No. 755,756. PATENTED MAR. 29, 1904.

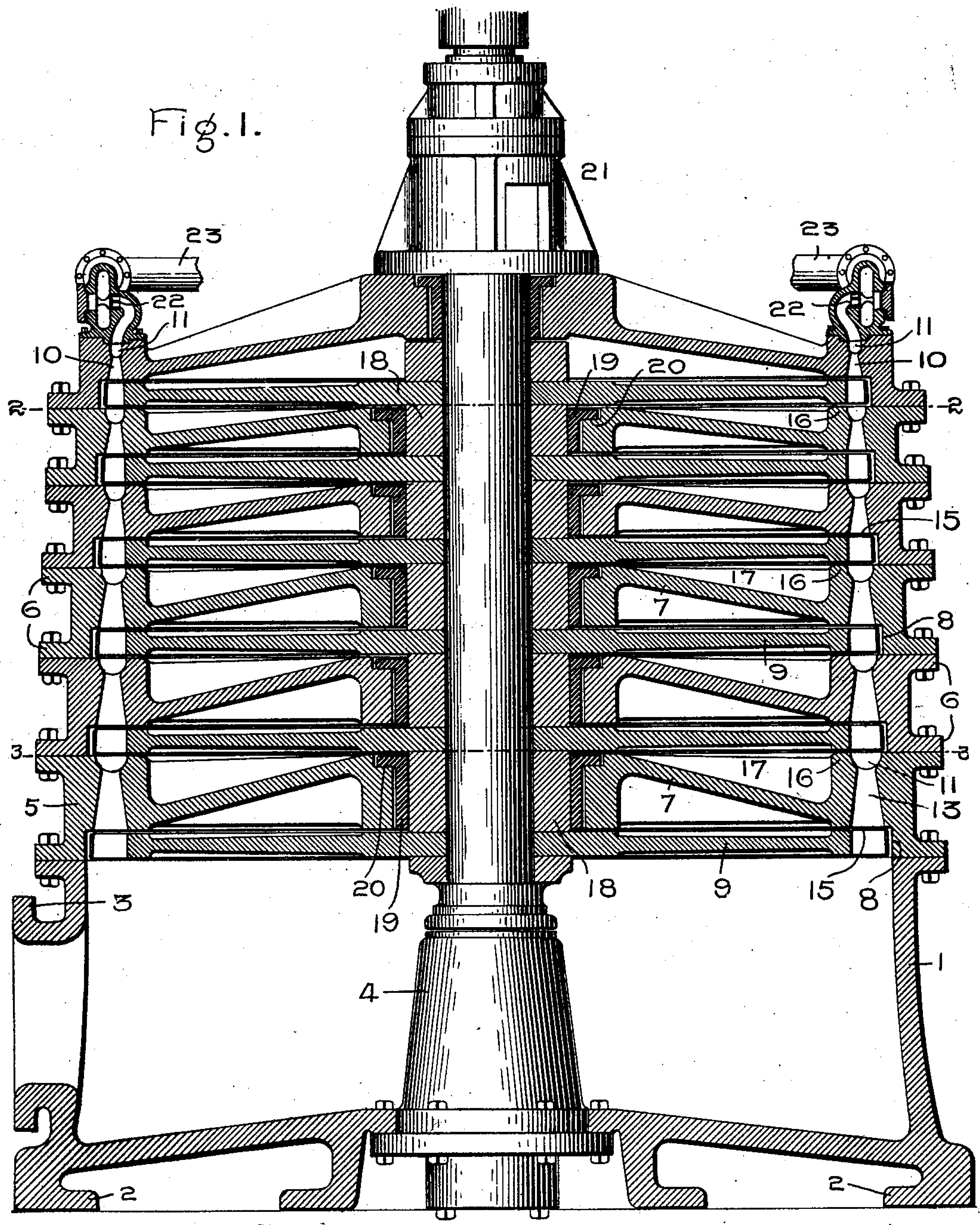
W. L. R. EMMET.

ELASTIC FLUID TURBINE.

APPLICATION FILED DEC. 5, 1902.

NO MODEL. 4 SHEETS—SHEET 1.

Fig. 1.



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THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

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NO MODEL. 4 SHEETS—SHEET 2.

Fig. 2.

