No. 754,292. PATENTED MAR. 8, 1904.

W. L. R. EMMET.

ELASTIC FLUID TURBINE.

APPLICATION FILED MAR. 14, 1903.

NO MODEL. 4 SHEETS—SHEET 1.

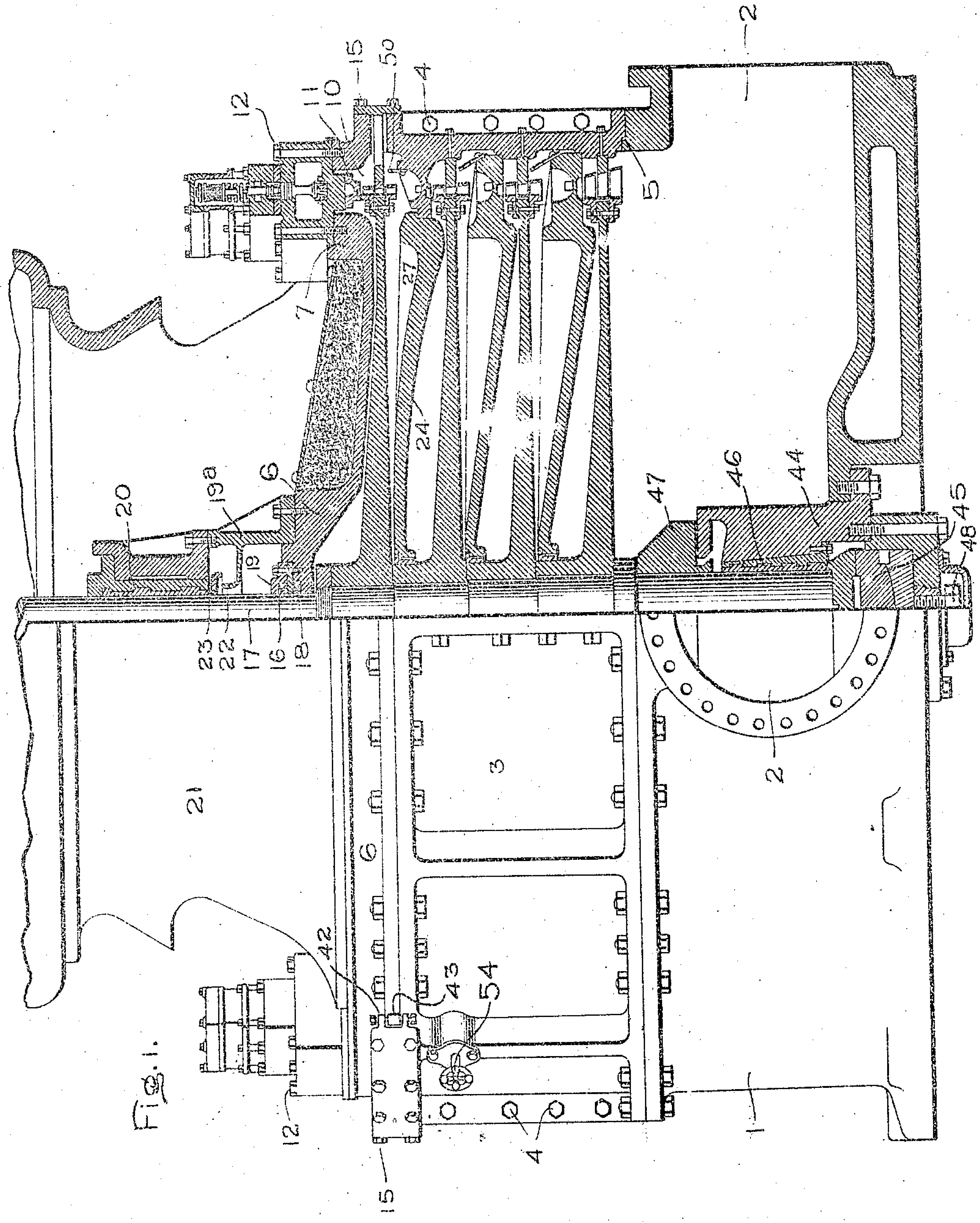

Fig. 1.

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NO MODEL. 4 SHEETS—SHEET 2.

Fig. 2.

