stages independently, and a common controller mechanism which by a lost-motion connection with said means effects a complete closure of all nozzles through the stages before changing the direction of rotation of the turbine.

35. In a multiple-stage reversing-turbine, a plurality of forward-driving nozzles for a stage, one or more valves therefor, and a cam-controlled means to operate said valve or valves, in combination with reverse-driving nozzles, one or more valves therefor, and a cam-controlled means to operate said latter valve or valves.

36. In combination, a plurality of forward and reversing nozzle-passages for a stage-compartment of a turbine, and a common controller device for successively opening or closing either the forward or the reversing nozzles independently of the nozzles for adjacent stages.

37. In a multiple-stage reversing-turbine, means to drive the turbine in a forward direction, in combination with succeeding passages which direct motor fluid against movable buckets to drive the turbine in a reverse direction, and means to simultaneously effect a relatively varying opening of the succeeding passages to vary the point of effective expansion of the motor fluid in the working passage comprising said succeeding passages.

38. In a multiple-stage reversing-turbine, reversely-disposed working passages and means to cut off the flow of motor fluid in one of said working passages and to simultaneously vary the cross-sectional area of the active working passage at various points to move the exhaust-pressure up into one or more stages and, by shortening the effective length of the working passage, to vary the speed of rotation of the turbine.

39. In a multiple-stage reversing-turbine, forward and reverse working passages leading across the stages, means to control the admission of motor fluid to each stage, and an operating merchanism to independently control said means for each stage comprising lost-motion connections which provide for the complete closure of both working passages between the closing of one and the variable opening across stages of the other.

40. In a multiple-stage reversing-turbine, forward and reverse driving nozzles, fluid-actuated valves therefor, a controller-valve for the fluid-actuated valves of each stage and means to actuate said controller-valves to control the flow of motor fluid and to reverse the turbine.

41. In a multiple-stage reversing-turbine, forward and reverse driving working passages and fluid-actuated valves therein to vary the flow of the fluid, a controller-chamber, a plurality of conduits leading therefrom to valves in both of said passages, and a common controller-valve in said chamber which maintains the valves in one of said passages closed while controlling the operation of the other valves.

42. In a turbine, an inner and an outer casing therefor, a controller-chamber, turbine-valves, and fluid-conduits leading from said chamber to said valves and disposed between the two casings.

43. In a turbine having a casing, a shell surrounding said casing, a chamber provided between said shell and casing, a plurality of fluid-controlled valves, and pipes for the valve-controlling fluid disposed around the casing within said chamber.

44. In a turbine provided with a superheating-jacket and fluid-controlled valves, a fluid-controller chamber and pipes, for conducting valve-controlling fluid therefrom to cause said valves to operate, which are disposed in said superheating-jacket.

45. In a multiple-stage turbine, means to subdivide the stages into groups, a superheat-

ing-chamber surrounding the side walls of each group and communicating with the supply nozzle or nozzles for the first stage of its group, means to supply motor fluid to the first group through the chamber surrounding them and to exhaust the motor fluid from each group into the superheating-chamber for the succeeding group.

46. In a multiple-stage turbine wherein the wheel-compartments are grouped in a plurality of separate shells, a superheating-chamber surrounding the wheel-compartments in each shell and serving as a motor-fluid-supply passage therefor, means to supply motor fluid to the chamber in the first shell, and conduits which exhaust the motor fluid from said shell and introduce it into the chamber in the succeeding shell.

47. In a multiple-stage turbine, two or more superheating-chambers each of which surround a group of stages, in combination with means to cause the motor-fluid supply to pass successively from each chamber through the stages it surrounds to the succeeding chamber before entering the exhaust or condenser.

48. In a reversing-turbine, a supply-head for a wheel-compartment, reversely-disposed nozzles therein at different distances from the shaft-center, a rotary valve for the outer nozzle and a reciprocating valve for the inner seated in the head.

49. In a turbine, a supply-head for a wheel-compartment, groups of differently-acting nozzles therein arranged at different distances from the shaft-center, rotary valves for the outer row and puppet-valves for the inner row of nozzles.

50. In a turbine, a supply-head for a wheel-compartment, a rotary valve and a reciprocating valve seated therein at different distances from the shaft-center, and acting to control reversely-disposed nozzles, and fluid means to actuate said valves.