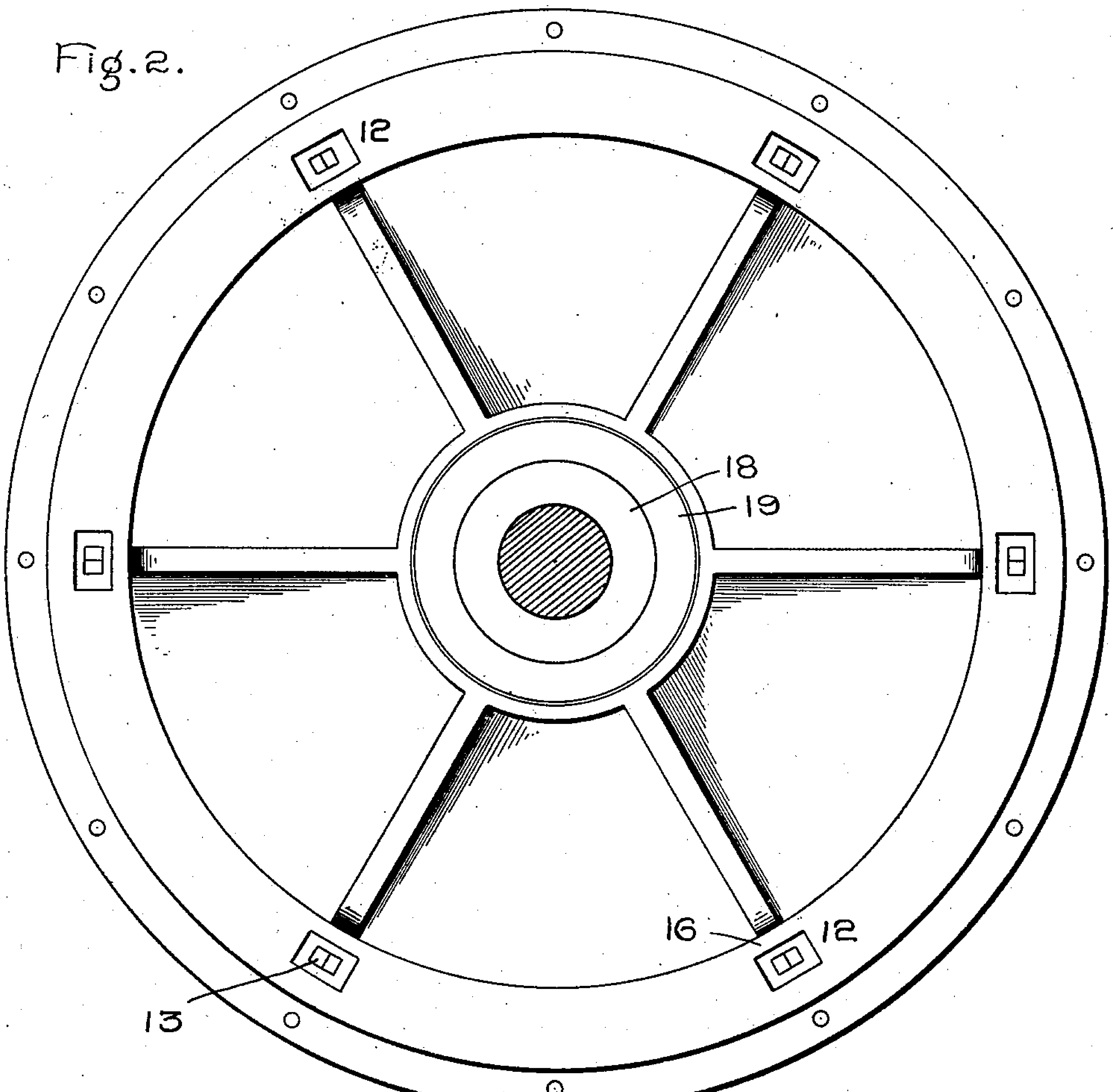
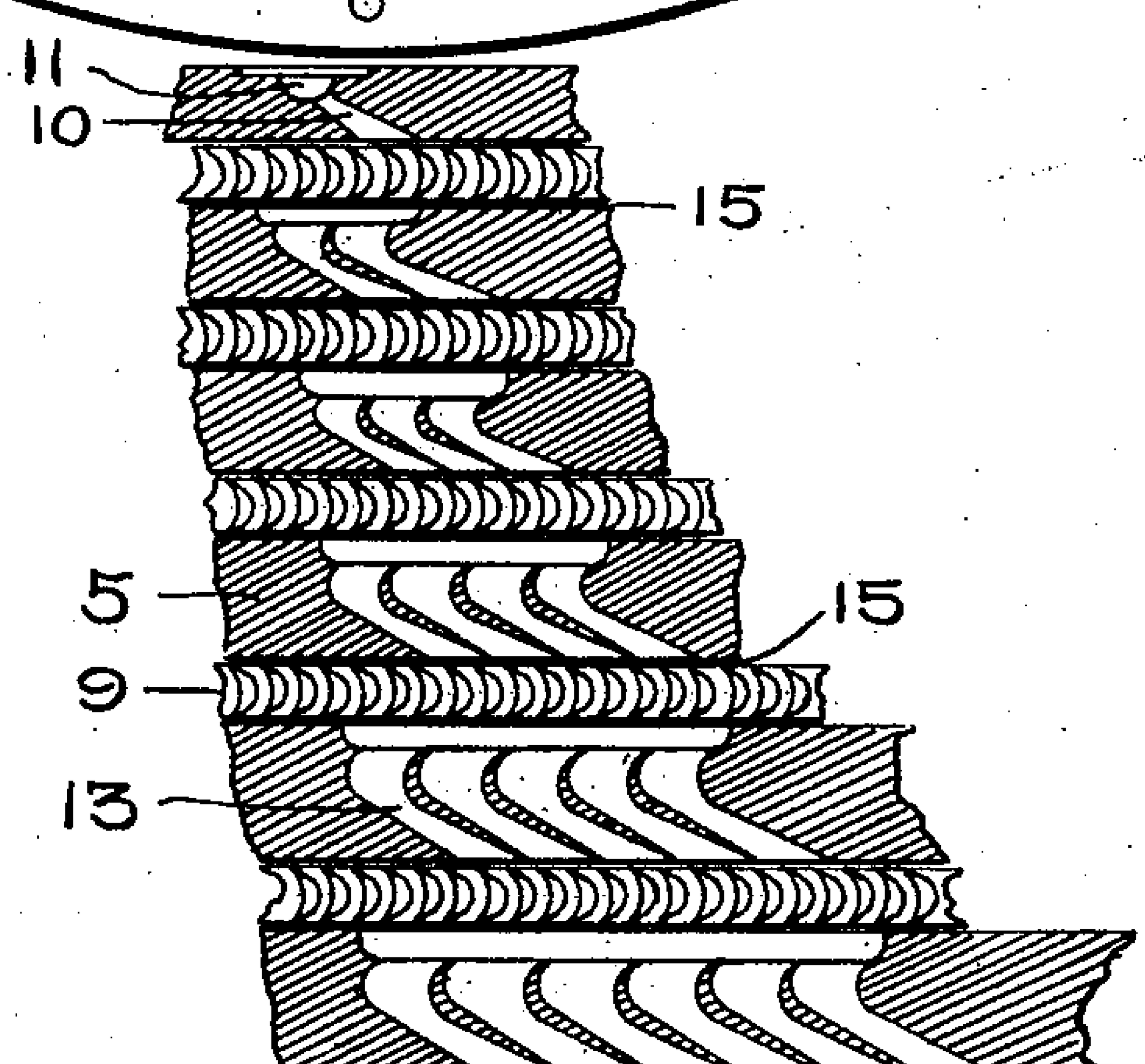


Fig. 4.