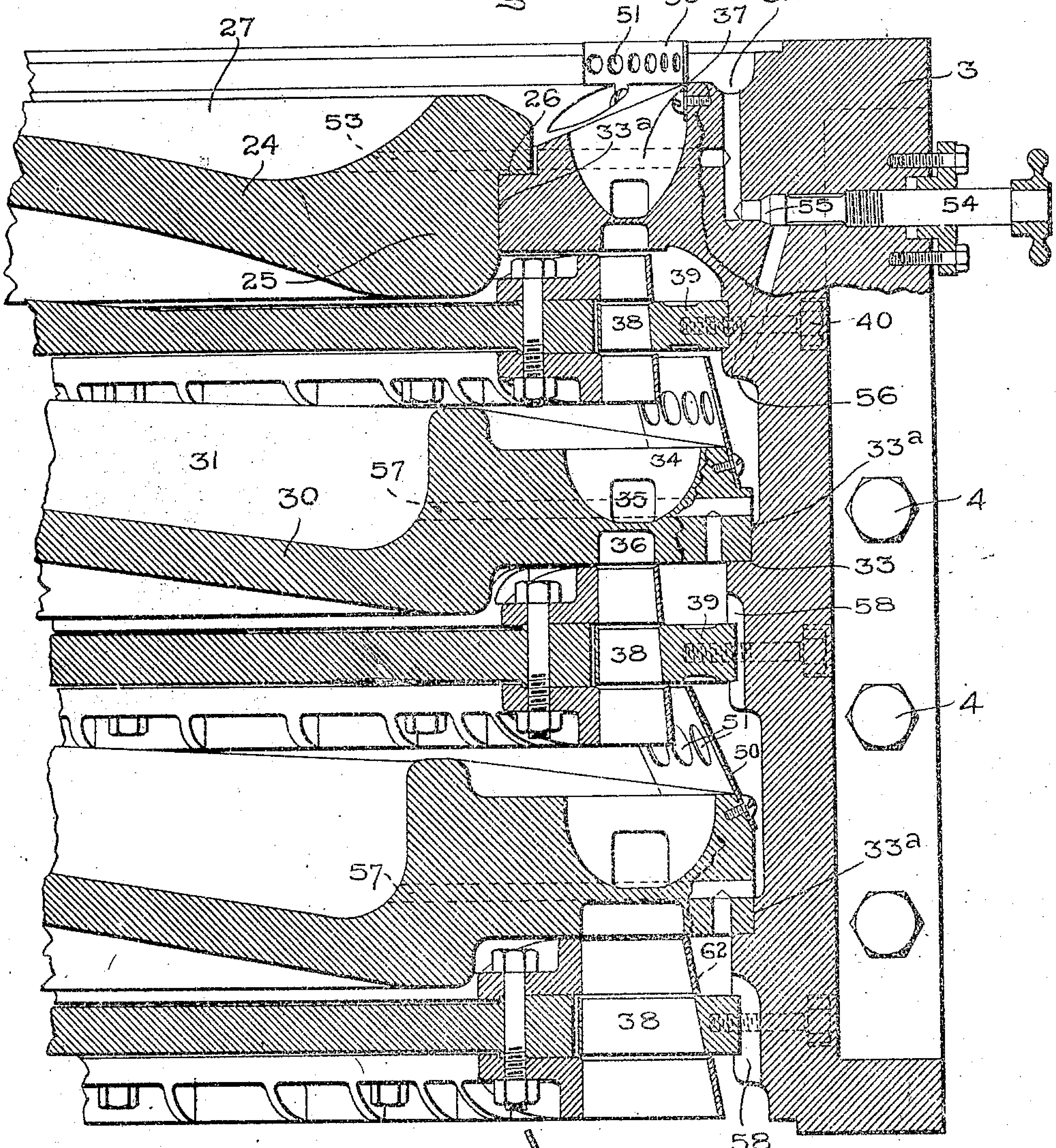
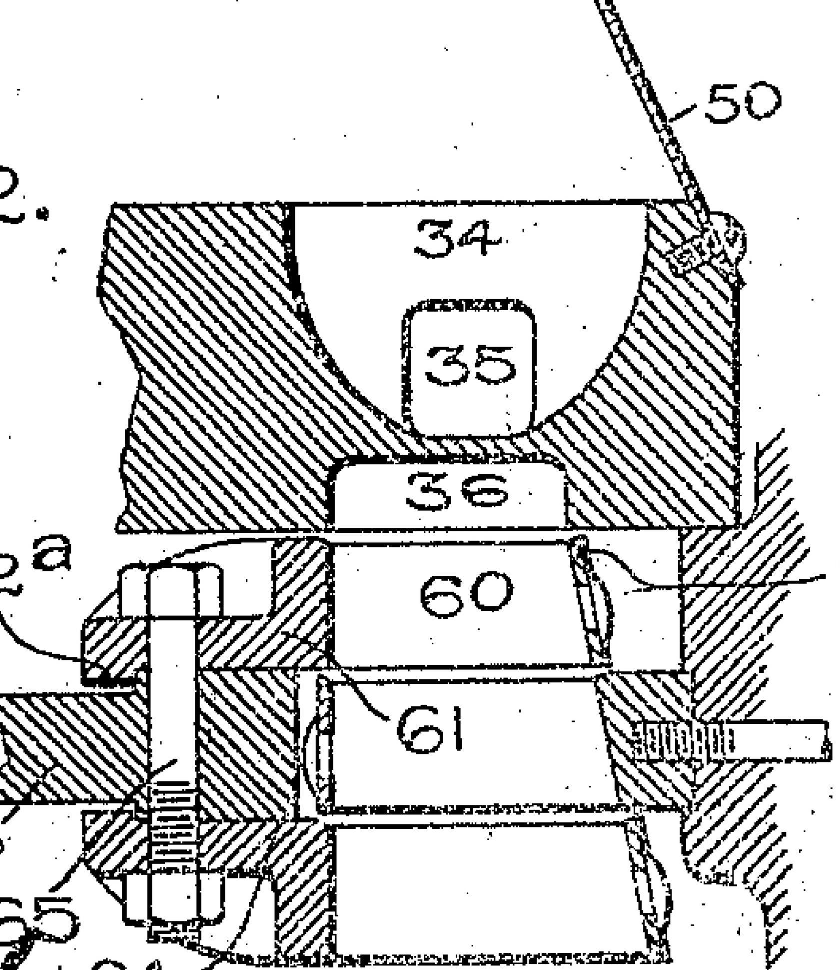


Fig. 12.



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NO MODEL.

4 SHEETS—SHEET 3.

Fig. 3.

