No. 787,907. PATENTED APR. 25, 1905.

E. S. FARWELL.

TURBINE ENGINE.

APPLICATION FILED DEC. 4, 1903.

2 SHEETS—SHEET 1.

Fig. 2.

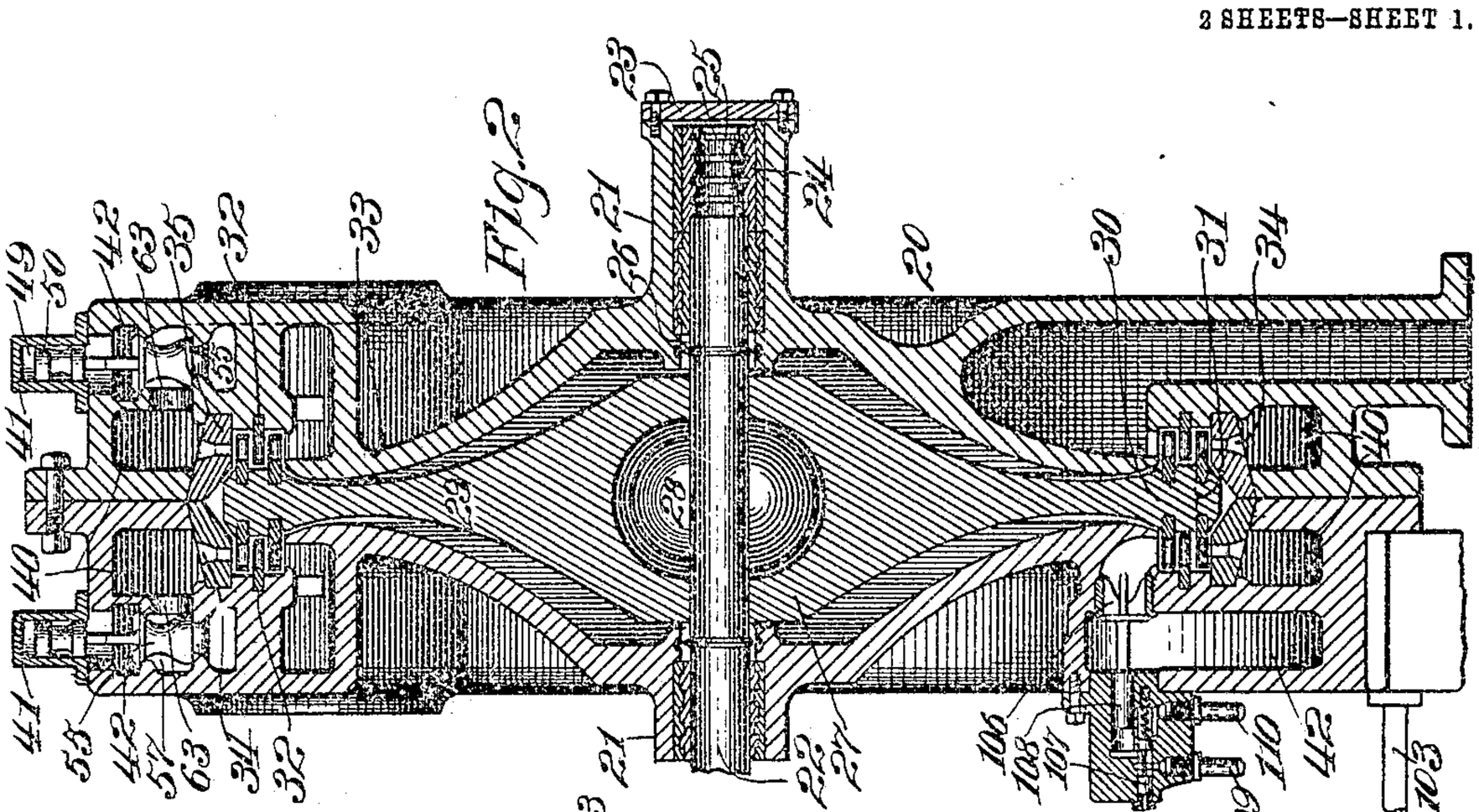
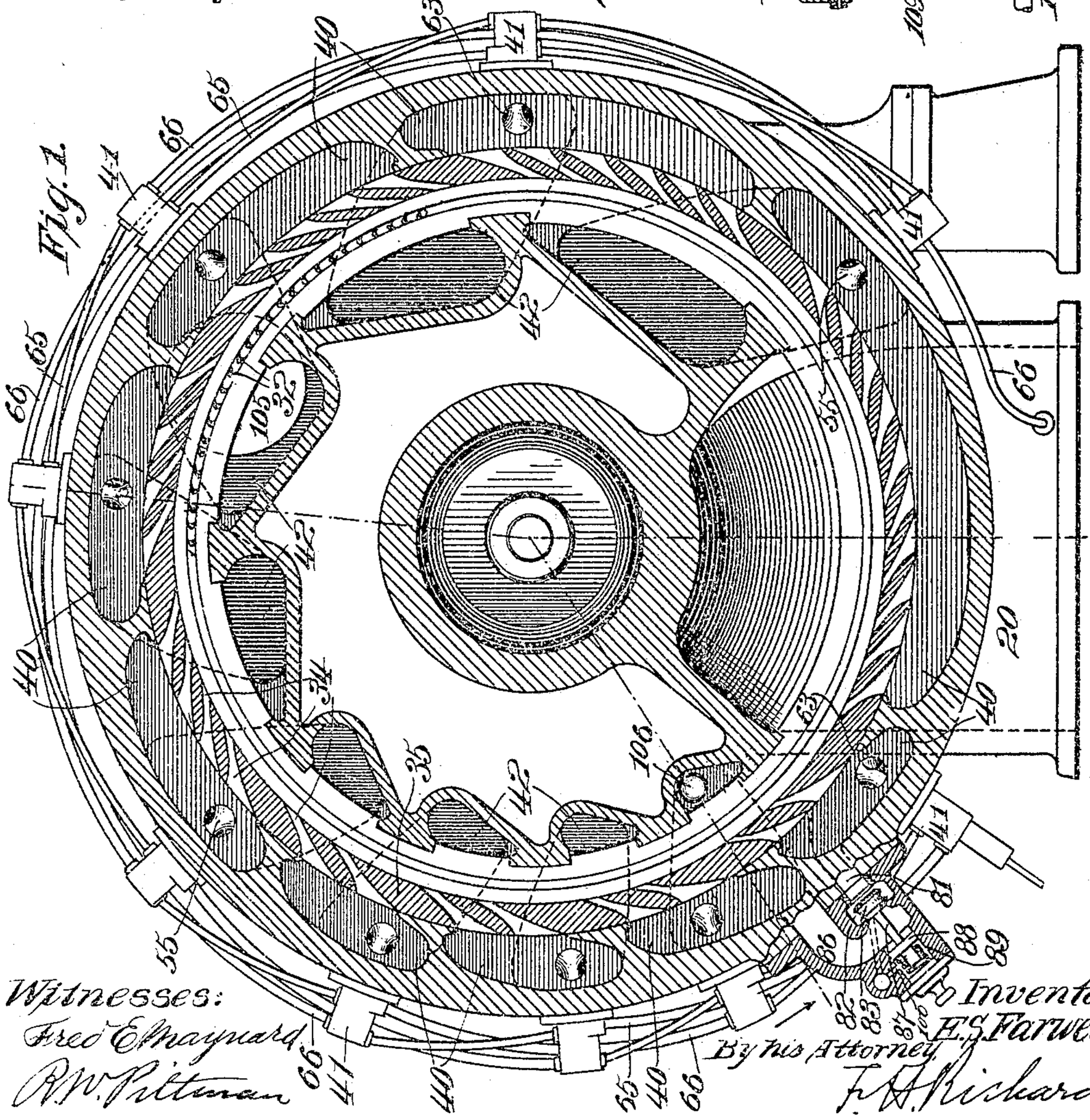


Fig. 1.