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NO MODEL. 4 SHEETS—SHEET 3.

Fig. 3.

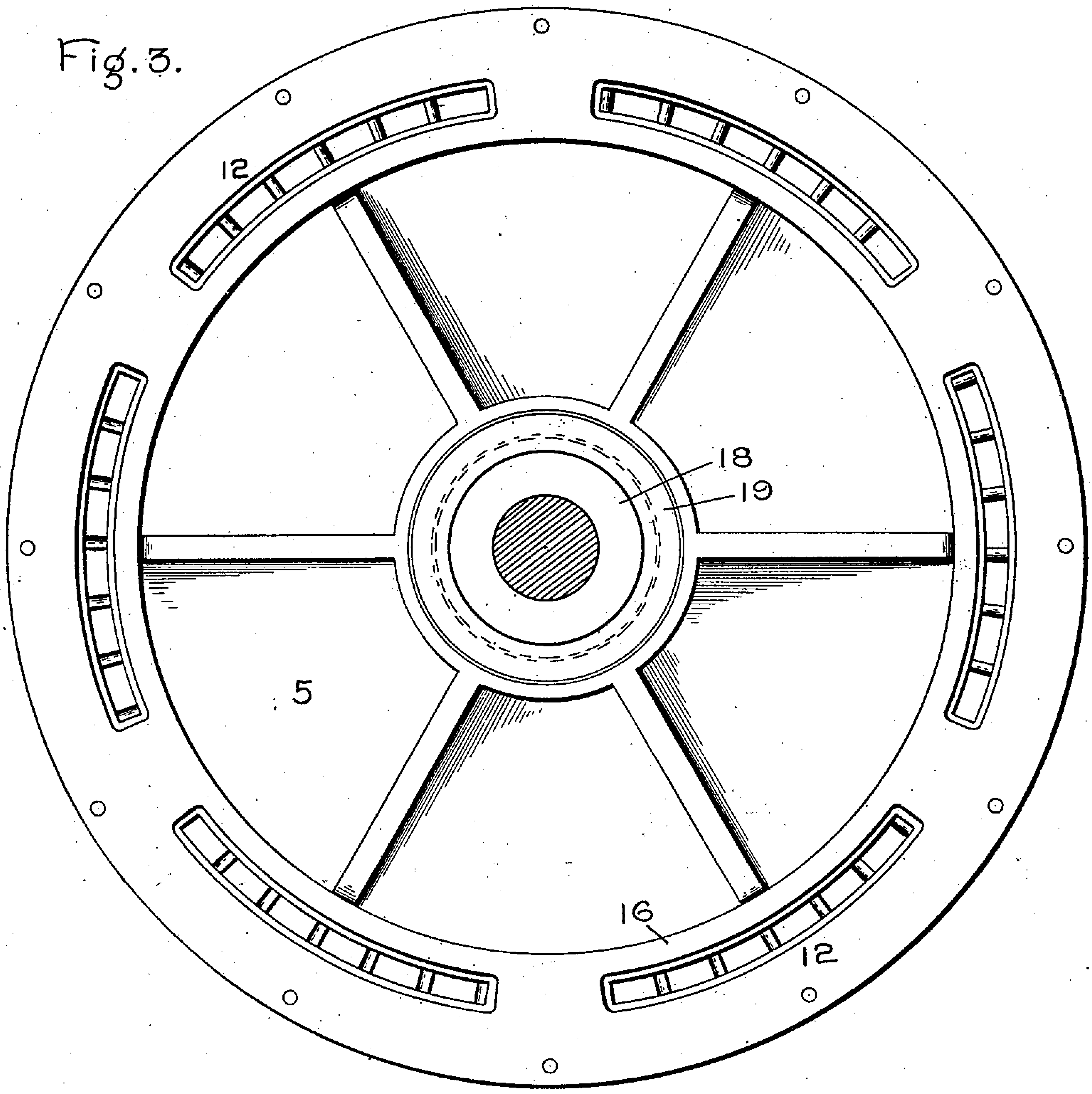
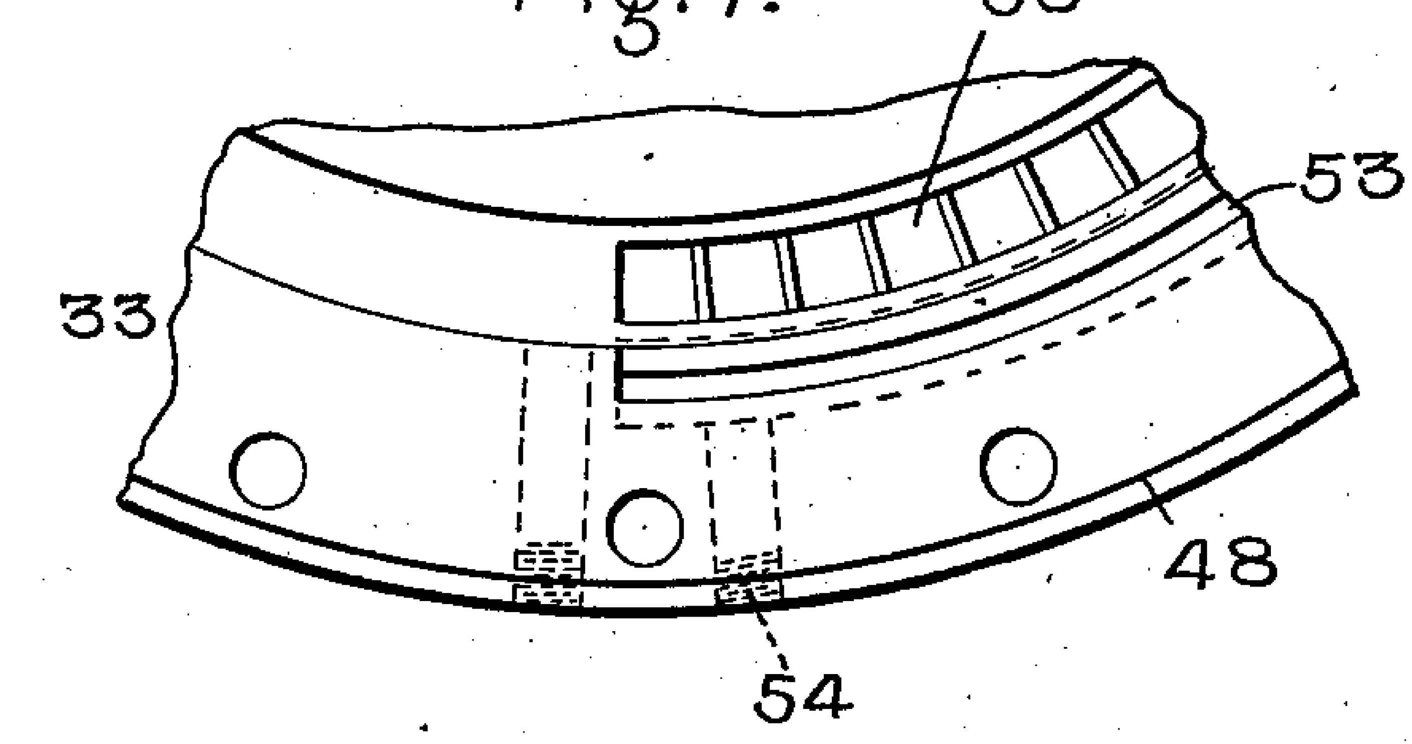


