No. 849,420. PATENTED APR. 9, 1907.

W. A. NUSSBAUMER.

ELASTIC FLUID TURBINE.

APPLICATION FILED DEC. 24, 1906.

4 SHEETS—SHEET 1.

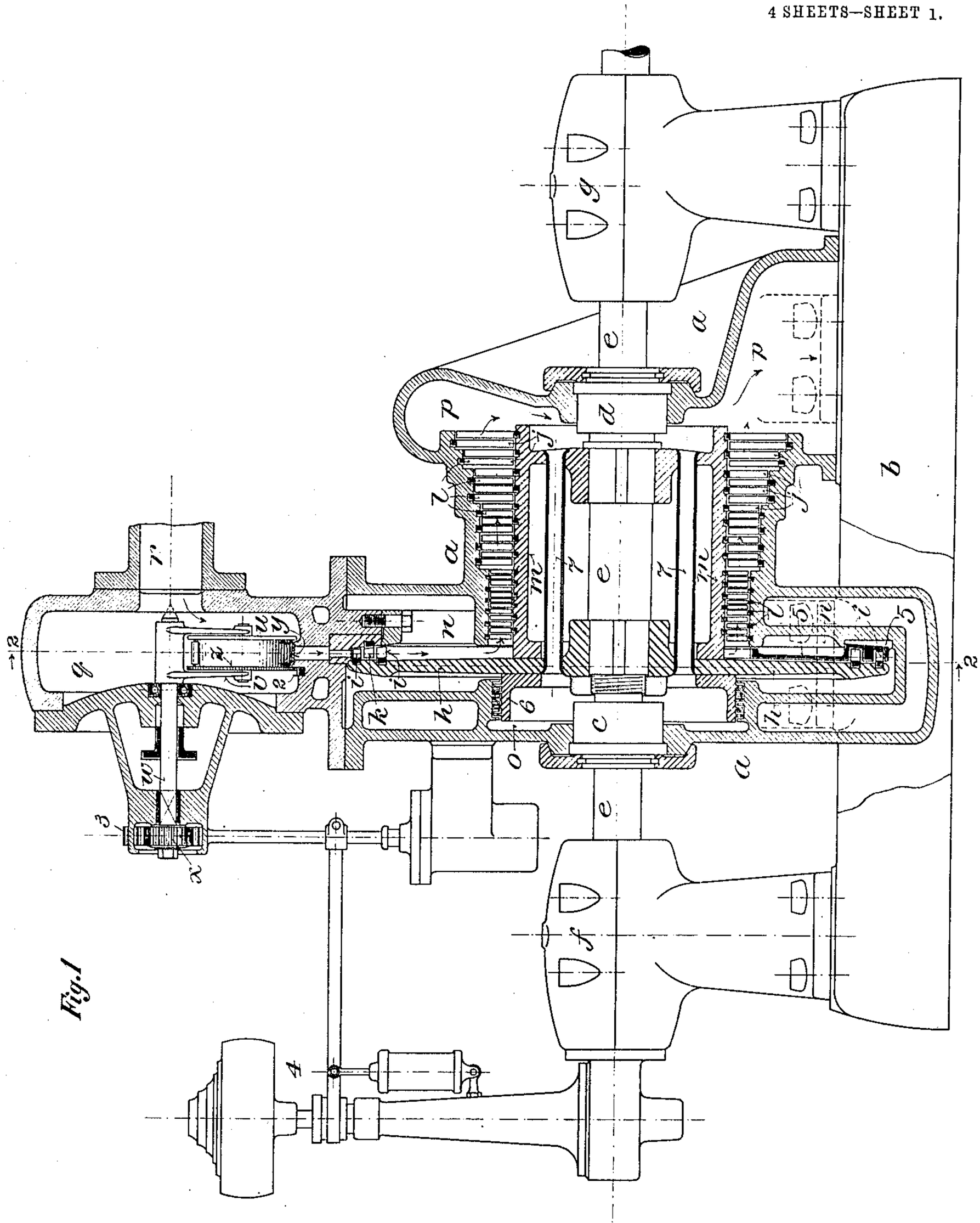

Fig. 1