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Inventor:
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2 SHEETS—SHEET 2.

Fig. 4.

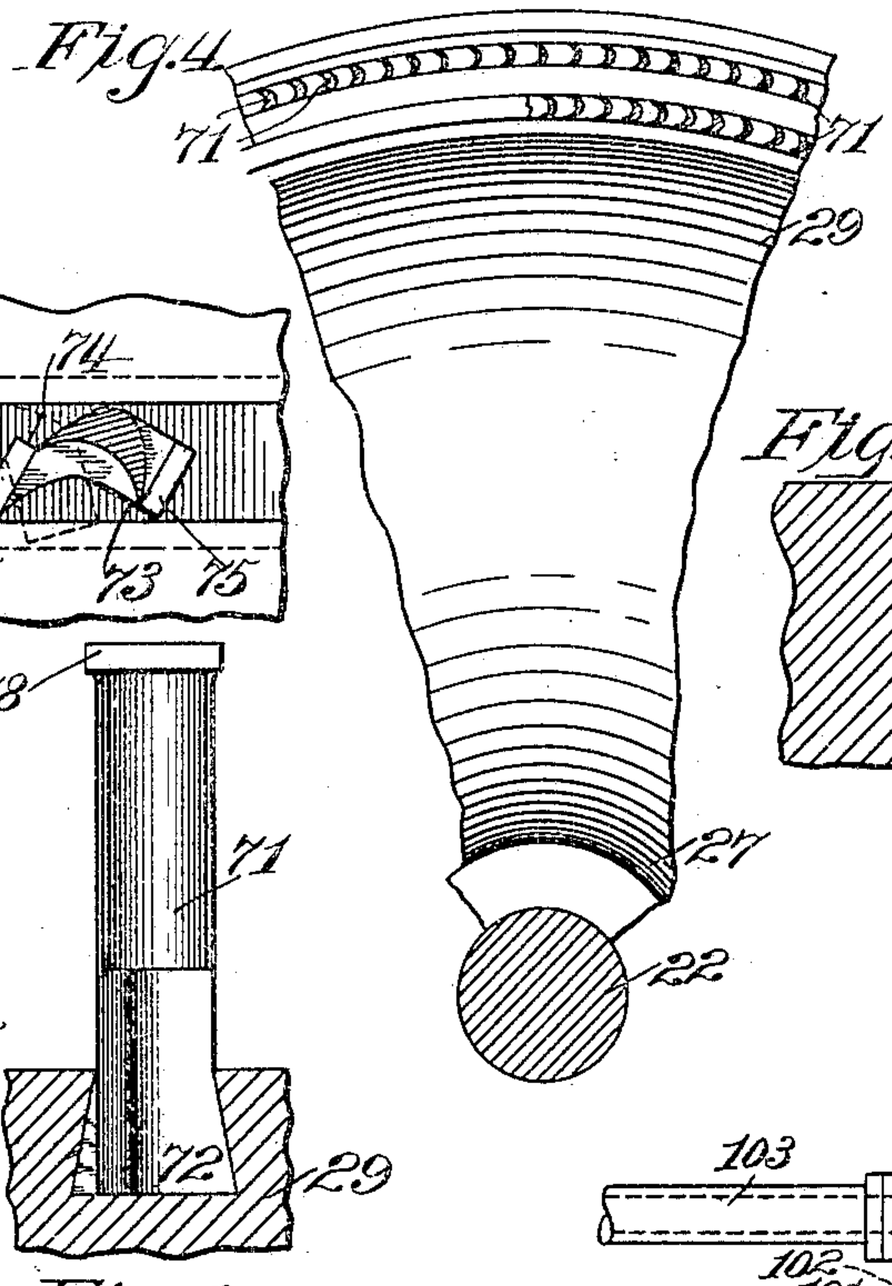


Fig. 5.

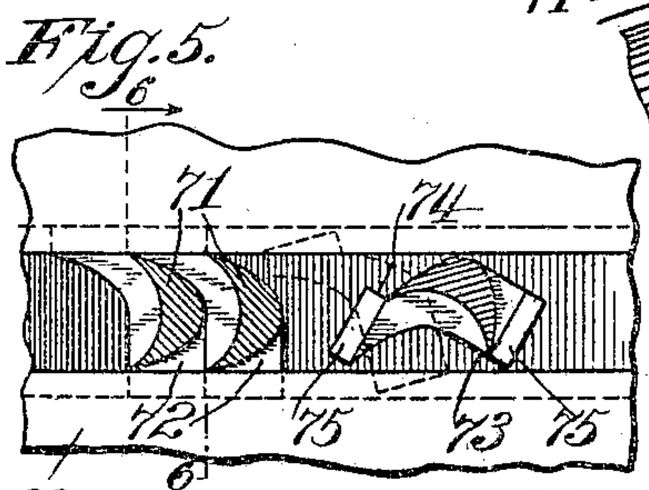


Fig. 7. Fig. 6.

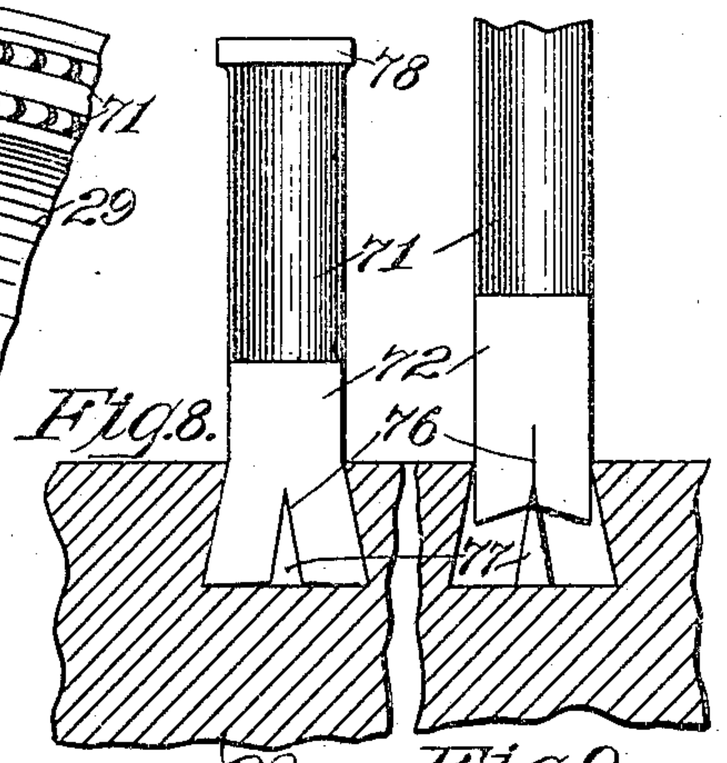


Fig. 8. Fig. 9.

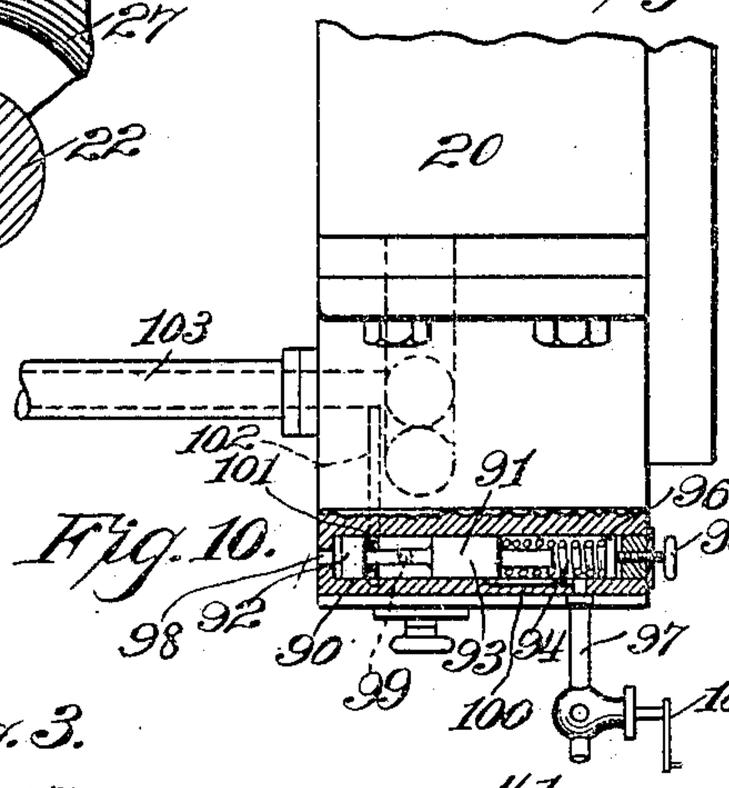


Fig. 10.