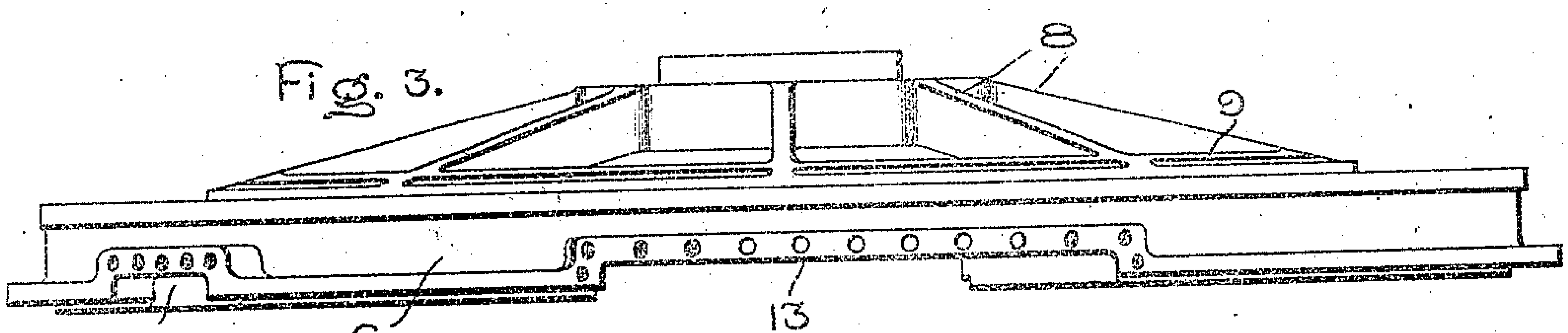
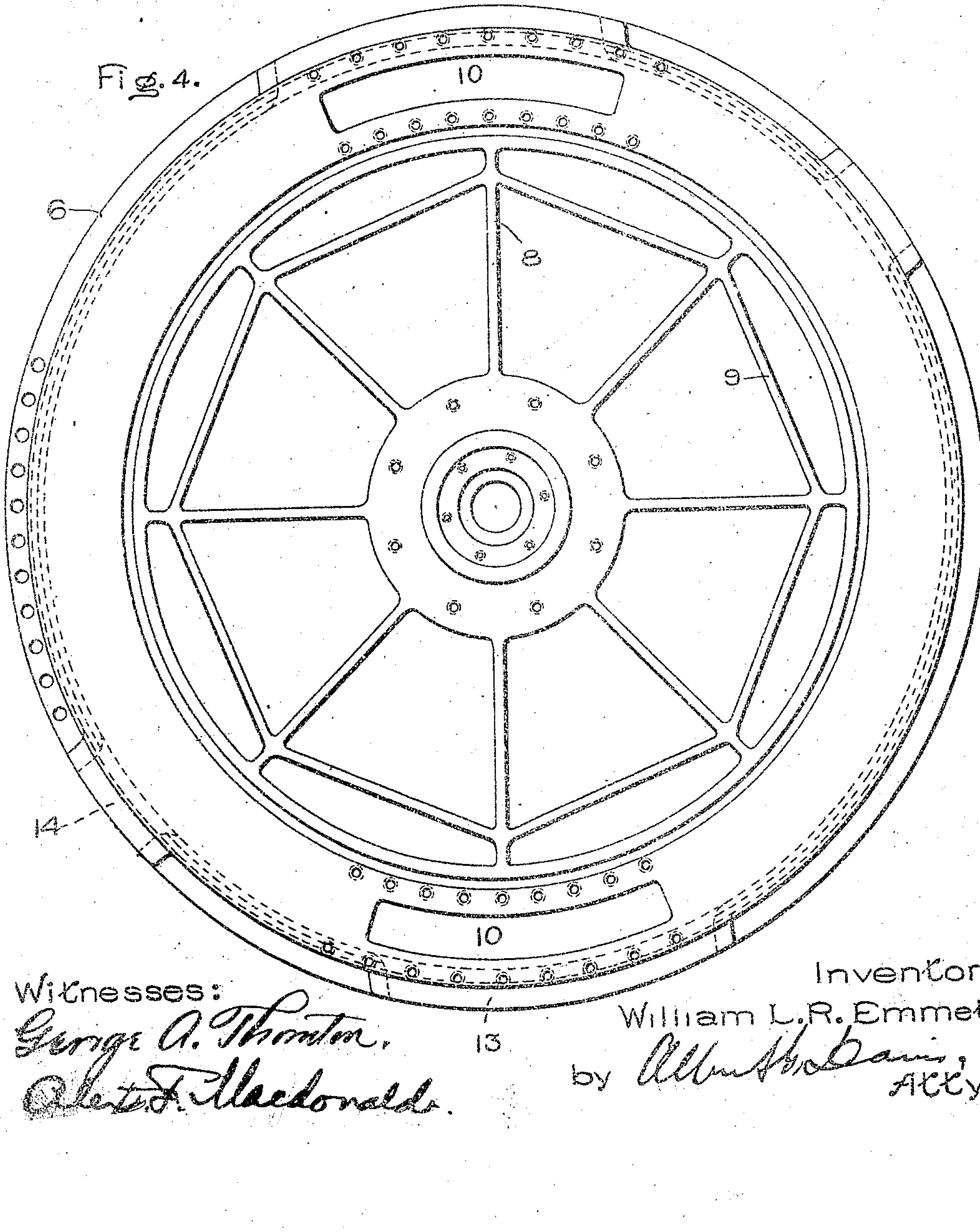


Fig. 4.



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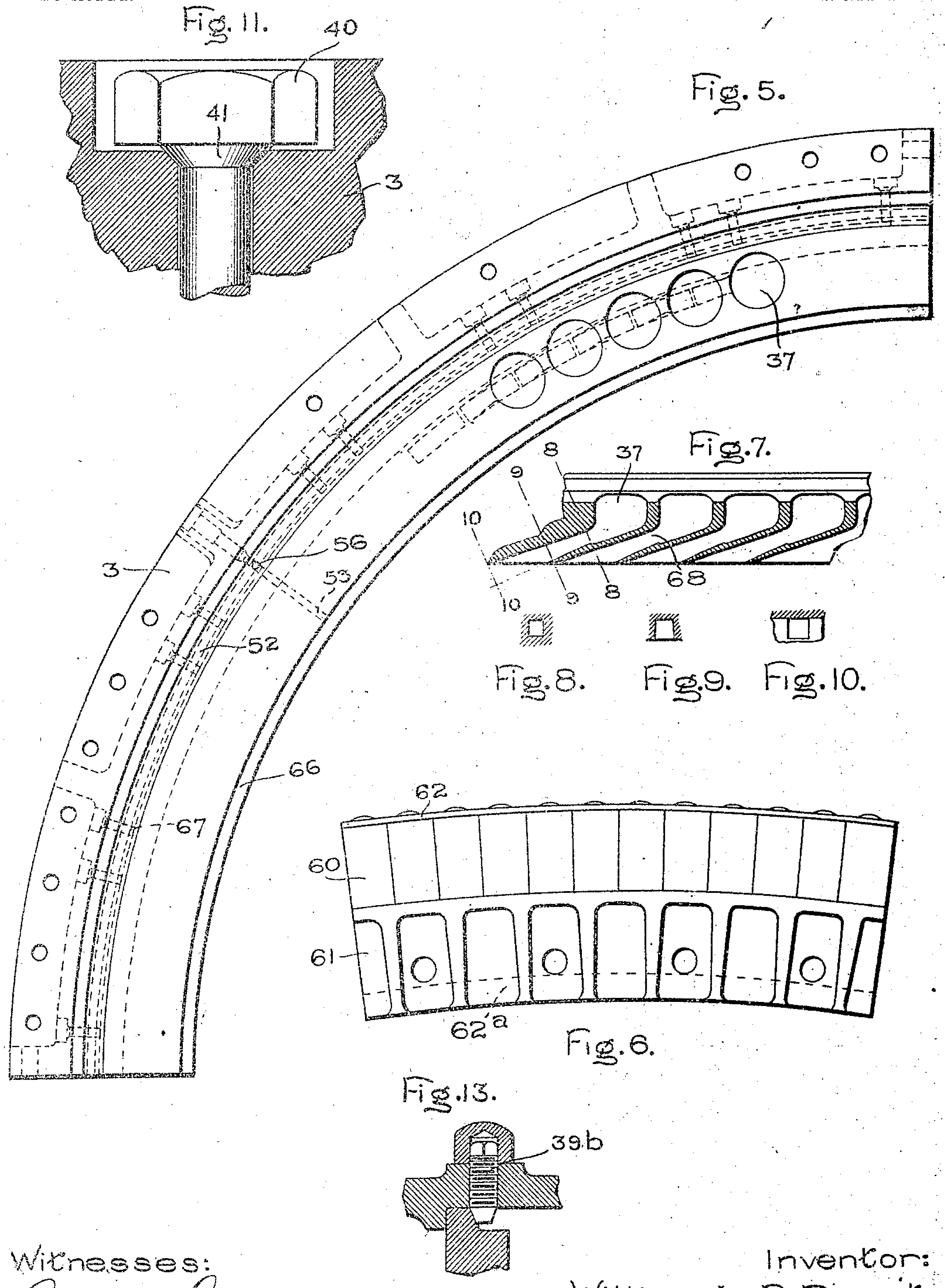
NO MODEL. 4 SHEETS—SHEET 4.