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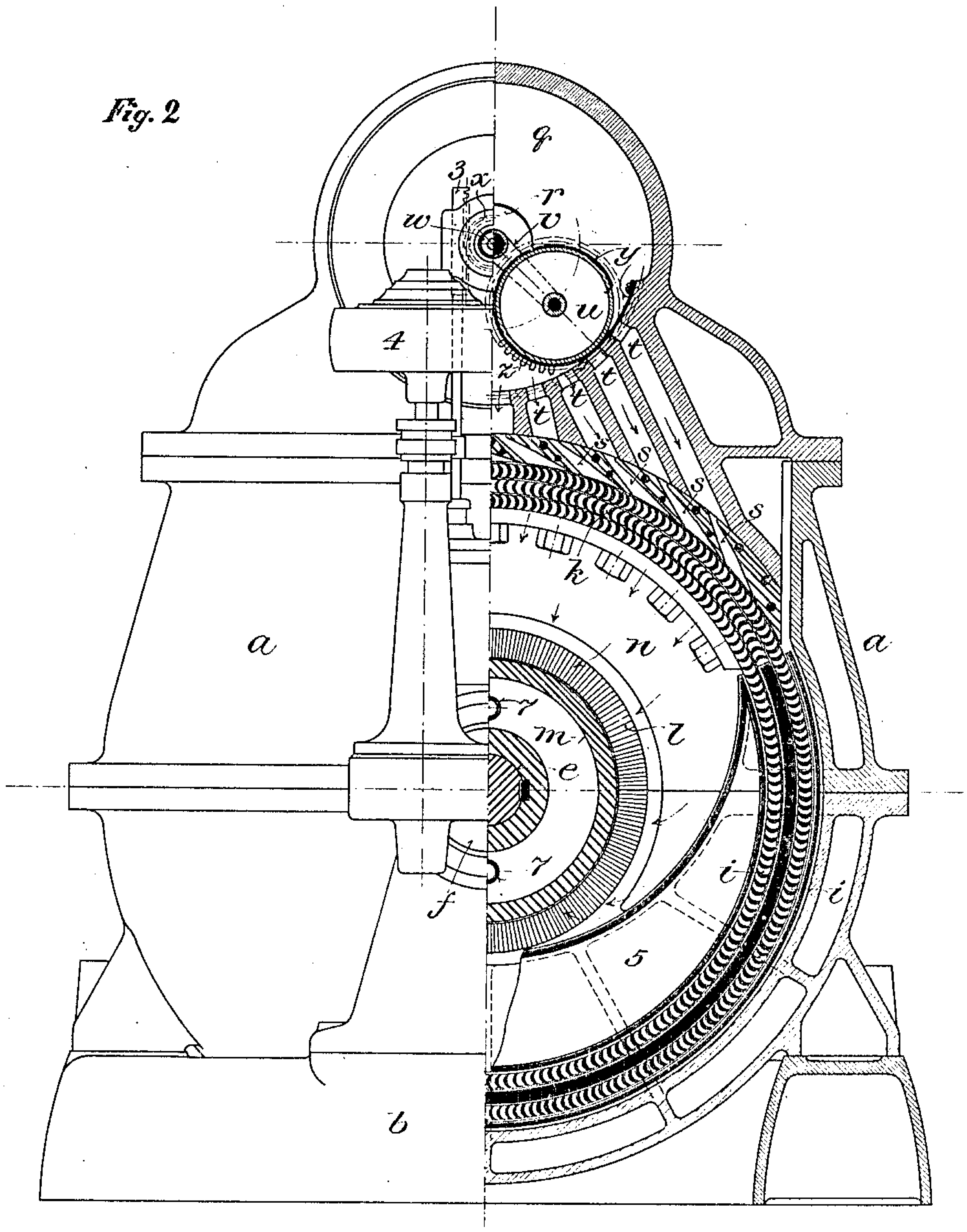
4 SHEETS—SHEET 2.

Fig. 2



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4 SHEETS—SHEET 3.