Fig. 3.

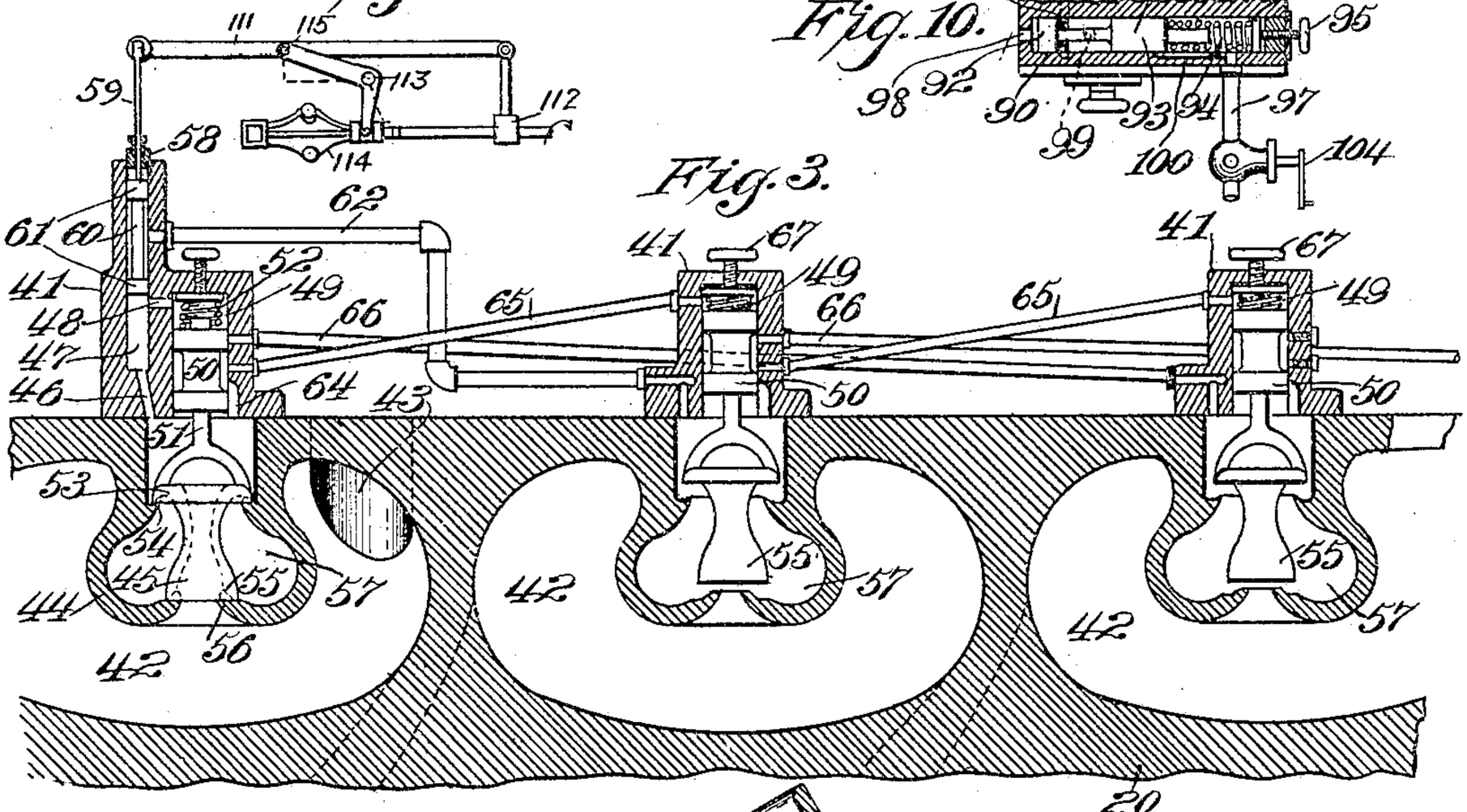
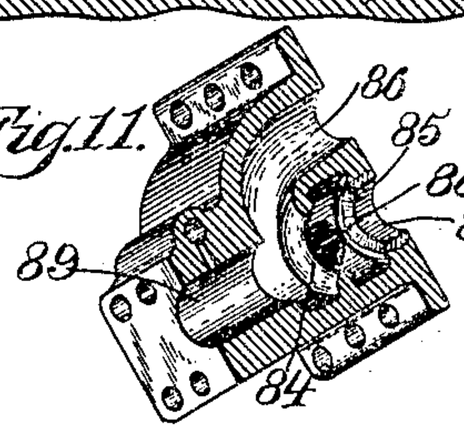


Fig. 11.



Witnesses:

Fred. E. Maynard.

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By his Attorney.

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No. 787,907. Patented April 25, 1905.

UNITED STATES PATENT OFFICE.

ELMER S. FARWELL, OF RIDGEWOOD, NEW JERSEY, ASSIGNOR TO EDWIN H. LUDEMAN, OF BROOKLYN, NEW YORK.

TURBINE-ENGINE.

SPECIFICATION forming part of Letters Patent No. 787,907, dated April 25, 1905.

Application filed December 4, 1903. Serial No. 183,687.

To all whom it may concern:

Be it known that I, ELMER S. FARWELL, a citizen of the United States, residing in Ridgewood, in the county of Bergen and State of New Jersey, have invented certain new and useful Improvements in Turbine-Engines, of which the following is a specification.

This invention relates to and has for an object to provide an improved turbine for utilizing the energy of steam or other elastic fluid under pressure. In such turbines the potential energy of the fluid is first converted into kinetic energy and this transferred to the rotating element by impinging upon a series of vanes or buckets fastened thereto.

In the drawings accompanying and forming a part of this specification an illustration of my invention is shown, wherein—

Figure 1 is a section a little to one side of the center of Fig. 2 and on a line cutting the steam-nozzles. Fig. 2 is a sectional view, the right-hand side whereof is taken on the section-line running from the top to the bottom of Fig. 1 and the left-hand side whereof is taken on such line running from the top to the center and then diverging toward the left and looking in the direction of the arrow pointed toward such diverging line. Fig. 3 is a longitudinal section showing an arrangement of the chambers, valves, and governing mechanism for controlling the steam or other elastic fluid at its successive stages, such view being condensed and partly diagrammatic for convenience of illustration. Fig. 4 is a segment of the turbine-wheel, showing the arrangement of the vanes or buckets. Fig. 5 is a detail view looking at the vanes from the same direction as in Fig. 4, the vanes shown in cross-section and with one of them in the process of being placed in position. Fig. 6 is a section of Fig. 5 on the line 6 6 thereof. Fig. 7 is a side view of Fig. 5. Fig. 8 is a detail showing the manner in which the last vane is secured in place. Fig. 9 is a view of such vane in the process of being secured. Fig. 10 is a detail of a valve to change the initial point of steam-supply, and Fig. 11 is a sectional perspective view of such valve.