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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. 754,292, dated March 8, 1904.

Application filed March 14, 1903. Serial No. 147,725. (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, in the 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 present invention has for its object to provide a high-efficiency turbine and one which is simple in construction, so that it may be assembled and alined or taken down by workmen of ordinary skill.

In the accompanying description and claims will be set forth with particularity the arrangement of parts whereby I am enabled to obtain the advantages sought.

In the accompanying drawings, which illustrate an embodiment of my invention, Figure 1 is a partial elevation of a turbine in quarter-section. Fig. 2 is an enlarged section of three of the stages. Fig. 3 is a view in side elevation of the cover for the high-pressure shell. Fig. 4 is a plan view of said cover. Fig. 5 is a plan view of one of the sections of the casing. Fig. 6 is a side elevation of a segment or sector of the detachable wheel-buckets. Fig. 7 is a longitudinal section of one of the nozzles. Fig. 8 is a cross-section of the throat of a nozzle, taken on line 8 8 of Fig. 7. Fig. 9 is a section of the nozzle, taken on line 9 9 of Fig. 7. Fig. 10 is a view looking at the end of the nozzle. Fig. 11 is a detail view of the means employed for securing the intermediate buckets of the lower-pressure stages in position. Fig. 12 is an enlarged view showing the shape of the intermediate and wheel buckets in cross-section, and Fig. 13 is a detail view of a means for holding the diaphragms in place when the machine is used horizontally.

In carrying out my invention I divide the turbine into a relatively large number of stages and provide nozzles between the boiler or other source of elastic-fluid supply and the first stage and also between the stages, which nozzles have only a small amount of expansion, so that the velocity of the fluid-stream delivered thereby is relatively low. With this arrangement I find that two rows of wheel-buckets and a partial or segmental row of intermediate buckets in each stage are sufficient to abstract by successive operations all or substantially all of the velocity developed by the preceding nozzle. When the turbine is divided into four stages, the pressure on the several diaphragms can be kept within reasonable limits and a large amount of energy from the steam or other elastic fluid can be abstracted, resulting in a turbine of high efficiency. This high efficiency is due principally to the fact that the velocity of the fluid-stream is moderate and the buckets relative to the stream more nearly approach the proper theoretical speed.

Referring more particularly to Fig. 1, 1 represents the base of the turbine, which is cylindrical in outline and is provided with discharge openings or conduits 2, each having an outwardly-extending flange by means of which it can be bolted to a condenser or to a conduit conveying steam to the condenser or other exhaust. The upper surface of the base is provided with an outwardly-extending flange on which is seated and secured a casing 3 for the several stages. The casing in the present instance is made in four pieces, which are bolted together with steam-tight joints between them, the lines of division being in axial planes. The several sections are provided with radially-extending flanges through which the retaining-bolts 4 pass, and all engage with the shoulder 5, formed on the upper end of the base. The upper surface of the casing is provided with a cover 6, having a thickened rim or flange 7 and radially-extending strengthening-ribs 8, Fig. 4. The ribs are also connected near their outer ends by webs 9. The cover is provided with openings 10, through which extend the nozzles 11. The nozzles are secured to the upper side of the cover by bolts 12, so that the nozzle structure as a whole can be removed without disturbing the cover or other parts of the turbine. The under side of the cover is provided with as many radially-extending openings 13 as there are sets of nozzles. In the present instance two of these opening are provided. I prefer to form these openings solely in the cover instead of making the openings partially in the cover and partially in the casing, because it simplifies the construction and decreases the amount of labor required to finish them. In addition to the openings 13 other openings 14 are provided, which have suitable detachable covers. The object in providing the second set of openings is to enable the bucket-wheel to be inspected without disturbing the intermediates or nozzles, and thus affecting the alinement. The intermediates are secured to the cover and to the casing by bolts 15, and by removing the bolts which secure them to the cover the latter can be raised bodily without disturbing the alinement of the intermediates or the wheels. The central portion of the cover is provided with a suitable packing 16, which surrounds the vertically-extending shaft 17. I have found that the carbon rings 18 may with advantage be employed for this purpose. In the present illustration two carbon rings are shown, which are separated from each other by a division-plate and are retained in place by a cover 19, the latter being secured to the hub of the cover by bolts. The hub of the cover is provided with a shoulder, and engaging therewith is a cylindrical support 19^a, that carries the bearing 20, the latter being surrounded by the support or stool 21, that carries the dynamo-electric machine or other apparatus to be driven. The support 19^a is provided with an inwardly-extending flange 22, having an upturned edge which acts as a receiver for the lubricant thrown outward by the ring 23, carried by the main shaft.

In the present illustration I have shown four wheels, each of which is provided with two rows of buckets, the construction of which will be hereinafter described. Between the wheels are diaphragms 24, the construction of which is best shown in Fig. 2. The upper diaphragm is constructed somewhat differently from the diaphragms for the lower-pressure stages in that it does not carry the nozzles. The diaphragm is arched in order to give it strength, and the periphery is thickened, as at 25, to resist the heavy strains to which it is subjected owing to the difference in steam-pressure between the first and second stages. The periphery of the diaphragm is provided with a shoulder 26, that engages with a corresponding shoulder formed on the upper part of the casing 3. In addition to being thickened at the periphery the upper diaphragm is strengthened by radial ribs 27.