Fig. 3

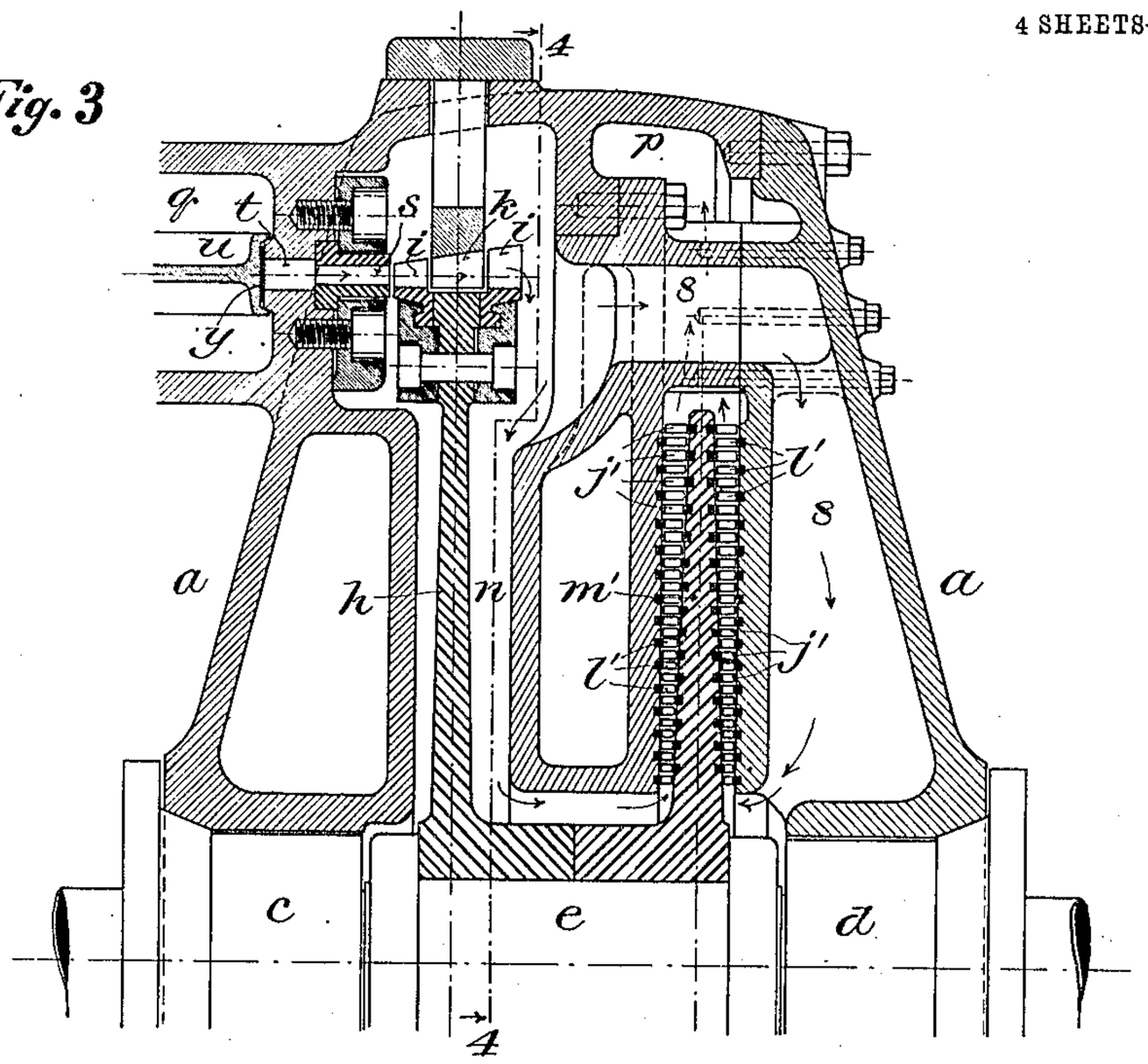