51. In a turbine reversely-disposed working passages at different distances from the shaft-center, rotary valves for the outer working passage or passages and fluid-actuated puppet-valves for the inner working passage or passages.

52. In a turbine, a supply-head for a wheel-compartment, a rotary valve seated therein and controlling a nozzle-passage, a block, comprising a fluid-motor, connected to said head, and means to operate said valve by said motor.

53. In a turbine, a nozzle-passage, a controller-valve therefor, a reciprocating motor therefor, and a lost-motion connection between said valve and a piston of said motor.

54. In a turbine, a nozzle-passage, a rotary valve therefor, and a fluid-motor for said valve comprising a cylinder and piston and a lost-motion connection between said valve and piston.

55. In a turbine, a nozzle-passage, a rotary valve therefor, a reciprocating fluid-actuated piston, a cylinder therefor, and a stem, connected to said rotary valve, which passes through said cylinder and is actuated by shoulders between the ends of said piston.

56. In a turbine, a nozzle-passage, a rotary valve therefor, and a motor for said valve comprising a cylinder, a piston having a flaring recess in its side, and a crank which engages in said recess and operates said valve.

57. In a turbine, a nozzle-passage for motor fluid, a double-ported fluid-actuated rotary valve therefor.

58. In a turbine, a nozzle-passage, a rotary valve therefor, an actuating device for said valve, a lost-motion connection between said device and valve, and means to compensate the variation in the valve's open position due to said lost-motion connection without affecting the volume of fluid admitted.

59. In a turbine, a nozzle-passage having admission edges, a rotary valve provided with two projecting longitudinal lips which overlap both of said edges when the valve is closed, means to actuate said valve and a lost-motion connection between said valve and means.

60. In a turbine, an induction-nozzle having admission edges, and a rotary valve adapted to open and close said nozzle and having a pair of lips between which, in both directions, a portion of the body of the valve is reduced, said valve being adapted, when open, to permit the motor fluid to flow around it on both sides into said nozzle to balance the said valve.

61. In an elastic-fluid turbine, motor-fluid nozzles, valves therefor, and detachable motors seated in the outer wall of the turbine-casing and outwardly removable therefrom, said motors having an operative connection with said valves.

62. In an elastic-fluid turbine, having an inner casing and a strengthening-shell surrounding it, valves controlling the flow of motor fluid, and motors detachably connected to the outer wall of said inner casing so as to be outwardly removable therefrom when said shell has been removed, said motors being adapted to operate said valves.

63. In an elastic-fluid turbine, nozzle-passages, valves therefor, and fluid-motors formed in detachable elements which are seated in the side wall of casing of said turbine so as to be outwardly removable therefrom without disturbing the parts composing said casing, said motors being operatively connected to said valves.

64. In an elastic-fluid turbine, a head for a wheel-compartment, a valve seated therein, an outwardly-opening recess in the periphery of said head, a motor detachably seated therein and adapted to operate said valve, and a nozzle-passage opened and closed by said valve.

65. In an elastic-fluid turbine, a rotary element, a nozzle-passage formed in a head of the compartment within which said element

rotates, a valve for said nozzle-passage, a recess in the outer periphery of said head, a detachable element seated therein and outwardly removable therefrom, a fluid-motor carried by said element, and means to operate said valve by said motor.

66. In a multiple-stage turbine, a plurality of superimposed diaphragms, turbine-valves, and detachable motors for actuating said valves, means to secure said motors within the abutting portions of said diaphragms so that they are outwardly removable therefrom without shifting said diaphragms.

67. In a turbine, a motor-fluid valve, a valve-controlled nozzle-passage, and a bucket element against which said passage discharges motor fluid, in combination with an element detachably seated in the outer periphery of the nozzle-bearing element and outwardly removable therefrom, a cylinder in said detachable element, a reciprocating piston in said cylinder, and an operating-stem for said valve which engages said piston and is moved thereby.

68. In a turbine, a head for a wheel-compartment, a recess leading inwardly from its periphery, a valve controlling the flow of motor fluid through a nozzle-passage and seated in said recess, and a motor also seated in said recess and operatively connected to said valve.

69. In a turbine, a diaphragm-partition, a recess in its periphery, a motor-fluid valve disposed in said recess, and a detachable block for closing said recess which carries a motor for operating said valve.

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

JAMES WILKINSON.

Witnesses:
H. M. Harton,
R. D. Johnston.