Fig. 7.



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APPLICATION FILED DEC. 5, 1902.

NO MODEL. 4 SHEETS—SHEET 4.

Fig. 5.

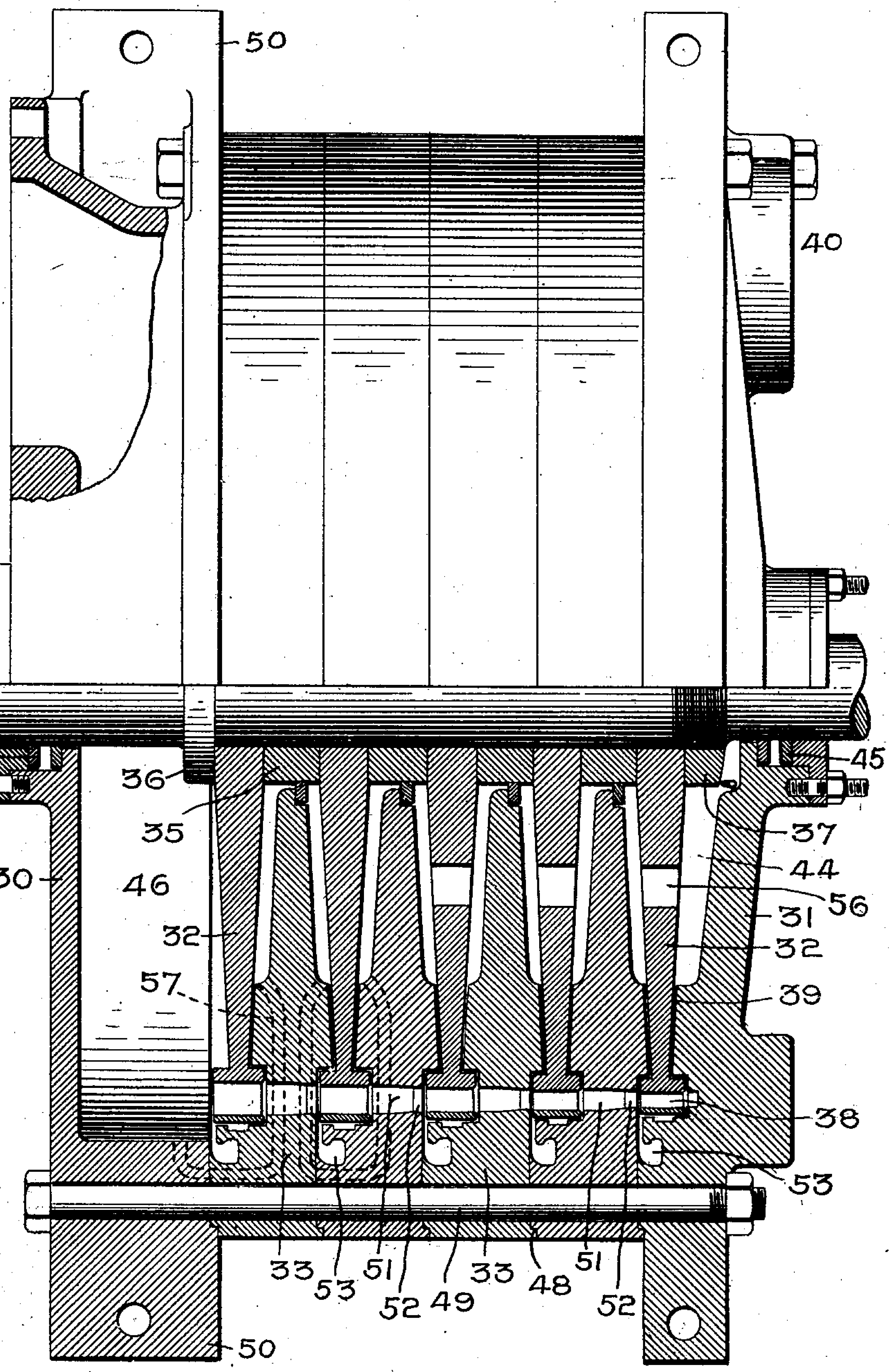
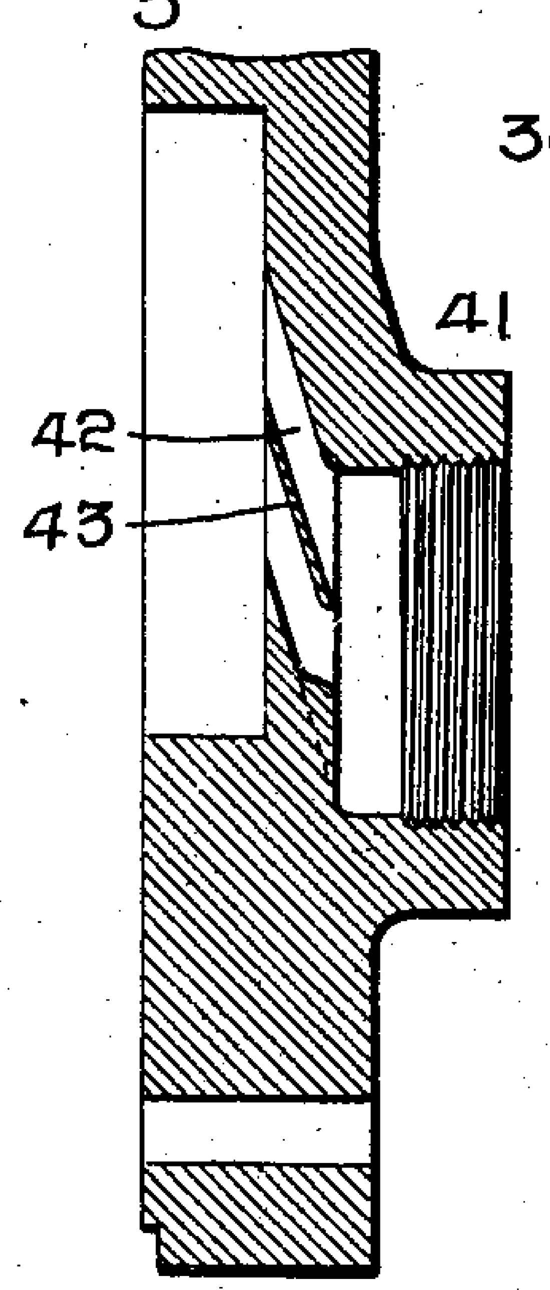