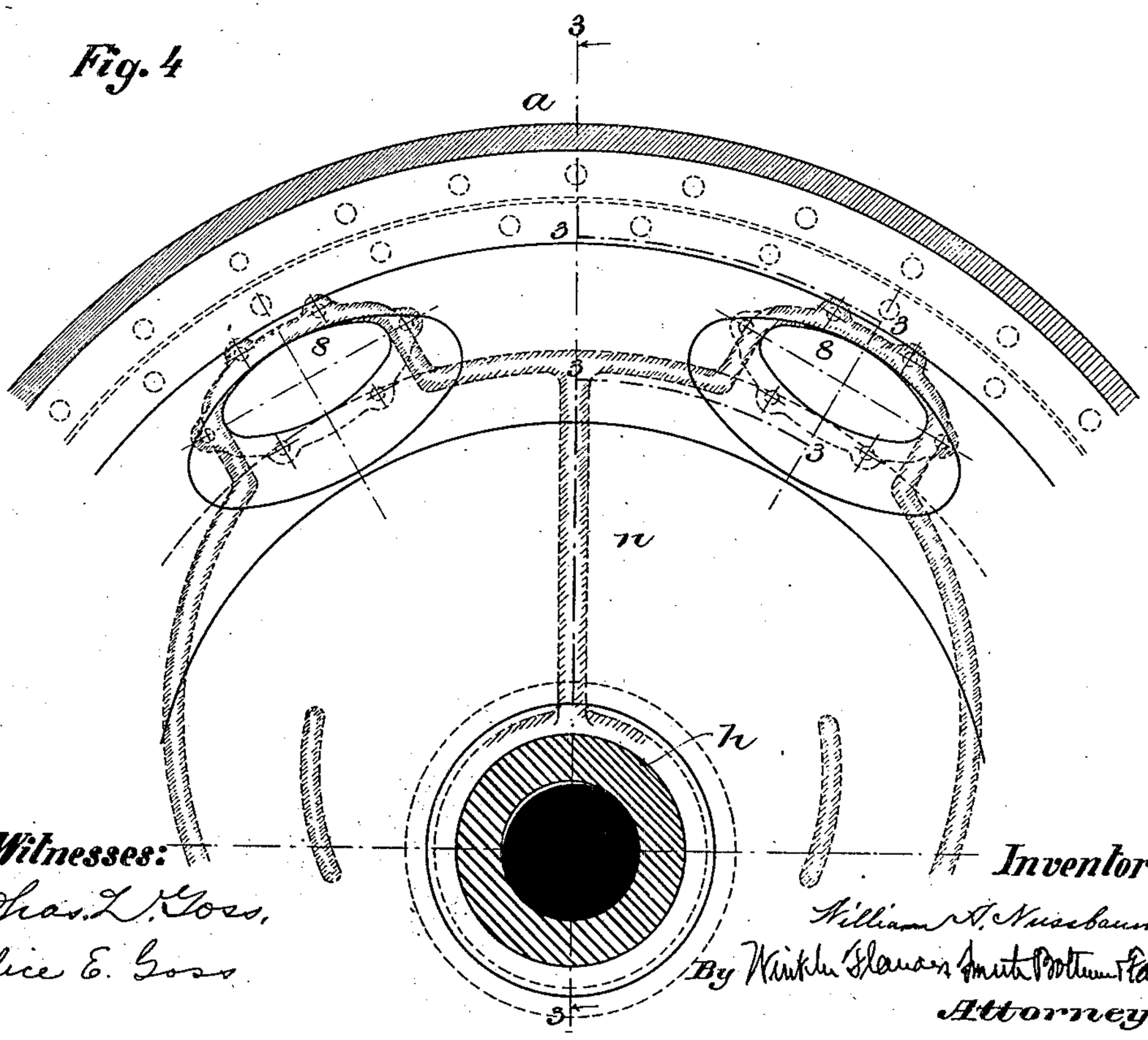