In the drawings the device is shown as mounted in a casing (designated in a general way by 20) which has journal-bearings 21 at each side, in which is mounted a journal or shaft 22 of the rotatable element. One end of the shaft in Fig. 2 is shown as broken away. At the other end is a cap 23, held in place by tap-bolts, and in which bearing is provided some suitable bushing 24, which may be separable, the journal or shaft having a series of rings 25 to receive the end thrust. This thrust-bearing may be provided upon one or both ends of the shaft, as occasion may require. The shaft may also be provided with an oil-ring 26 to work in a well-known manner.

As illustrated in Fig. 2, the turbine head or wheel comprises a body portion 27, shown as having a chamber 28 within it for the purpose of lightness, the body being comparatively broad at its point of contact with the journal and gradually tapering down to a thin annular portion 29, from which it again increases in thickness, providing a sufficient body 30, of metal, to carry a suitable seat for the buckets or vanes, (designated in a general way by 31.) In the present instance two concentric rings of vanes are shown upon each side of the wheel, the vanes projecting toward the sides and substantially parallel with the axis of the wheel and are organized to travel upon the respective sides of a ring 32 of guide-vanes or coöperative buckets in the casing. The walls of the casing at 33 nearly approach to the head or flange portion of the wheel which carries the vanes. Steam is admitted through nozzles, (designated in a general way by 34,) so that steam will be admitted to each side of the wheel, thus applying force and pressure to both sides of the wheel and assuring an even running and balance thereof. The admission of steam to the respective sides may be simultaneously or in sequence of order—that is, alternately. If the entire available energy of the steam be transformed into kinetic energy in a single nozzle, the velocity of the steam would be very high. If in addition it is intended to absorb this energy by a single ring of vanes, the velocity of these vanes will be so high as to be very objectionable. If the wheel

is sufficiently small to run with safety, the number of revolutions to give best efficiency may be twenty thousand to thirty thousand per minute. In order to reduce this speed, resort is had to dividing the available energy into several portions, transforming and utilizing each portion in a different part of the mechanism. In the illustration shown the machine has been organized to utilize the steam when divided into nine such portions or stages; but this number of stages may be greater or less, as the necessities of the case require. The velocity of exit from the nozzles will be very much reduced, and by utilizing that on two or more rings of moving vanes the velocity of the vanes may be again reduced to such a point that the turbine may revolve at a moderate speed and be coupled direct to the mechanism desired to be driven without recourse to reducing-gearing. It is not necessary, however, to have an independent ring or rings of vanes for each successive stage. By arranging the nozzles of the successive stages as shown in Figs. 1 and 2 the steam from the nozzles of all the stages will impinge upon the same ring or rings of vanes, but at different points or stations about its path of travel in its revolution.

It may be seen in the drawings that the nozzles for the jets of steam are openings or passages through bodies 35, which in the present instance are annular and are normally organized for disassemblage from the structure. In practice it has been found that the nozzles in such a structure as is here embodied must be accurately adjusted to the rest of the organization and that the passage of steam through such nozzles under certain conditions cuts the nozzles, making it necessary to repair the same or to substitute new ones. If the nozzles are made directly in the casing, it is with difficulty that they are replaced and with greater difficulty and frequently with great expense that the body carrying the same may be remade, whereas by this feature of the invention it is possible to cast a ring which may be turned down to give it an exact and steam-tight juncture with the casing and to drill the holes at the proper angle and to ream the same out as may be desired, thus giving a much lighter and smaller body for the workman to handle and one in which the tools required for its fashioning may be conveniently applied. It will be seen also by reference to Fig. 2 that the casing is made in two sides or sections bolted together, having their juncture at about the center of the wheel, and that two nozzle or jet rings are fastened in place in the casing by the fastening thereof and that they have no independent fastening, but are made to fit within suitably-formed channels and are held in position by bolting the casing together.

The present improvement contemplates the application of steam at its several stages to the same revolving body, the steam being conveyed from point to point or from stage to stage and applied to the rotatable body—the wheel or turbine—in such manner that the engine may be directly coupled to its work. The structure shown in the drawings comtemplates passing the steam from stage to stage and automatically controlling its passage and operation by valves, permitting the steam to act at its successive stages in sequence. There are provided means to utilize the steam at nine stages or to divide it into nine stages in the performance of its work. The steam after its primary admission will traverse nozzles provided therefor, be directed in jets against the first ring of vanes, pass through the vanes, having a reaction upon the same, and be directed by the coöperative ring or rings of guide-vanes upon the succeeding ring of moving vanes, after which the steam will pass to a chamber, which may be considered as an exhaust for this stage, from which it will pass through a valve into another chamber, supplying other nozzles, and be directed in jets against the vanes, again being received in a larger exhaust-chamber, and so on through the successive stages. Each valve is arranged to automatically control the next, and so on around the apparatus, the first valve controlling the initial introduction of steam being actuated by some movable part of the mechanism—as, for instance, a cam or an eccentric or some other convenient device—and may be controlled by a governor. In Fig. 1 there is shown a series of nine chambers, each of which is designated in a general way by 40, and which communicate by nozzles to the vanes or movable part of the engine. It will be seen that each of such chambers is larger than the chamber before it and that the area of the nozzles or the combined area of the nozzles of each chamber progressively increases, the arrangement being such that the interval of discharge of the entire contents of each chamber will be the same for all chambers. Cubic contents of successive chambers will be proportioned to the volume delivered by the corresponding sets of nozzles, depending upon conditions under which the steam is to act in successive stages. By reference to Fig. 3 a number of valves (designated in a general way by 41) will be seen. This view shows the parts in their positions at the very instant of the seating of the valve in the first or left-hand chamber. The valves are located in chambers 42, corresponding to the chambers 42 of Fig. 1, the outlines of which are shown in dotted lines, and all communicate with the chambers 40, as will be apparent from such figure and from Fig. 2. It will be assumed that steam from the boiler is admitted at 43 and finds access within the valve-seat 44 or a portion thereof through the hollow interior of the valve 45 and passes the port 46 to the piston chamber or cylinder 47, where it finds access,