The diaphragms 30 of the lower-pressure stages are provided with thickened rims for the purpose of resisting internal strains, and they are also provided with deep radially-extending ribs 31. The outer face of the diaphragm is turned off true and is seated on a shoulder 33, formed on the casing or shell.

It is to be noted that both the high and low pressure diaphragms rest on shoulders formed on the shell or casing 3 and are held in place by gravity and also by the pressure exerted thereon when the turbine is in operation. By this arrangement I am able to greatly reduce the amount of machine-work and at the same time dispense with all small parts, such as bolts, &c. When the machine is used in a position other than a vertical one, devices may be employed to prevent the diaphragms from leaving their seats when the pressure is taken off. I have found that bolts 39^b, having conical ends arranged to engage with bevel-faces on the diaphragms, as shown in Fig. 13, are satisfactory for this purpose. The diaphragms are prevented from moving laterally by the cylindrical guide-surfaces 33^a, which extend at right angles to the shoulders and are turned at the same time the shoulders are formed.

The nozzles in the diaphragms are formed by cores at the time the casting is made. These nozzles comprise a bowl 34, a throat 35, and a discharge end 36. The throat and discharge end of these nozzles are rectangular in outline as distinguished from those nozzles which have a round throat and a rectangular discharge end. This arrangement is made desirable for simplicity and by reason of the slight expansion which is given to the nozzles. This will be hereinafter referred to.

It will be noted that the sectionalized nozzle 37, Fig. 2, for the second stage is formed in the casing 3 as distinguished from forming it in the diaphragm. The nozzle is composed of a plurality of expanding passages situated adjacent to each other, so that the motive fluid is delivered therefrom in the form of a solid stream or jet. These passages are formed in an inwardly-extending projection formed near the upper end of the casing or shell 3. It is advantageous to form the nozzles in the casing as distinguished from forming them in the diaphragm on account of the great strain to which the high-pressure diaphragm 24 is subjected. By this construction the high-pressure diaphragm can be made considerably smaller in diameter. Hence the pressure exerted thereon is correspondingly decreased. The construction and arrangement of the nozzle on the casing is such that the necessary metal can be provided to give it the requisite strength. Another advantage in this construction resides in the fact that the parts can be made of different kinds of metal. For example, the casing may be made of cast-iron and the diaphragm of cast-steel on account of its great strength. For various reasons it is impracticable to form a nozzle, and particularly one composed of a number of sections, in a steel casing at the time it is made; but this can be done in cast-iron without difficulty under proper conditions. In this manner I utilize the metals to their best advantage.

The fourth or lowest wheel is in direct communication with the vacuum-chamber formed within the base 1. Between the double row of buckets on each wheel is situated a row of intermediate buckets 38, which are segmentally arranged—that is to say, they extend around a portion only of the circumference of the casing. The arc covered by these intermediates increases, however, from the high to the stage of lowest pressure. This is made necessary by reason of the increased volume of the steam or other elastic motive fluid, due to its decreased pressure. The intermediates are carried by supports 39, and the latter are seated in grooves formed on the several parts of the shell or casing 3. They are retained in place by bolts 40, the heads of which are located outside of the casing. In Fig. 11 one of these bolts is shown on an enlarged scale. It will be noted that the under side of the head is provided with a conical surface 41, which engages with a similar surface on the casing 3. The object of this arrangement is to prevent steam from escaping around the body of the bolt, and hence to the atmosphere. It is advantageous to mount these intermediates in grooves formed in the casing, because it simplifies the matter of alinement and also the work of machining. After the ends of the several parts of the casing are finished and are united by retaining-bolts it is mounted on a boring-mill and the shoulders for receiving the diaphragms and the grooves for the intermediates are made. This work can all be done on a boring-mill of ordinary construction and by means of a suitable templet the exact location and size of all the shoulders and grooves determined, the bed of the boring-mill serving as a base from which to make the measurements. In this manner absolute accuracy in construction is assured. It is important that these intermediate buckets be accurately alined on account of the limited clearance between them and the wheel-buckets. The intermediates for the first or high-pressure stage are made adjustable, but those for the lower-pressure stages are immovable. The clearance between the stationary and moving buckets in the first stage is made as small as possible consistent with good operation and the clearances between the stationary and moving parts of the lower-pressure stages successively increased. This is made possible by reason of the decreased pressure of the motive fluid.

The adjustability of the high-pressure intermediates is apparent from Fig. 1. The ends of the intermediate-support are provided with projections 42, containing adjusting-bolts, which engage with opposite sides of the projections 43, formed on or secured to the cover 6. Between the bodies of the retaining-bolts and the support for the intermediate is a slight amount of clearance, so that when the bolts 15 are backed off slightly the intermediate can be adjusted up or down, as desired.

The vertically-extending main shaft 17 is provided with a suitable support 44, which is mounted in the base of the machine. It comprises, essentially, a bearing 45, which is situated directly under the shaft, and a bearing 46, which prevents the shaft from moving laterally. Situated above the bearing-support is a collar 47, which engages with the support when the shaft is lowered by rotating the adjusting-screw 48 backward. By reason of this construction the wheels and the shaft will be supported when it is desired to remove the lower bearing. The wheels are seated on shoulders formed on the shaft, and engaging with the upper wheel is a suitable nut.

In assembling the turbine the wheels are mounted in place and properly adjusted with respect to the high-pressure nozzles and the fixed intermediates, after which the high-pressure intermediates are adjusted to the proper position. It is important to maintain small clearances between the moving and stationary parts of the first wheel because of the difference in pressure which exists between the discharge end of the nozzle and the inclosing shell. When it is considered that the leakage through the clearances is determined by pressure differences, the necessity of making small clearances is apparent. The nozzles discharge steam at a pressure slightly above that of the shell, and owing to the fact that they cover an extended area the total leakage may amount to considerable with an improper relation of parts.