Fig. 6.



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UNITED STATES PATENT OFFICE.

WILLIAM L. R. EMMET, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

ELASTIC-FLUID TURBINE.

SPECIFICATION forming part of Letters Patent No. 755,756, dated March 29, 1904.

Application filed December 5, 1902. Serial No. 133,995. (No model.)

To all whom it may concern:

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

The jet type of elastic-fluid turbines possesses certain features of advantage in the way of low shaft-speed, large wheels, and freedom from end thrust, which render it highly desirable. In machines of this kind the high-pressure nozzle or nozzles for delivering motive fluid to the wheel cover a portion only of the buckets on the wheel, and the number of buckets thus covered varies with the power of the machine. Between the rows of moving buckets are stationary intermediate buckets which reverse the direction of the fluid stream or streams and discharge them against the buckets of the succeeding wheel. When the turbine is in operation, the wheel casing or shell is filled with the motive fluid under a pressure more or less great. The fluid contained in the shell is due principally to the motive fluid discharged from the last wheel; but it is also due to a certain degree to the leakage between the moving and stationary elements. Obviously this leakage means a decrease in efficiency, even though the fluid from the first stage is collected and delivered by a suitable nozzle to the wheel or wheels of a succeeding stage. In order to maintain an economical condition of operation, it is customary to control these jet-machines by varying the volume of motive fluid delivered to the wheel, and this without varying its velocity. This is commonly done by cutting in or out more nozzles or sections of the nozzles, and since the intermediates are also sectionalized it affects them in a corresponding manner. The motive fluid due to leakage at various points is, however, present in the shell and is affected to only a limited extent by the cutting in or out of nozzle-sections. For each nozzle cut out there is a slight decrease in leakage at the particular point; but it is small compared with the total. There is also a loss due to cross-leakage, meaning by "cross-leakage" that which takes place between one group of nozzles or nozzle-sections and the next between the wheel and the surrounding casing and in the same stage, irrespective of the positions occupied by the nozzles.

In addition to the losses mentioned there is a further loss due to spill at each nozzle, meaning by "spill" the side portions of the fluid-stream, which spread out unduly and eventually find their way into the shell without having done their full amount of work.

The present invention has for one of its objects to provide a jet type of turbine wherein the losses due to leakage and spill are reduced to a minimum, thereby insuring high economy in operation.

A further object of the invention is to improve and simplify the construction of the turbine as a whole.

The first and most important consideration is to reduce the leakage of motive fluid to a minimum. To do this, I divide the machine into a number of stages by suitable diaphragms, with one wheel for each stage, so that the leakage between one wheel and its adjacent stationary nozzle or intermediate can be used on the second wheel, and so on. Each stage is provided with two or more nozzles or groups of nozzles, which are situated at suitable points around the circumference of the wheel and preferably, although not necessarily, equidistant. The casing for each wheel is made as small as possible consistent with the diameter and thickness of the wheel, and the clearances between moving and stationary parts are made relatively small, so that the operation of one nozzle or nozzle-section will not affect the operation of any other nozzle or nozzle-section to any great extent. Of course where there is even a slight clearance there is an opportunity for cross-leakage; but by reason of my improved construction this leakage is reduced to a minimum. The first wheel is situated in front of two or more suitably-designed nozzles, and following each wheel are two or more sets of nozzles, each set being provided with a small segmental collection-chamber for equalizing the pressure between the fluid streams delivered from the bucket-wheel at a given point and also for creating a pressure, such as will cause the motive fluid to be discharged against the buckets of the adjacent wheel with the proper velocity.

By making segmental collection-chambers, as distinguished from those extending entirely around the wheel, the circumferential or cross leakage between nozzles or sets of nozzles is reduced to a minimum.