by means of port 48, to a chamber or cylinder 49 at the top of a piston-valve 50, which carries, by means of a stem 51, the valve 45. The steam under pressure—say, for instance, one hundred and fifty pounds—will press upon the piston 50 at both ends. A spring 52 will hold the valve 45 to its seat, its seating in the present instance comprising a top flange 53, resting upon a corresponding flange 54, and the bottom flange 55 resting upon a corresponding flange 56, whereby the valve 45 closes the chamber 57, but permits ready access of the steam-pressure to the parts beyond. The chamber 57 is at all times in free communication with the chamber 40. The cylinder 47 is closed by suitable glands and packing 58, through which enters a rod 59, which will be secured to an eccentric or to some other device for giving it strokes of equal length. Such rod is fastened to a pilot-valve comprising a body portion 60 of smaller area in cross-section than the area of the cylinder 47, and such body carries at its ends pistons 61, having steam-tight fit with the interior of such cylinder. Some convenient means will be employed for imparting to such piston-valves strokes of uniform length, but varying the interval during which steam will be admitted to the chamber 49 according to the load, the interval being controlled by some form of governing device, one form of which is shown in Fig. 3. Attached to the rod 59 is a lever 111, operated by an eccentric 112. Lever 111 has a moving fulcrum attached to one end of the bell-crank 113, the other end of which is connected to the governor 114. The eccentric may be assumed to be of such proportions as to impart to the piston-valve 60 uniform strokes of, say, one inch each. The range of this stroke will be varied by the position of the moving fulcrum 115, which in turn is determined by the position of the governor. The piston-valve 60 may move in the extreme upper portion of the cylinder 47, so as never to place the port 48 in communication with the pipe 62, or it may reciprocate in the lower part of the cylinder 47, so as never to put the ports 46 and 48 into communication, depending entirely upon the speed which the turbine gives to the governor. Upon the pilot-valve occupying the position shown in Fig. 3 the valve 45 in the first chamber will be held upon its seat and no steam will be admitted to the chamber 40, controlled by such first valve, and the succeeding valves will also close in rapid succession, so that no steam will be admitted to any of the chambers to perform work; but upon the governing device changing the stroke, so that one of the pistons 61 will occupy a position below the port 48, communication will be cut off between the boiler-steam and the chamber 49 and steam will be exhausted from such chamber through the cylinder 47 and the pipe 62, which will then make the steam-pressure upon the lower end of the piston 50 greater than the steam-pressure upon its upper end and will unseat the valve 45 against the pressure of its spring, permitting the steam within the chamber 42 to find access through the chamber 57 and the port 63 into the communicating chamber 40, whereupon it will pass through the nozzles in jets against the ring of vanes, imparting movement to the same and passing from such ring of vanes into the next succeeding chamber 42, which in the diagram of Fig. 3 is the central chamber. The steam when it gets to this chamber may be considered as at one hundred and twenty pounds pressure, and for the purpose of this description it will be assumed that the piston 61 has not been again raised, permitting the valve 45 to remain open, whereby the charge of steam first admitted will pass to the second chamber 42 and will be free to pass through the second chamber 57 into the next succeeding chamber 40, and so on through the various nozzles. After the piston 61 has been again raised the first or left-hand valve 45 will assume the position shown, in which position steam will enter through a by-pass 64 in the cylinder 49 and find passage by the pipe 65 to the upper part of the cylinder 49 of the second valve and press such valve to its seat. Upon the raising of the piston-valve 50 the port of the pipe 66 is opened, so that steam will exhaust from above the second piston-valve 50 through the pipe 65, the chamber 49 of the first valve, and the pipe 66 to the third chamber 42, the pressure in which may be at about ninety pounds. If there are but three valves in the engine, the last of the series will be exhausted, the same as the second valve, except the pipe 66 in this instance will go to the exhaust instead of to another valve. Thus it will be seen that each valve works the next in the series. The first valve being operated by some suitable part of the engine dominates all the rest, although each valve is controlled by the valve immediately preceding. The springs 52 may be adjusted by hand-wheels or set-screws 67. In Fig. 3 there are shown three chambers and three valves. This is for the purpose of illustration merely, although in some instances an engine may be built embodying the features of my invention wherein the entire energy of the steam will be utilized in three stages; but at Fig. 1 there are shown compartments and valves to utilize the steam at nine stages, the operation being substantially the same as in Fig. 3, it of course being apparent that the mere multiplication of this operating apparatus in the detailed description would be burdensome rather than instructive. The pipes and various parts in Fig. 1 have the same reference characters applied to them as in the diagrammatic illustration of Fig. 3, and the pipe 66 from the next to the last valve-piston cylinder runs into the exhaust. By this system of controlling the

steam or expansive fluid in its passage from one point of utilization to another in the system it is possible to permit the governor to control the steam almost instantly. It will be seen that after the governor has seated the first valve that valve will seat the others, and the steam will be held imprisoned in the several compartments 42 until such a time as the governor permits the first valve to become active, in its turn opening the others. If the governor only controlled the first valve and permitted the steam which had passed it to escape through the jets at all the stages, the engine might run away with itself and do damage; but by this organization all the valves are automatically closed by the engine responsive to the closing of the first valve.

The vanes or buckets and the guide-vanes may be arranged in channels about the wheel and about the casing, which channels in practice may be undercut, and each vane will have a steam receiving or working body portion 71 and a base 72, conforming to the undercut channel. The vanes may be placed in position, as shown in Fig. 5, inserting them sidewise into the channel, then turning them to position, as is shown in full-line and dotted-line position. The ends of the base are dodged—that is, the front face 73 of one end is on a line with the rear face 74 of the other end, which line is at about right angles to the faces 75 of such ends. This conformation permits the bases to readily turn in a channel of their own width. The last one or two vanes, however, cannot be so positioned, owing to there being no room in which they may turn.

When the vanes are being placed in the channel, they may be driven up tightly together by means of slight blows of a hammer, and as the workman approaches the completion of the ring of vanes he will decide how many vanes the space will take and will drive the vanes tighter together or will pass around the circle with some convenient implement and slightly separate the same, somewhat after the manner a compositor justifies his type, after which the end vanes will be inserted. These last vanes will have some other means of securement than turning them to position, and to accomplish the setting of the last vanes the same may be provided with split ends 76, as seen in Figs. 8 and 9, and may be held in place by a suitable wedge 77, the wedge being placed in position, the vanes driven in, as shown in Fig. 9, and into the position shown in Fig. 8. The vanes may be provided with heads 78, which may rest one against the other to steady the vanes.

After the vanes have been justified they may be "staked" in, so that the sides of the vane-bases will be securely clamped in position and prevent any movement of the vanes relative to the body which carries the same.

Engines of this class are frequently connected to work in such a manner that additional load will be thrown upon them suddenly, whereupon it will be necessary to instantly and automatically compensate for such changes even at the expense of using a greater amount of steam for a short period. Similarly an increased demand for steam results from a loss of vacuum due to the condenser being overburdened or for some reason refusing to act. It will be seen in Fig. 1, as was heretofore pointed out, that the area of the nozzles or the sum of the area of the nozzles for each of the stages increases, so that under normal conditions and getting the full benefit of the steam the steam will be first applied in jets of the smallest and minimum area; but when the additional load is thrown upon the engine by shifting the entry of steam to nozzles of larger area than that of the first set of nozzles more power can be brought to bear upon the vanes, and at each successive stage of such admission of steam more power will be had, although a greater amount of steam will be consumed for each initial charge. By cutting out the nozzles of smallest area a less number of nozzles is employed and the steam is used at a less number of stages, it being divided into a smaller number of successive stages. The foregoing shifting of nozzles may be automatically accomplished by the means shown in Figs. 1 and 10. Steam is admitted to the engine by the port 80 and passes to the first of the chambers 40 by the conduit 81. The port 80 is within a valve-chamber or steam-box 82, having a valve 83 therein, adapted to seat on a seat 84 to throw the steam into conduit 81 and to seat on a seat 85 to throw the steam into a conduit 86, leading to the second or a later chamber 40. The double-faced valve 83 carries a stem 87, upon which is fast a piston 88, mounted in a cylinder 89, the head 90 of which cylinder is removable. To control the valve 83, a pilot-valve is employed (shown in Fig. 10) which comprises a cylinder 90, in which is mounted a piston-valve 91, which comprises a reduced body portion and a pair of enlarged ends 92 and 93, having working steam-tight fit with the cylinder. At one end of the cylinder is a coiled spring 94, adjusted by means of a set-screw 95. The chamber 96, containing the spring, is connected, by means of the pipe 97, to the condenser. When a vacuum is maintained in this chamber, the atmospheric pressure acting through the opening 98 overcomes the tension of the spring and pushes the valve 91 to the opposite end. In this position the cylinder 89 is exhausted through conduit 99, the reduced portion of valve 91, and by-pass 100 to the condenser, when the steam-pressure on the under side of the piston 88 raises the valve 83 to the seat 84, admitting steam to the first chamber by way of conduit 81. Should the vacuum in the chamber 96 be destroyed in any manner, the spring 94 will shift the valve 91 to the position shown in Fig. 12. In this

position steam will enter the cylinder 89 through the now open port 101, supplied from the conduit 102 from the main steam-pipe 103, which supplies the port 80 and by the aid of the spring will throw the valve 83 onto the seat 85, admitting steam to the second or succeeding chamber 40 through the conduit 86. The vacuum in chamber 96 may be destroyed either as a result of the condenser losing its vacuum or by the governor opening the vacuum-breaking valve 104. Should the load require more steam than the full capacity of the nozzles in the first stage, the governor will break the vacuum in the chamber 96, but not in the condenser, and shift the valve 83 to the seat 85, and when the load becomes less again the governor will close the vacuum-breaking valve 104 and the valve 83 will return to its normal seat 84, as already described. The same actions will follow the loss of vacuum by the condenser. In the latter case, as fewer stages are required to expand the steam to atmosphere when maintaining approximately the same ratio of expansion, an exhaust 105 is provided on the exhaust-chamber 42 from one of the later stages. On this outlet 105 is an automatic relief-valve set to open at any predetermined pressure. As the construction of this relief-valve is well known in the art and forms no part of my invention, it is not shown in the drawings. When the valve 83 is shifted to admit steam through the passage 86 to one of the later stages, it is necessary to have a valve 106 to prevent the steam from flowing backward through the chamber 42 to the vanes of the wheel, which would result in considerable loss of steam. This valve is also operated automatically by a small pilot-valve 107, similar to that shown in Fig. 10. When a vacuum is maintained, this valve 107 will remain open, and when the vacuum is destroyed steam is admitted back of the piston 108, forcing the valve to its seat, the pipes 109 and 110 corresponding to conduit 102 and pipe 97.