It is important to drain off the water of condensation, so as to prevent it from being carried along with the steam, and thus absorbing heat therefrom. A system of drainage is provided for this purpose, which is best shown in Figs. 1 and 2, wherein 50 represents a deflector having perforations 51. These perforations are in line with the discharge end of the first wheel, as shown in Fig. 1. The upper end of the deflector is situated just below the clearance between the wheel and intermediate buckets, so that any water projected outward at this point will pass to the outside of the deflector and be collected in the gutter 52. The diaphragm 24 is provided with a number of catch-basins formed between the radial ribs and the thickened rim. In order to convey water from this point to the outside of the wheel, passages 53 are provided, as shown in dotted lines. These passages communicate with the vertically-extending passages that drain the gutters 52. In order to control the flow of water from one stage to the next, a valve 54 is provided having a conical surface 55, which engages with a corresponding seat in the passage leading from one shell to the next. These passages are formed in the casing or shell 3. The second wheel is provided with a perforated deflector-plate arranged similar to plate 50. It will be noted that these plates are situated between the water-discharging passage 56 of the preceding stage and the bucket-wheels. In this manner water drained from one stage is prevented from being entrained with the steam discharged from the second wheel.

The diaphragm 30 is provided with a passage 57 for conveying water to a point beyond the bucket-wheel. This passage communicates with a space or gutter located back of the deflector-plate, which is attached to the periphery of the diaphragm and also communicates with the adjacent stage of lower pressure. After the water is discharged from this passage it flows through the opening or passage 58, that is formed back of and shunts the intermediate. This construction being the one followed in the next stage of lower pressure, further description is unnecessary.

Referring to Figs. 6 and 12, the construction of the buckets will be described. A plurality of radially-extending buckets 60, having sharpened receiving and discharge ends, are cast or formed integral with a segmental support 61. For large machines it will be found best to make these buckets up in relatively short segments; but for smaller machines it is not so necessary, and the segments can be made much larger, or even the whole row of buckets can be formed in a single ring.

The buckets are provided with a detachable cover 62, which is preferably made up in sections and secured in place by tenons formed integral with the buckets, the said tenons being riveted over at their outer end. The support for the buckets is provided with a hook-like projection or shoulder 62[a], which engages with a peripheral shoulder or enlargement on the bucket-wheel 63. The opposite faces of the wheel are faced off true, and engaging therewith are the finished surfaces 64 on the bucket-supports. These surfaces are preferably made of considerable extent, so as to afford a firm bearing for the buckets. In order to retain the buckets in place, bolts 65 are provided, which extend through the buckets of both rows and also axially through the web or flange of the wheel. The hook-like projections or shoulders on the buckets engage or interlock with the shoulders formed on the wheel, and the major portion of the strain due to centrifugal action is taken up by these shoulders. By this construction all danger of breakage under centrifugal strain is obviated, and the buckets and wheel can be made at a minimum cost.

Referring to Fig. 12, it will be seen that the support 61 and the cover 62 are somewhat wider than the bucket and that the sharpened rear edge of the bucket is flush with the support and cover, whereas the front edge is set back slightly from said support and cover. It will also be seen that the support and cover are beveled or cut away slightly at the entrance of the working passage between the buckets. The object in this arrangement is to insure an unobstructed entrance of motive fluid to the passage, since any restriction at this point tends to create eddies resulting in a decrease in efficiency. By having the support and cover project beyond the buckets there is less liability of injury to the buckets in case the moving and stationary parts should momentarily rub for any cause.

In Fig. 5 is shown in plan one section of the cylindrical casing 3. This clearly illustrates the feature of the inwardly-extending projection having a shoulder 66 to receive the diaphragm 24 and the nozzles 37 and also that the lines of division are in radial planes. 53 represents the passage shown in dotted lines for conveying water of condensation from the diaphragm to a point beyond the wheel, and 52 represents the gutter which collects the water received from the wheel and discharges it through the opening 56 into the adjacent stage of lower pressure. In this figure the valve 54 is not shown, although the opening and the seat therefor are illustrated in dotted lines. At 67 are illustrated in dotted lines the openings for receiving the intermediate retaining-bolts 40.

In Fig. 7 is shown a longitudinal section of a nozzle for converting the pressure of the motive fluid into velocity and discharging it against the bucket-wheels. The nozzle comprises a plurality of passages, each provided with a well-rounded bowl 37 and a restricted throat 68 in the form of a parallelogram. The cross-section on line 8 8 at the throat is as indicated in Fig. 8. At 9 9 the section is a parallelogram of the form illustrated in Fig. 9. In Fig. 10 is shown the shape of the stream of motive fluid as it strikes the bucket-wheel. It will be noted that it corresponds closely to the shape of the passages between wheel-buckets.

It has been customary heretofore to make the throat 68 of the nozzle or nozzle-section of circular cross-section and to gradually change the form to a rectangle at the point of discharge, which arrangement is, generally speaking, satisfactory where the velocity of the fluid stream is relatively high. I have found, however, where the velocity of the fluid stream is relatively low that it is better to change the form of the throat from one having a circular cross-section to one having the form of a parallelogram, because by so doing the several passages or sections may be grouped in a manner to occupy a smaller space and the angle of the throats with respect to the wheel can be improved. The feature of a nozzle section or passage having flat diverging walls as contrasted with one having a cylindrical wall with a rectangular discharge-opening is also advantageous, because it gives a better lateral expansion to the motive fluid. The reason why my improved nozzle sections or passages can be grouped in a smaller space than those having circular throats is readily apparent when the difference in area between a circle and a square whose sides equal the diameter of the circle is considered. For example, a rectangular opening having an area of one square inch would have sides one inch long, whereas a circle having a cross-sectional area of one inch would have a diameter of 1.128 inches. In other words, each cylindrical throat occupies a greater space than a rectangular throat of the same cross-section. Hence the total space occupied by the nozzle will be greater in the former case than in the latter.

The area of the throat of a nozzle or nozzle-section is determined by the amount of fluid which must pass through it to fulfil the conditions of operation. The discharge end of the nozzle must be so shaped that the contour of the fluid stream as delivered will correspond to that of the receiving passage or passages between the wheel-buckets; otherwise they will not be filled, and there will be a loss in efficiency. By making the throat of each nozzle or nozzle-section where a number are grouped together in the form of a parallelogram I can obtain any desired expansion, no matter how small it may be, and at the same time group the sections into a minimum amount of space. The bowl of each nozzle or nozzle-section should be rounded, so as to reduce the frictional retardation of the steam, and the surfaces uniting the throat with the bowl should be carefully rounded for the same reason.

It will be seen that by taking off one of the sections of the casing all of the wheels are exposed, and this without altering the alinement of the machine as a whole. To put the matter in a different way, each casing-section is common to a plurality of wheel-chambers.