Under ordinary conditions of service it would be preferable to provide the turbine with two or more nozzles for the purpose of regulation, but my invention is not limited thereto, as it is broad enough in certain aspects to include a turbine having a single wheel per stage with a single high-pressure nozzle supplying motive fluid to the working passages and a segmental collection or pressure chamber situated between each pair of wheels.

In the accompanying drawings, which illustrate one embodiment of my invention, Figure 1 is a vertical section of a vertical turbine having a single wheel per stage. Fig. 2 is a horizontal sectional view of the machine, taken on the line 2 2 of Fig. 1. Fig. 3 is a horizontal section taken on the line 3 3 of Fig. 1. Fig. 4 is a vertical section in a developed plane of a part of the nozzles and moving buckets. Fig. 5 is a plan view in quarter-section of a horizontal turbine having one wheel per stage. Fig. 6 is a detail sectional view of a nozzle, and Fig. 7 is a detail view showing the arrangement of the parts for draining off the water of condensation.

Referring to Fig. 1 of the drawings, 1 represents a cast-metal base, which is provided with feet 2 and a flange 3 for making connection with the condenser. The base is cored out to form a vacuum-chamber, and mounted therein is a step-bearing 4 for the vertical or main shaft of the machine. The bearing is suitably arranged to prevent lateral movement of the shaft and is detachable from underneath. It forms the subject-matter of a separate application and for that reason will not be specifically described herein. The upper edge of the base is provided with an outwardly-extending flange, and mounted thereon is the lower diaphragm 5, which separates the two lower wheels from each other except through the nozzle-openings. Each diaphragm is provided with a ring-like portion or flange at its periphery, having small top and bottom flanges 6, the flanges on one diaphragm engaging with those on an adjacent diaphragm or base, as the case may be, and being bolted together. Each diaphragm is provided with a hub which is connected to the ring by an inclined web 7, and the diaphragms are cut away at 8 to receive the wheels 9. It will thus be seen that each wheel and diaphragm are so related to each other that each wheel is surrounded by its own diaphragm and casing, and when the parts of the machine are separated the line of division will be complete in planes parallel with the line of division between diaphragms. The diaphragms are of such form that they may readily be machined in an ordinary boring-mill, and this with a minimum amount of labor. The number of diaphragms would vary with the desired difference in pressure between shells, and this would be largely dependent upon the difference in terminal pressures. It is a simple matter to add one or more diaphragms or to take away one or more, as the conditions demand. Each diaphragm is provided with one or more nozzles or sets of nozzles 10, which open into a segmental collection or pressure chamber 11. I find it desirable to form the nozzles and collection-chambers in the diaphragms at the time they are cast, because it reduces the number of parts, simplifies the mechanical construction and alinement, and reduces the cost of manufacture. The construction and arrangement of these working passages is best shown in Fig. 4. In this figure one high-pressure nozzle is shown, which is directly connected with the boiler or other source of fluid-supply. The steam or other motive fluid received by the bowl or chamber 11 is given a certain velocity by the diverging walls of the nozzle 10. The nozzle may be of the expanding type or it may be straight, depending upon conditions—such, for example, as the terminal pressure of the machine and the number of stages. The fluid discharged by the nozzle imparts a rotary motion to the bucket-wheel directly in front thereof. The fluid streams discharged from the several working passages of the wheel and due to one nozzle or group of nozzles are received by the chamber 11 and are there collected and the pressure between streams equalized. This chamber also acts as a pressure-chamber for a second set of nozzles, so that fluid discharged against the adjacent bucket-wheel will have the proper velocity. The successive chambers 11 for the several stages gradually increase in area as they recede from the high-pressure or first nozzle. I have found it desirable to obtain this increase by making each chamber both larger and deeper. The increase in size is to compensate for the increased volume due to the decreased velocity. I have found it advantageous to enlarge the chambers in the manner specified; but it can be done in other ways, if desired. It is to be noted that the nozzles are enlarged in the direction of the exhaust, and for the same reason that the chambers increase in size. I have found it advisable to attain this enlargement or increase in cross-section partly by enlarging the nozzle and partly by increasing the number of nozzle-sections 12 in each succeeding diaphragm. The said diaphragms also increase in depth from the high to the low pressure side of the machine, although this is not necessary, since the nozzles themselves can be given the desired length. It has this advantage, however, that the clearance between the wheel and the wall of the casing can be made very small, so as to prevent cross-leakages. The increase in cross-sectional area of the working passage is a gradual one. In the present illustration one nozzle is provided for the first stage, two nozzles or sections for the second, three for the third, and so on. The intermediate nozzles 13 and their chambers, in addition to collecting and imparting a proper velocity to the fluid stream, act also to reverse its direction and discharge it at the proper angle against the adjacent row of moving buckets.

A turbine constructed as described, with only one high-pressure nozzle, will operate satisfactorily within certain limits. In order to increase the power of the machine and also to facilitate the governing thereof, I provide a number of high-pressure nozzles, which are distributed around the wheel and preferably at equidistant points. This is best illustrated in Figs. 1 and 2, where six high-pressure nozzles are shown. Situated below each nozzle, or in line therewith if the machine be a horizontal one, are other nozzles arranged in the same manner as set forth in connection with Fig. 4. It is evident that if one high-pressure nozzle is cut out of service all of the nozzles and sections of the working passage in line therewith are also cut out. By reason of the improved construction of the turbine the nozzles and collection-chambers of one set are isolated from those of another set, and communication between them is established only through a restricted passage, such as 15, which offers a much higher resistance to the passage of motive fluid than does the normal working passage or passages. Each diaphragm is provided with a ring-like portion 16, having a surface that is situated in close proximity to a wheel and tends to retard the passage of motive fluid into the chamber 17, formed by a wheel and an adjacent diaphragm.