The present form of engine utilizes the steam in each of several successive stages and passes the same at each stage through the same ring of vanes, which ring may either be one or more contiguous rings, the steam being passed through the same several times. In the present instance the device is shown as capable of passing the steam through such ring of vanes nine times. The nozzle area through each stage increases from the first to the last stage, and when load is thrown upon the engine steam may be admitted to the second or a later chamber, so as to utilize the enlarged area of the nozzles from such chamber. By this means it is possible to admit steam through large nozzles without having a multiplication of unnecessary nozzles which will only be used as such occasions of emergency, but which will be normally inactive. In this organization all the nozzles are normally active, the steam being admitted at a different point to take advantage of the condition of the nozzles at such later period.

Although this invention is described as operated by steam, it may equally well be operated by any other elastic fluid without departing from the spirit of my invention.

Having described my invention, I claim—

1. In a turbine-engine, the combination with a rotatable element having upon it a ring of vanes, of chambers about the path of movement of such element; nozzles from said chambers to pass steam to the vanes; chambers to receive the steam after its passage, the same to store it for a subsequent passage; automatically-controlled valves to admit the steam from the second chambers into the first chambers for such subsequent passage.

2. In a turbine-engine, the combination with a rotatable element having upon each side of its periphery a number of concentric rings of vanes or buckets, of a ring of guide vanes or buckets coöperative therewith; a series of chambers about the path of movement of the buckets upon each side of the element; a second series of chambers about such path; nozzles for admitting fluid from the respective chambers of the first series through the buckets and into the chambers of the second series; ports between the several chambers of the second series and the respective chambers of the first series; valves to control such ports; steam-controlled means to actuate the valves successively one from the other; and governor-controlled means to actuate one of the valves.

3. In a turbine-engine, the combination with a rotatable element having upon it a ring of vanes or buckets, of a series of chambers about the path of movement of such element; a second series of chambers about such path; nozzles for admitting fluid from the respective chambers of the first series through the ring of buckets and into the chambers of the second series; means of communicating between the several chambers of the second series and the respective chambers of the first series; valves for controlling such communication; and steam-controlled means for actuating the valves successively one from the other.

4. In a turbine-engine, the combination with a rotatable element having upon it a ring of vanes or buckets, of a series of chambers contiguous to the path of movement of such element; a second series of chambers contiguous to such path; automatic means to control the admission of steam to one of the chambers of the first series; nozzles for admitting fluid from one of the first series of chambers through the ring of buckets and into one of the chambers of the second series; means of communication between such chamber of the second series and the succeeding chamber of

the first series; a valve to control such communication; and steam-actuated means to control the valve.

5. In a turbine-engine, the combination with a wheel having about its perimeter a ring of vanes disposed substantially parallel with the axis of the wheel; a ring of nozzles for directing the jets of steam upon the vanes the prolongation of the line of jet forming a secant to such ring; a series of chambers outside of the nozzle-ring to receive steam and discharge the same through the nozzles; a series of chambers within the nozzle-ring to respectively receive the steam discharged from the several chambers of the first series; and automatically-controlled means to admit the steam from the chambers of the second series respectively into the chambers of the first series.

6. In a turbine-engine, the combination with a wheel having about its perimeter a ring of vanes disposed substantially parallel with the axis of the wheel; a ring of nozzles for directing the jets of steam upon the vanes the prolongation of the line of jet forming a secant to such ring; a series of chambers outside of the nozzle-ring to receive steam and discharge the same through the nozzles; a series of chambers within the nozzle-ring to respectively receive the steam discharged from the several chambers of the first series; and automatically-controlled means to admit the steam from the chambers of the second series respectively into the chambers of the first series, but each to a later chamber than that from which it received the steam.

7. In a turbine-engine, the combination with a casing, of a wheel journaled therein; a ring of vanes carried upon each side of the perimeter of the wheel; means to divide the expansion of steam into several stages; a valve and port to control the passage of steam from one stage to the next stage; and automatic means to actuate said valves.

8. In a turbine-engine, the combination with a casing, of a wheel journaled therein; a ring of vanes carried upon each side of the perimeter of the wheel; means for supplying steam at several successive stages to such vanes upon each side; and automatic means to control the steam at each stage.

9. In a turbine-engine, the combination with a casing, of a wheel journaled therein; a ring of vanes carried upon each side of the perimeter of the wheel; means for supplying steam at several successive stages to such vanes upon each side; a series of valves to control the steam at each stage; and automatic means to actuate the valves.

10. In a turbine-engine, the combination with the casing, of a turbine-head mounted therein; vanes upon the turbine-head; nozzles organized to direct steam upon the vanes; and a series of chambers for supplying portions of the nozzles successively with steam; a governor-actuated valve to control the admission of steam to the first chamber of the series; and valves to control the admission of steam to each succeeding chamber, each actuated by the preceding valve.

11. In a turbine-engine, the combination with a turbine-head carrying a number of vanes, of a number of chambers surrounding the same, chambers upon the opposite side of the ring of vanes to receive the fluid; and valves for admitting the fluid from one receiving-chamber to the next supply-chamber in sequence.

12. In a turbine-engine, the combination with a rotatable body and a ring of vanes carried thereby, of means to direct steam upon the vanes at successive stages; a chamber for each of such directing means proportionate to each of the others to discharge in equal timing therewith; a chamber to receive the steam at each stage after its passage through the vanes; a valved conduit from each of the respective receiving-chambers to the next succeeding primary chambers; and means to actuate the valves of such conduits in sequence.

13. In a turbine-engine, the combination with a rotatable body and a ring of vanes carried thereby, of means to direct steam upon the vanes at successive stages; a chamber for each of such directing means proportionate to each of the others to discharge in equal timing therewith; a chamber to receive the steam at each stage after its passage through the vanes; a valved conduit from each of the respective receiving-chambers to the next succeeding primary chambers; and automatic means to actuate the valves of such conduits in sequence.

14. In a turbine-engine, the combination with a rotatable body and a ring of vanes carried thereby, of means to direct steam upon the vanes at successive stages; a chamber for each of such directing means proportionate to each of the others to discharge in equal timing therewith; a chamber to receive the steam at each stage after its passage through the vanes, a valved conduit from each of the respective receiving-chambers to the next succeeding primary chambers; and means controlled by the steam-pressure to actuate the valves.