I have shown my invention in connection with a machine having two wheels per stage, meaning thereby a machine having two rows of wheel-buckets in each stage; but I do not wish to be understood as limiting myself to such a construction. The turbine shown is of the vertical type, and many of the improvements are particularly applicable thereto; but the invention is broad enough in certain of its aspects to include horizontal turbines or turbines operating at other angles.

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 in other ways.

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 separate compartments or shells, a wheel for each shell, a double row of buckets for each wheel, one on each side of the plane of the wheel, supports for the buckets which are secured to the sides of the wheel, a single row of intermediate buckets for each compartment or shell which is in line with the wheel-periphery, and nozzles for delivering motive fluid to the several wheels.

2. In an elastic-fluid turbine, the combination of a plurality of separate compartments or shells, a wheel for each shell having a smooth periphery, a double row of buckets for each wheel, supports for the buckets which are secured to opposite sides of the wheel, a single row of intermediate buckets for each compartment or shell which is situated between the double rows of buckets and opposite the wheel-periphery, and expanding nozzles for delivering motive fluid to the buckets, each nozzle having a rectangular throat and a similar discharge end.

3. In a turbine, the combination of a wheel or support having a shoulder formed on one side of its rim, with detachable buckets which extend radially beyond the rim and engage with said shoulder, the bottom of the passage between the buckets being located beyond the rim, and a cover which closes in the space between the outer ends of the buckets.

4. In a turbine, the combination of a wheel or support having a shoulder formed on one of its faces, detachable buckets formed integral with a support which engages with the shoulder, the bottom of the bucket-passage being located beyond the wheel-rim, means for holding the support in engagement with the shoulder, and a segmental cover which is secured to the outer ends of the buckets.

5. In a turbine, the combination of a wheel or support having shoulders formed on opposite faces, detachable buckets, supports therefor arranged in segmental form and provided with shoulders which interlock with the wheel-shoulders, means for retaining the buckets in place, and a cover which closes in the outer ends of the buckets whereby the motive fluid is caused to flow from one side to the other.

6. In a turbine, the combination of a wheel or support having a web with a peripheral flange which extends both sides thereof and forms shoulders, buckets having hook-like projections which engage with the shoulders, retaining means that pass through the bucket projections into the wheel, and a cover which closes in the outer ends of the buckets and causes the motive fluid to flow from one side to the other.

7. In a turbine, the combination of a wheel or support having a web, detachable segmental buckets having shanks formed integral therewith which engage with opposite sides of the wheel-web, and retaining-bolts which pass through the shanks and also through the web.

8. In an elastic-fluid turbine, the combination of a shell, a wheel within the shell having cylindrical shoulders formed on opposite sides thereof, detachable buckets having projections which engage with the shoulders for resisting the centrifugal strains, a single row of

intermediate buckets in the shell and extending between the wheel-buckets, and a nozzle for delivering a jet of motive fluid to the wheel.

9. In an elastic-fluid turbine, the combination of a row of buckets, a support and cover therefor which project beyond one edge of each bucket and are flush with the other edge, a second row of buckets adjacent thereto, and a support and cover therefor which project beyond the buckets on the side adjacent to the the first row of buckets and are flush therewith on the opposite side.

10. In an elastic-fluid turbine, the combination of a plurality of buckets having sharpened front and rear edges, with a support and cover therefor which project beyond the sharpened front edge of the bucket and are provided with cut-away surfaces to facilitate the entrance of motive fluid to the passages between buckets.

11. In an elastic-fluid turbine, the combination of a wheel, a casing therefor having a groove formed in the interior wall, an intermediate bucket-support which is seated in said groove, a diaphragm, a shoulder between the diaphragm and the casing whereby the former is supported, and nozzles for converting the pressure of the motive fluid into velocity and discharging it against the wheels.

12. In an elastic-fluid turbine, the combination of two or more wheels, a casing which incloses the wheels and has a groove formed in the interior wall, intermediate buckets which are fitted into the groove and are situated entirely within the casing, bolts for securing the buckets in place which are accessible from the outside of the casing, and a diaphragm for separating adjacent wheels which is entirely inclosed by the casing.

13. In an elastic-fluid turbine, the combination of a wheel, a casing which incloses the wheel and has a groove formed in the interior wall, intermediate buckets which are fitted into the groove and are situated entirely within the casing, bolts for securing the buckets in place which are accessible from the outside of the casing, and an enlargement on each of the bolts for preventing the escape of motive fluid around its body.

14. In an elastic-fluid turbine, the combination of a wheel, a casing therefor, intermediate buckets and their support which are entirely inclosed by the casing, bolts which enter the casing from the outside, and a conical enlargement under each bolt-head for preventing the escape of motive fluid around its body.

15. In an elastic-fluid turbine, the combination of a plurality of wheels having radial buckets, a sectional casing having an inwardly-extending projection formed integral therewith, which overhangs the wheel and has a nozzle cast therein, said nozzle comprising closely-associated passages for delivering fluid to the wheel, a detachable diaphragm between the wheels which rests on the projection, and a shoulder between the projection and the diaphragm.

16. In a staged turbine, the combination of a casing having a projection which overhangs a bucket-wheel, a shoulder which is formed on its inner wall and outside of a wheel-periphery, nozzles for the projection, a diaphragm which rests on the projection, a second diaphragm larger than the first, which rests on the shoulder, and bucket-wheels inclosed by the casing and located adjacent to the diaphragms.

17. In a turbine, the combination of a bucket-wheel, a casing therefor having a projection which extends inward over the buckets toward the axis of the wheel, nozzles for delivering motive fluid to the wheel, which are formed in the projection, a shoulder formed on the projection, and a diaphragm which is seated on said shoulder.

18. In an elastic-fluid turbine, the combination of a wheel having rows of buckets, intermediate buckets situated between the wheel-buckets, and a cylindrical casing comprising a number of sections, divided in axial planes which are removable radially to expose the wheel and intermediate buckets, certain of said sections being provided with nozzles cast therein.

19. A turbine-casing comprising a cylinder which is split into sections in radial planes, certain of the sections having a plurality of closely-associated nozzle-passages and the remainder being without.

20. In a turbine, the combination of a bucket-wheel, a casing therefor comprising a plurality of sections each of which is provided with a projection that extends inward over the buckets, and a plurality of closely-associated nozzle-passages which are formed in certain of the said projections and not in others.