To put the matter in a different way, each wheel moves between the adjacent surfaces of a pair of diaphragms, and the clearances at this point are relatively small, as is indicated at 15, Fig. 4. This means that each set of nozzles will operate to a certain extent independently of every other set of nozzles and that when one set is cut out by closing its admission-valve the cross leakage between the sets which are working and the set or sets which are idle is reduced to a minimum. By "cross-leakage" I mean the fluid that escapes from one set of nozzles or working passages and creeps through the clearances and is discharged into or through another set or sets of nozzles or working passages. The direct reason for this reduced cross-leakage is the relatively small clearance or gaps 15 between each wheel and the stationary diaphragms. As before pointed out, this leakage cannot be eliminated so long as clearances between moving and stationary parts are provided, but it can be greatly reduced by the construction and means specified. Owing to the reduction in leakage the efficiency of the machine at light loads is correspondingly increased. It is evident from Fig. 4 that if the turbine is provided with a plurality of high-pressure nozzles and one of said nozzles is cut out that the power of the machine as a whole will be decreased, and since all of the working passages and chambers are cut out the spill at this point is eliminated.

Surrounding the main shaft of the machine and acting as spacers for the wheels are sleeves 18. Loosely mounted on the sleeves are cylindrical bushings 19, each having an outwardly-extending flange that engages a shouldered portion 20 on a diaphragm. Between the bushings 19 and the walls of the diaphragms is a small space which permits the parts to shift slightly with respect to each other. The bushings prevent the passage of motive fluid from one diaphragm or wheel chamber to another, and the pressure in the discharging-chamber holds the bushing in place. The upper diaphragm also acts as a cover and support for the bearing 21. Mounted on the cover at points adjacent to the high-pressure nozzles are fluid-controlling valves 22, the casings for which are bolted to the wall of the diaphragm. Steam or other elastic fluid is admitted to the valves by conduits 23. The valves 22 in practice are controlled by an automatic governor, which in turn is responsive to speed changes of the wheel-shaft.

Assuming that the machine is running under normal conditions with five sets of high-pressure nozzles in service and the load is decreased, which would tend to increase the speed, one of the valves 22 will close and shut off the supply of motive fluid to its nozzle, and the machine will resume its normal speed. On the other hand, if the speed is decreased, owing to increased load, a valve 22 will open and cause more fluid to be delivered to the wheel.

Referring to Figs. 5, 6, and 7, I have shown my invention applied to a horizontal machine, in which 30 and 31 represent the end heads, 32 the wheels, and 33 the stationary diaphragms, which also form the casing. In addition the diaphragms divide the casing into compartments or shells, in which the wheels 32 are situated. The wheels are mounted on the main shaft 34 and are separated by spacers 35. On one end of the shaft is a collar or shoulder 36, with which the last wheel engages, and on the opposite end is a nut 37, engaging with a screw-thread on the shaft for clamping the wheels together.

The wheels are tapered from the shaft to the flange formed on their periphery, the latter containing the buckets, between which are working passages 38 for the motive fluid. The diaphragms are provided with beveled projections 39, which are situated in close proximity to the beveled web of the wheel and by reason of their close association prevent to a large degree the escape of motive fluid at this point and reduce to a minimum the cross-leakage from one nozzle or set of nozzles to another. Each diaphragm is provided with two projections having inclined surfaces, which are in operative relation with respect to two wheels.

The motive fluid is supplied to the turbine by two nozzles 40 and 41, which are situated on opposite sides of the shaft. The construction of these nozzles is best seen in Fig. 6, wherein 42 represents the fluid carrying passage, which is divided into two parts by a partition 43. Situated opposite the nozzle is a projection having an internal screw-thread, to which a steam or other fluid carrying conduit can be attached. In order to prevent leakage of motive fluid from the high-pressure wheel-chamber 44, a packing 45 of suitable construction is provided. On the opposite end of the machine is an exhaust-chamber 46, which is formed in the end head, and between this chamber and the atmosphere is a packing 47. The diaphragms are provided with interlocking shoulders 48 and are secured together and to the end heads by the horizontally-extending bolts 49. The end heads are provided with projections 50, by means of which the turbine can be supported at two points diametrically opposite. Each diaphragm is provided with an expanding-nozzle 51, which receives fluid from one wheel and discharges it against the adjacent wheel. In addition to this each diaphragm is provided with a segmental collection-chamber 52, wherein the streams of motive fluid delivered by the preceding wheel are collected and the pressure of the several streams equalized. These chambers also serve to create a pressure for forcing the motive fluid through the nozzle and buckets situated in front of the nozzle. The arrangement of the chambers and buckets corresponds to that shown in Fig. 4 and previously described.

As the motive fluid passes through the working passages of the turbine a certain amount of water will be formed due to the expansion of the steam. In order to collect this, and thereby prevent it from reëntering the steam and being evaporated, (which means a loss in energy,) a receptacle 53, having a restricted throat, is provided in each of the diaphragms and also in the right-hand or high-pressure end head, the said throat being located adjacent to the discharge side of the wheel. As the bucket-wheels revolve under the action of the motive fluid, the water will be discharged outwardly, owing to centrifugal force, and it will be collected in the said receptacles.

Referring to Fig. 7, I have shown a small detail view of one of the water-holding receptacles 53, which opens into a passage 54. The walls of the passage at the lower end are provided with a screw-thread, to which a pipe can be secured for carrying off the water given up in expansion of the steam. The receptacles 53 cover a certain arc of a circle, which arc increases with the increase in the number of nozzle-sections. I have shown in Fig. 7 the diaphragm as being provided with seven nozzle-sections 55, as the figure illustrates a part of one of the low-pressure diaphragms; but it is evident that the number of these nozzle-sections will vary, depending upon the position occupied by the diaphragm. The higher the pressure to which the diaphragms are subjected the fewer the nozzle-sections.

As the load on a turbine changes, the effect of the condenser changes, it being greatest when the load is light, because the amount of steam handled by the condenser is small. This means that a vacuum will be created in the wheel-casings, which gradually works toward the high-pressure nozzles. Ordinarily the leakage would be enormously increased under this condition; but owing to the restricted clearances previously mentioned the leakage is descreased to a minimum.