15. In a turbine-engine, the combination with a rotatable body and a series of buckets carried thereby, of nozzles to direct steam upon such buckets; a number of chambers each constituting a steam-chest for a distinctive portion of the nozzles; ports thereto from the chambers; a valve to control each of such ports; yieldable means to seat the same; a piston-valve cylinder adjacent to each valve closed at one end and open to the steam-pressure of the chest at the other end; a piston-valve within each cylinder and carrying the valve; a slide-valve cylinder open at one end to the steam at the pressure of the first steam-

chest; a port from the median portion of the slide-valve cylinder to the closed end of the first valve-cylinder; a port from such slide-valve cylinder at a point beyond such port to the second steam-chest, the organization being such that the slide-valve may admit steam to the closed end of the first valve-cylinder to hold the valve on its seat, and upon movement may exhaust from such cylinder into the second chest and permit the first valve to open; a port from each valve-cylinder at a position to be closed by the movement of the piston-valve to the open end of the cylinder and opened by the said piston-valve when at the closed end of the cylinder to the closed end of the next succeeding cylinder; a by-pass adapted to be opened and closed by said respective movements of the piston-valve to the steam-chest to pass steam from one chest through such port to the cylinder of the next piston-valve to cause the same to open and close responsive to the opening and closing of the previous valve; a port from each piston-valve cylinder to the second succeeding steam-chest and from the next to the last of the series to the exhaust, and opened to the ports from the succeeding piston-valve cylinder by the opening of the valve, whereby one valve upon its opening permits the next succeeding valve to open, and upon closing permits the same to close.

16. The combination with a movable element, of impact-receiving members thereon; means to direct jets of steam thereon; a number of steam-chests; a port from each steam-chest to a portion of the jet-directing means; a valve to close each port; yieldable means to close each valve; means to maintain a balanced steam-pressure on each side thereof; means to exhaust from one side of the first of the closing means to overbalance the yieldability thereof; and means controlled by each valve to overbalance the yieldability of the closing means of the next succeeding valve.

17. In a turbine-engine, the combination with a wheel, of a casing therefor divided into two portions on substantially the plane of the center of the wheel; means to secure said portions together; a ring of buckets on each side of the perimeter of the wheel; a pair of nozzle-rings one for each side of the wheel and held in place by the securement of the casing; a series of chambers about the path of movement of each of such rings of buckets and in communication with the respective nozzle-rings; a second series of chambers adjacent to each of the first series and adapted to receive fluid after its passage through the nozzles and the buckets; means of communication between the several chambers of the second series and the respective chambers of the first series upon each side of the wheel; valves for controlling such communication; and fluid-controlled means to actuate the valves successively one from the other.

18. In a turbine-engine, the combination with a wheel, of a casing therefor divided into two portions; means to secure said portions together; buckets on the perimeter of the wheel; a nozzle-ring held in place by the securement of the casing; a series of chambers about the path of movement of such wheel and in communication with the nozzle-ring; a second series of chambers adjacent thereto and adapted to receive fluid after its passage through the nozzles and the buckets; means of communication between the several chambers of the second series and the respective chambers of the first series; valves for controlling such communication; and fluid-controlled means to actuate the valves successively one from the other.

19. In a turbine-engine, the combination with a wheel carrying vanes; of means to direct steam upon the vanes at each of several successive stages; a port to pass the steam from one stage to the next successive stage; valves to control such ports; means controlled automatically by the load to actuate the first valve; and means controlled by such first valve to actuate the balance of the valves in sequence.

20. In a turbine-engine, the combination with a rotatable body; of buckets or vanes carried thereby to receive steam at each of several successive stages; chambers to divide the steam into a number of stages; nozzles communicating from such chambers to the buckets; a supply; a valve to control the steam at its supply and direct the same into the first or a succeeding chamber; and comprising a valve having a seat at each end; ports running from the said seats to the said respective chambers; a piston carried by such valve; a cylinder for the piston; a pilot-piston adjacent thereto open at one end to the exhaust and at the other end to the atmosphere; a spring for pressing the piston against the atmosphere; a chamber medially disposed in such piston; a port from the supply to such chamber; a port from such chamber to the piston on said valve; a by-pass around the piston to make communication between the port going to the valve-piston and the port to the exhaust; and governor-controlled means for breaking the vacuum in such port.

21. In a turbine-engine, the combination with a wheel having buckets thereon; of chambers to receive steam at each of several successive stages; nozzles to pass the steam to the buckets; chambers to receive the steam and pass it to the next successive chamber; a supply; an exhaust; a valve to direct the steam into the first or the succeeding chamber; means controlled by the governor and by the exhaust to actuate said valve; a valve to prevent the back pressure reaching the first chamber when cut out; a piston carried by said valve; a pilot-valve to control the same open at one end to the exhaust and at the other end to the atmosphere; a chamber in such pilot-

valve; and ports controlled by the same to admit steam to such piston or to exhaust from the same; and means connected to the governor to actuate the same.

22. In a turbine-engine, the combination with a wheel carrying vanes; of means to direct steam upon the vanes at each of several successive stages; a port to pass the steam from one stage to the next successive stage; valves to control such ports; means controlled automatically by the load to actuate the first valve; and means controlled by such first valve to actuate the balance of the valves in sequence and comprising yieldable means to seat the valves; a slide-valve cylinder open at one end to the steam at the pressure of the first stage; ports controlled by the slide-valve to open and close said valves; and governor-controlled means to actuate the slide-valve.

23. In a turbine-engine, the combination with a rotatable body, and vanes carried thereby; of means to direct expansive fluid under pressure upon the vanes at successive stages; means to receive the fluid from each stage after its passage through the vanes; ports to admit steam from such means to the next set of nozzles; valves to control such ports; and automatic means to actuate the valves in sequence.

24. In a turbine-engine, the combination with a rotatable body, and a ring of vanes carried thereby; of means to direct expansive fluid under pressure upon the vanes at successive stages; means to receive the fluid from each stage after its passage through the vanes; ports to admit steam from such means to the next set of nozzles; valves to control such ports; and means automatically controlled by the load to actuate said valves.

25. In a turbine-engine, the combination with a wheel carrying a ring of vanes; means to direct steam upon the vanes at each of several successive stages; a port to pass the steam from one stage to the next successive stage; a valve to control such port; and means to actuate the valve in sequence.

26. A turbine-engine having a rotary element carrying concentric rings of vanes; a casing therefor having vanes interposed between the vanes upon said rotary element; means to direct steam successively against said rings of vanes at each of several portions thereof; and automatic valves to control the admission of steam to such several portions.

27. In a turbine-engine, employing steam at several successive stages; a governing mechanism comprising a series of valves to control the admission of steam to such stages; means to actuate the first valve; and means controlled by such first valve to actuate the balance of the valves in sequence.

28. In a turbine-engine, a governing mechanism comprising a series of valves all of which are in active operation; means to actuate the first valve; and means controlled by each valve to actuate the next succeeding valve.

29. In a turbine-engine employing steam at several successive stages; a governing mechanism comprising a series of valves to control the admission of steam to such stages, and means to periodically actuate said valves in sequence.

30. In a turbine-engine, employing steam at several successive stages; a governing mechanism comprising a valve for each stage; means to close each valve; means to maintain a balanced steam-pressure on each side thereof; means to exhaust from one side of the first of the closing means, to open the valve; and means controlled by each valve to open the next succeeding valve.

31. In a turbine-engine, the combination with a casing, of a wheel rotatable therein and carrying a number of rings of vanes; and a nozzle-ring for each ring of vanes, the nozzle-rings severally constituted for disassemblage from the engine.

32. In a turbine-engine the combination with a wheel, of a casing therefor divided on substantially the central plane of the wheel; means to secure the portions of the casing together; means on the wheel to receive the impulse from jets of steam; and a ring perforate with nozzles to direct jets upon said means and held between the portions of the casing by said securing means.

33. In a turbine-engine the combination with a wheel, of a casing therefor divided into two portions on substantially the plane of the center of the wheel; means to secure said portions together; a ring of buckets on each side of the perimeter of the wheel; and a pair of nozzle-rings one for each side of the wheel and held in place by the securement of the casing.