21. In a turbine, the combination of a casing having a shoulder formed on the inside thereof, a cover for the casing, a bucket-wheel, and a diaphragm which rests on the shoulder and is held there by its own weight and by the pressure to which it is subjected.

22. In a turbine, the combination of a casing having two or more internal shoulders formed thereon, a cover for the top of the casing, two or more bucket-wheels mounted on a common shaft, and diaphragms which separate the wheels one from the other and rest on the shoulders within the casing and are retained in place by their own weight and by the pressure to which they are subjected.

23. In a turbine, the combination of a casing having an internal shoulder formed thereon at a point between the ends, a bucket-wheel, a diaphragm which rests on the shoulder and is held in place by its own weight and by the pressure to which it is subjected, and nozzles which are movable with the diaphragm.

24. In a turbine, the combination of a cylindrical casing having a shoulder and a guide

formed thereon at a point between its ends, a diaphragm which rests on the shoulder and is held by its own weight and by the pressure exerted thereon, and is prevented from moving laterally by engaging with said guide, a nozzle movable with the diaphragm, and a bucket-wheel receiving motive fluid from the nozzle.

25. In an elastic-fluid turbine, the combination of bucket-wheels, a casing which incloses all of the wheels and is separated in axial planes, shoulders formed on the inner walls of the casing between the ends, and diaphragms which separate the space between the wheels and are supported by the shoulders.

26. In an elastic-fluid turbine, the combination of a plurality of wheels, a casing which incloses the wheels, a projection on the inner wall of the casing which is provided with a shoulder and a groove, a diaphragm which separates one wheel from the next and rests on the shoulder, and intermediate buckets which are seated in the groove.

27. In an elastic-fluid turbine, the combination of a plurality of stages, a wheel for each stage, adjustable intermediates for the high-pressure stage, and fixed intermediates for the lower-pressure stages.

28. In an elastic-fluid turbine, the combination of a plurality of stages working at successively-decreasing pressures, a bucket-wheel for each stage, a nozzle for each stage, and intermediate buckets for each stage which are separated by a clearance from the wheel-buckets, the said clearances gradually increasing in amount as the pressure in the stages decreases, substantially as and for the purpose described.

29. A nozzle for a turbine compri ing a body of metal having a plurality of closely-associated expanding discharge-passages, each having a throat and a discharge end, both of which form parallelograms in cross-section, the discharge end of the several passages being arranged to deliver the motive fluid in a solid stream, in combination with a shoulder formed in said body of metal adjacent to the passage, and a diaphragm which rests on the shoulder.

30. In a turbine, the combination of bucket-wheels, a casing therefor, a diaphragm between the wheels, and an expanding nozzle formed in said diaphragm comprising a plurality of closely-associated sections, each of which has a throat and a discharge end both of which form parallelograms in cross-section, the discharge ends of the several passages being arranged to discharge the motive fluid in a solid stream.

31. In an elastic-fluid turbine, the combination of a bucket-wheel and intermediate, a deflector partially surrounding a row of wheel-buckets and having one edge nearly in line with the clearance between the moving and intermediate buckets whereby the water discharged from the wheel due to centrifugal force is collected.

32. In an elastic-fluid turbine, the combination of a bucket-wheel, intermediate buckets located between wheel-buckets, and a perforated deflector situated beyond the wheel-buckets for collecting water thrown from the wheel.

33. In an elastic-fluid turbine, the combination of a plurality of bucket-wheels, intermediate buckets, a diaphragm between one wheel and the next, and a deflector which is attached to the diaphragm for collecting water thrown from the wheel.

34. In an elastic-fluid turbine, the combination of two or more stages, a wheel for each stage, a diaphragm which separates one stage from the next, water-conveying passages which extend from one stage to the next, and deflectors which are situated between the passages and the wheels.

35. In an elastic-fluid turbine, a plurality of separate nozzle sections or passages grouped together and arranged to discharge motive fluid as a solid stream, each nozzle section or passage having a throat and discharge end which in cross-section form a parallelogram, bowls which are anterior to said nozzle sections or passages, a casing in which the nozzle is formed, and a diaphragm which rests on the casing.

36. In an elastic-fluid turbine, the combination of a casing, a bucket-wheel, a cover for the casing having radially-extending openings on the under side, the upper end of said casing acting as the lower wall for said openings, and intermediate buckets which are mounted in said openings.

37. In an elastic-fluid turbine, the combination of a casing, a bucket-wheel, a cover for the casing having radially-extending openings on the under side, the upper end of said casing forming the lower wall for the openings, intermediate buckets which are mounted in said openings, axially-extending nozzle-receiving openings, and nozzles which are located in the axial openings.

38. In an elastic-fluid turbine, the combination of a casing having a shoulder, a gutter formed in the shoulder for collecting water due to condensation, and a diaphragm mounted on the shoulder.

39. In an elastic-fluid turbine, the combination of a casing having a projection which extends inwardly over the wheel-buckets, nozzles carried thereby, a gutter formed in the projection, a passage for drawing the water from the gutter, and a bucket-wheel.

40. In a turbine, the combination of a plurality of bucket-wheels, a diaphragm between each pair of wheels, a sectional casing for the wheels which is divided in axial planes, each section covering a plurality of wheels.

41. In a turbine, the combination of a plurality of wheels, a sectional casing which surrounds the wheels and is divided in axial planes, each of said sections being common to a plurality of wheel-chambers.

42. In a turbine, the combination of a casing, a diaphragm engaging with a seat on the casing and normally held in place by the pressure to which it is subjected, and means for preventing the diaphragm from leaving its seat when the pressure thereon is removed.

43. In a turbine, the combination of a casing having a seat formed thereon, a diaphragm engaging therewith and normally held against the seat by the pressure to which it is subjected, and bolts which engage with the diaphragm for preventing it from leaving its seat when the pressure is removed from the diaphragm.

44. In an elastic-fluid turbine, the combination of a shell or casing, a wheel mounted therein having a single-piece web, a double row of buckets for the wheel, supports for the buckets which are secured to opposite sides of the wheel-web, a single row of intermediate buckets located between the rows of wheel-buckets, and means for discharging motive fluid against the buckets.

In witness whereof I have hereunto set my hand this 12th day of March, 1903.

WILLIAM L. R. EMMET.

Witnesses:

ALEX. F. MACDONALD,

HELEN ORFORD.