In order to reduce the thrust on the bucket-wheels due to pressure differences on opposite sides, one or more openings 56 are provided in the wheels through which the necessary amount of fluid can flow to create a substantial balance. For the first stages I have found it satisfactory to make holes in the wheels; but for the low-pressure stages it is desirable to make passages 57 in the casing, because the volume of fluid to be carried increases as the pressure decreases. The passages are situated between the nozzles and for that reason appear in dotted lines in Fig. 5. I may use either the wheel-openings or the passages, or both, as desired.

In accordance with the provisions of the patent statutes I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof; but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means.

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

1. In an elastic-fluid turbine, the combination of a plurality of diaphragms, each of which forms a section of the casing and divides it into compartments, wheels for the compartments which are separated from the

walls of the diaphragms by small clearances, segmental chambers which are formed within the diaphragms for collecting the fluid discharged from the preceding wheel, and fluid-discharging passages which are also formed in the diaphragms and open into the chambers.

2. In an elastic-fluid turbine, the combination of a casing, diaphragms which divide the casing into compartments, wheels for the compartments, a plurality of nozzles which deliver fluid to the first wheel, subdivided fluid-discharging passages between one compartment and the next, the number of said divisional passages increasing as the pressure of the fluid decreases, chambers which collect the fluid streams from the bucket-wheels and deliver it to the succeeding fluid-discharge passages, and separately-actuated valves which control the passage of motive fluid through the nozzles.

3. In an elastic-fluid turbine, the combination of a casing, a diaphragm which divides the casing into compartments, the diaphragm being provided with a segmental collection-chamber and a passage which receives fluid from the chamber and delivers it to an adjacent wheel, the said chamber and passage being situated between the surfaces of the diaphragm, and bucket-wheels which revolve in close proximity to said surfaces and prevent cross-leakage.

4. In an elastic-fluid turbine, the combination of a plurality of diaphragms which are provided with peripheral rings that form the casing, means for uniting the rings, collection-chambers which are formed in the diaphragms, sets of fluid-passages also formed in the diaphragms that expand toward the exhaust, bucket-wheels that are situated between the diaphragms and revolve in proximity thereto, and separate valves for controlling the supply of motive fluid to the passages.

5. In an elastic-fluid turbine, the combination of a casing, a plurality of diaphragms for dividing the casing into compartments, the diaphragms successively increasing in thickness near their periphery, a number of nozzles which are distributed around the casing, separate valves for controlling the passage of fluid through the nozzles, a single wheel for each compartment, and collection-chambers and expanding working passages which are formed in the diaphragms.

6. In an elastic-fluid turbine, the combination of a casing, a diaphragm for the casing, bucket-wheels, and a receptacle formed in the diaphragm which is situated adjacent to a wheel and in a position to receive the water of condensation.

7. In an elastic-fluid turbine, the combination of a casing, a diaphragm for the casing, bucket-wheels, a receptacle formed in the diaphragm which surrounds a portion of a wheel for collecting the water of condensation, and a conduit connecting with said receptacle.

8. In an elastic-fluid turbine, a casing comprising a plurality of diaphragms, each diaphragm having formed therein a segmental collection-chamber, a nozzle that extends at an angle to the plane of the diaphragm and opens into the chamber, and bucket-wheels arranged to move in close proximity to the walls of the segmental collection-chambers.

9. In an elastic-fluid turbine, the combination of a plurality of diaphragms, each having an enlarged peripheral flange which engages with an adjacent flange, a collection or pressure chamber, and a water-receiving receptacle.

10. In an elastic-fluid turbine, the combination of a casing which includes a number of diaphragms having inclined concentric walls, with bucket-wheels situated between the diaphragms, each of said wheels being provided with a web that has the same inclination as a diaphragm-wall.

11. As an article of manufacture, a diaphragm for a turbine, comprising a main body portion which is bored to receive the driving-shaft, and a peripheral flange that forms a part of the external casing of the turbine, the said flange being cut away to form a chamber for a bucket-wheel and also to form a water-collecting receptacle, the said receptacle opening into the wheel-chamber.

12. In an elastic-fluid turbine, the combination of a casing divided into compartments, a bucket-wheel mounted in each compartment and arranged to run close to its inclosing walls, nozzles for delivering fluid to the wheel, and a segmental collection or pressure chamber between each pair of wheels which receives motive fluid from one wheel and discharges it against the next.

13. In an elastic-fluid turbine, the combination of a casing divided into compartments, a bucket-wheel mounted in each compartment which revolves in close proximity to the walls of the compartment, nozzles for delivering fluid to the wheels, the cross-sectional area of the successive nozzles increasing toward the exhaust, and a segmental collection-chamber for each compartment which is situated in line with a high-pressure nozzle and discharges into a number of nozzle-sections, the successive chambers in the several compartments gradually enlarging and the number of nozzle-sections increasing toward the exhaust.

14. In an elastic-fluid turbine, the combination of a plurality of bucket-wheels, casings for the wheels, and passages formed in the casing for conveying fluid from one side of a wheel to another to balance end thrust.

15. In an elastic-fluid turbine, the combination of a bucket-wheel, a fluid-carrying pas-

sage arranged to discharge fluid against the wheel, a passage for conveying fluid from one side of the wheel to the other for balancing the end thrust, and a receptacle which has an opening adjacent to the discharge side of the wheel for receiving water due to condensation.

16. In an elastic-fluid turbine, the combination of a bucket-wheel, a fluid-carrying passage arranged to discharge fluid against the bucket-wheel, and a receptacle which has a restricted throat, the said throat being situated adjacent to the discharge side of the wheel.

In witness whereof I have hereunto set my hand this 4th day of December, 1902.

WILLIAM L. R. EMMET.

Witnesses:

ALEX. F. MACDONALD,

HELEN ORFORD.