34. In a turbine-engine, the combination with a body carrying vanes; of a series of sets of nozzles delivering intermittently jets of steam against such vanes; a chamber supplying each set of nozzles, each chamber and its set of nozzles being proportioned to discharge its contents in equal time with that of every other chamber and set of nozzles.

35. In a turbine-engine the combination with a body carrying vanes, of a series of sets of nozzles delivering intermittent jets of steam against such vanes in successive stages; a series of chambers each supplying a set of nozzles, such chambers having a progressively-increasing cubic capacity proportionate with the discharge capacity of their respective sets of nozzles, that the contents of every chamber shall be discharged in equal intervals of time.

36. In a turbine-engine the combination with a plurality of expansion-chambers to accommodate the successive stages of steam in

its work; of ports to the respective chambers progressively increasing in delivery capacity; means to supply steam; an exhaust; and means controlled by the load to determine at which chamber the steam shall be supplied.

37. In a turbine-engine, the combination with a plurality of expansion-chambers to accommodate the successive stages of steam in its work; each successive chamber adapted to contain steam at a lower pressure; of ports to the respective chambers progressively increasing in delivery capacity; means to supply steam; a primary exhaust; and automatic means to connect one of the chambers containing steam below atmospheric pressure with a secondary exhaust.

38. In a turbine-engine, the combination with a body adapted to be driven by steam, of a series of expansion-chambers effective in sequence upon said body at successive stages of the steam each at a lower pressure; ports from chamber to chamber progressively increasing in delivery capacity; means to exhaust by vacuum from the end of the series; means to supply steam to the first or a succeeding chamber of the series; means controlled by loss of vacuum to admit steam to the second or a succeeding chamber; and means also controlled by loss of vacuum to connect one of the chambers normally containing the steam at a pressure below atmosphere with the atmosphere.

39. In an engine, the combination with a body adapted to be driven by steam, of a series of expansion-chambers effective in sequence upon said body at successive stages of the steam; ports from chamber to chamber progressively increasing in delivery capacity; means to exhaust by vacuum from the end of the series; means to supply to the beginning of the series; and means controlled by loss of vacuum to cut out one or more of the ports and chambers at both ends of the series.

40. In an engine, the combination with a body adapted to be driven by steam, of a series of expansion-chambers effective in sequence upon said body at successive stages of the steam; ports from chamber to chamber progressively increasing in delivery capacity; means to exhaust by vacuum from the end of the series; means to supply to the beginning of the series; and automatic means to cut out one or more of the ports and chambers at the beginning of the series.

41. In an engine, the combination with a body adapted to be driven by steam, of a series of expansion-chambers effective in sequence upon said body at successive stages of the steam; ports from chamber to chamber progressively increasing in delivery capacity; means to exhaust by vacuum from the end of the series; means to supply to the beginning of the series; and means controlled by the load to cut out one or more of the ports and chambers at the beginning of the series.

42. In a turbine-engine, the combination with a member having an undercut channel for the reception of vanes, of a series of vanes each having a flaring base portion whereby the vanes may be secured within such channel, and means to secure the last vane of the ring comprising a vane having an end equal in width to the width of the channel, a split in such end, and a wedge to spread the same to embrace the undercut.

43. In a turbine-engine, the combination with a member, of an undercut channel therein; buckets carried thereby and comprising a body portion, a base portion to enter the said channel and having end faces flaring to fit the same, such end faces disposed upon the respective sides of a line transverse to their planes.

44. In a turbine-engine, the combination with a member, of an undercut channel therein; buckets carried thereby and comprising a body portion, a base portion to enter the said channel and having end faces flaring to fit the same, such end faces disposed upon the respective sides of a line transverse to their planes, and heads to abut each other.

45. In a turbine-engine, the combination with a wheel, of an undercut channel therein; buckets carried thereby and comprising a body portion; a base portion to enter the said channel and having end faces flaring to fit the same, such end faces disposed upon the respective sides of a line transverse to their planes, and vanes having bases split to receive wedges to cause the same to conform to the channel.

46. In a turbine-engine, the combination with a rotatable body and a series of buckets carried thereby, of nozzles to direct steam upon such buckets; a number of chambers each constituting a steam-chest for a distinctive portion of the nozzles; a valve to control the admission to each of such chambers; a cylinder adjacent to each valve open to the steam-pressure of the chest at one end; a piston within each cylinder connected to the valve and operating as a valve to control the succeeding valve; and means for controlling the first valve of the series.

47. In a controlling mechanism for a turbine-engine, the combination with two or more valves and seats forming exits for corresponding chests, of a cylinder adjacent to each valve closed at one end and open at the chest at the other end; a piston within such cylinder connected to and operating the valve; a pilot-valve controlling admission to and exhaust from the closed end of the cylinder; ports in the cylinder so placed that the piston working in the cylinder will control the admission to and exhaust from the closed end of the succeeding cylinder; and means for operating said pilot-valve.

48. In a turbine-engine the combination with a rotatable body, of buckets or vanes carried thereby to receive expansive fluid at

each of several successive stages; chambers to divide the steam into a number of stages; a supply; and a valve to control the fluid at its supply and direct the same into the first or a succeeding chamber.

49. In a turbine-engine the combination with a rotatable body, of buckets or vanes carried thereby to receive expansive fluid at each of several successive stages; chambers to divide the steam into a number of stages; nozzles communicating from such chambers to the buckets; a supply; and a valve to control the fluid at its supply and direct the same into the first or a succeeding chamber, and comprising a valve having a seat at each end; ports running from said seats to the said respective chambers; and means for automatically shifting the valve from one seat to the other.

50. In a turbine-engine the combination with a rotatable body, of buckets or vanes carried thereby to receive expansive fluid at each of several successive stages; chambers to divide the fluid into a number of stages; nozzles communicating from such chambers to the buckets; a supply; and a valve to control the fluid at its supply and direct the same into the first or a succeeding chamber, and comprising a valve having a seat at each end; ports running from the said seats to the said respective chambers; a piston carried by such valve, a cylinder for the piston, a pilot-valve adjacent thereto adapted to control the port to said valve-piston; and governor-controlled means for operating said pilot-valve.

51. In a turbine-engine, the combination with a wheel having buckets thereon; of chambers to receive steam at each of several successive stages; nozzles to pass the steam to the buckets; chambers to receive the steam and pass it to the next successive chamber; a supply; an exhaust; a valve to direct the steam into the first or a succeeding chamber; means controlled by the governor and by the exhaust to actuate said valve; a valve to prevent the back pressure reaching the first chamber when cut out; and automatic means for operating said valve.

52. In a turbine-engine, the combination with a wheel having buckets thereon; of chambers to receive steam at each of several successive stages; nozzles to pass the steam to the buckets; chambers to receive the steam and pass it to the next successive chamber; means controlled by the governor and by the exhaust to actuate said valve; a valve to prevent the back pressure reaching the first chamber when cut out; a piston carried by said valve moving in a suitable cylinder; a pilot-valve to control the admission to the exhaust from the cylinder; and means for operating said pilot-valve.

53. In a turbine-engine, the combination with a casing having a series of chambers formed therein separated by partitions integral with the casing; of a nozzle-ring slightly conical on its surface; a surface of said casing and partitions correspondingly conical; said nozzle-ring when in place forming one wall of the said chambers and making a tight fit with said casing and partitions; and means for securing said nozzle-ring in place.

54. In a turbine-engine the combination with a member, of an undercut channel therein; buckets carried thereby and comprising a body portion, a base portion to enter the said channel equal in width to the width of the channel; a split in such base and a wedge to spread the same to embrace the undercut.

55. A bucket for a turbine-engine comprising a body portion, a base portion having opposite faces substantially parallel; a split in such base and a wedge to spread the same for the purpose of fastening.

Signed at Nos. 9 to 15 Murray street, New York, N. Y., this 1st day of December, 1903.

ELMER S. FARWELL.

Witnesses:
CHAS. LYON RUSSELL,
C. A. WEED.