Fig. 4



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4 SHEETS—SHEET 4.

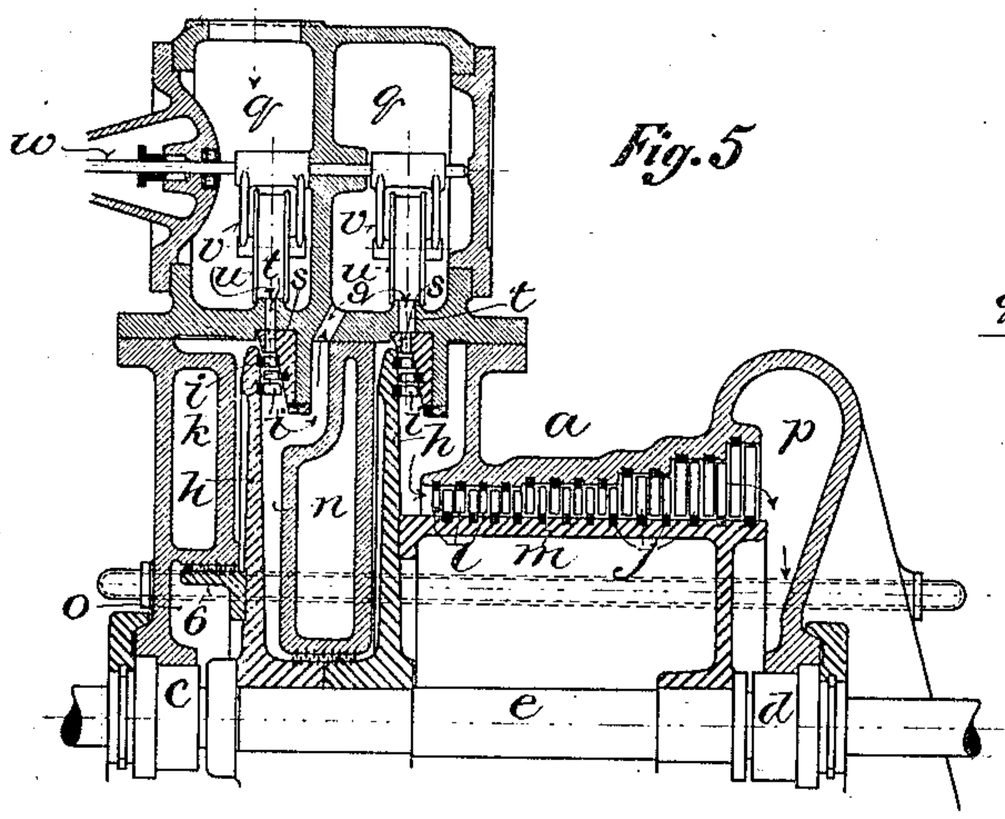

Fig. 5

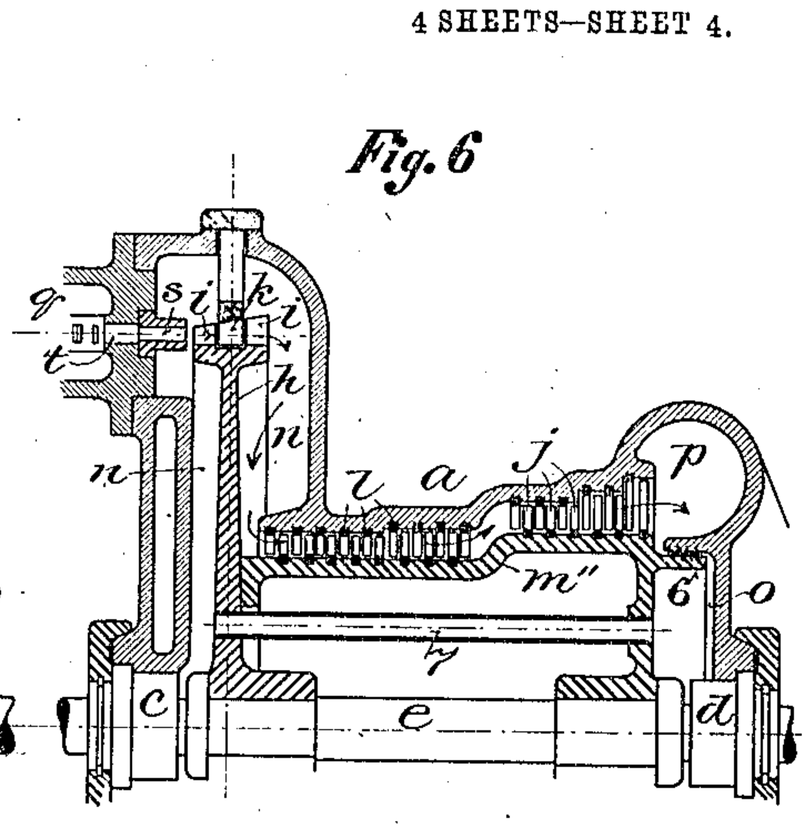

Fig. 6

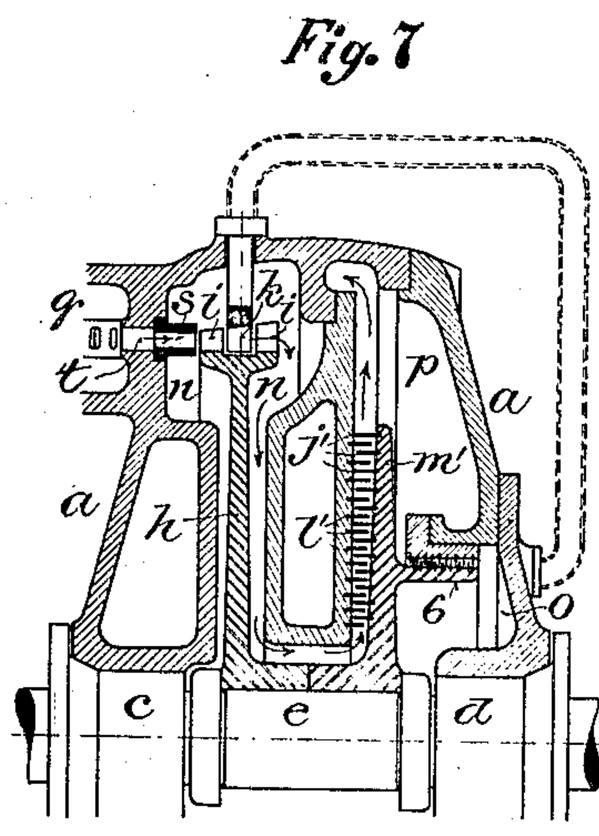

Fig. 7

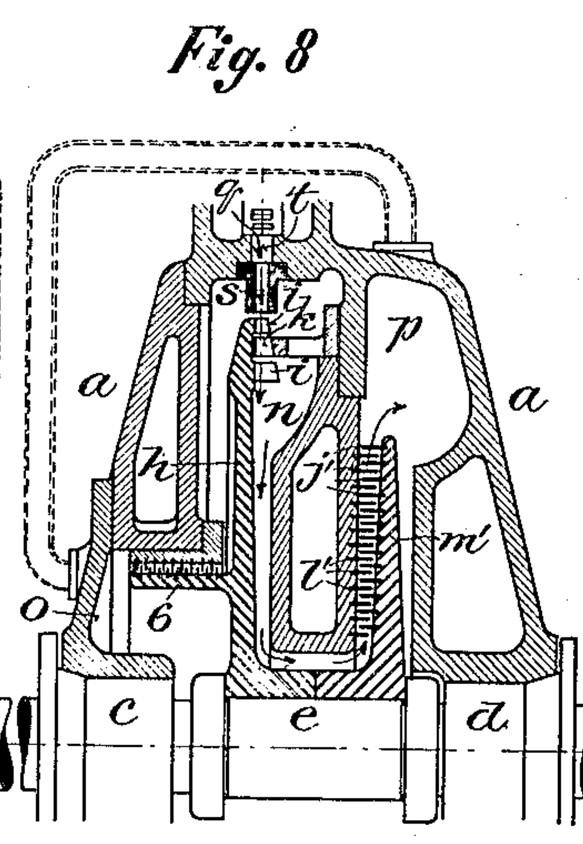

Fig. 8

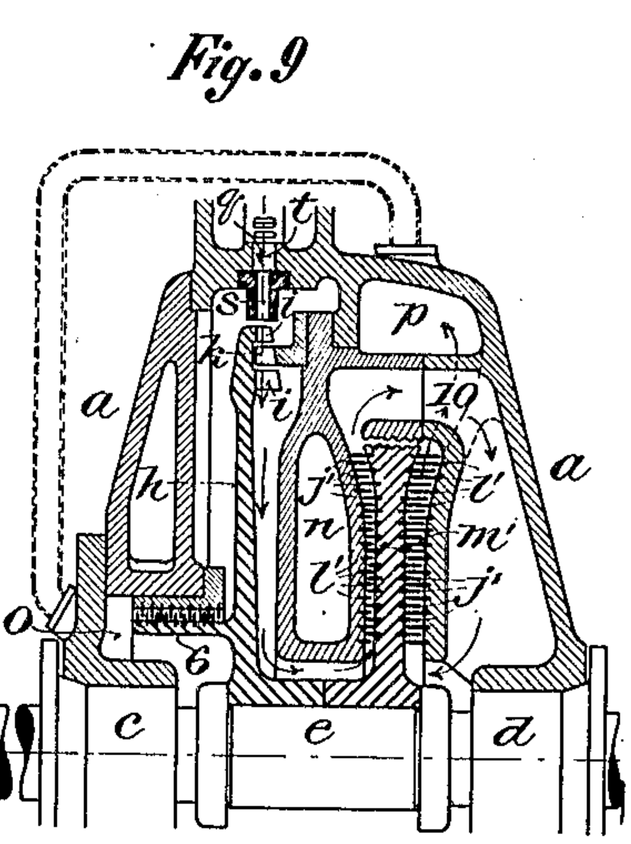

Fig. 9

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UNITED STATES PATENT OFFICE.

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ELASTIC-FLUID TURBINE.

No. 849,420. Specification of Letters Patent. Patented April 9, 1907.

Application filed December 24, 1906. Serial No. 349,285.

To all whom it may concern:

Be it known that I, WILLIAM A. NUSSBAUMER, a citizen of the Republic of Switzerland, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented certain new and useful Improvements in Elastic-Fluid Turbines, of which the following is a specification, reference being had to the accompanying drawings, forming a part thereof.

The main objects of this invention are to convert the energy developed in the drop of steam or other motive fluid from a higher to a lower pressure or temperature into mechanical work to the greatest advantage and with the greatest economy, to so combine the principles of impulse and reaction turbines as to eliminate the disadvantages and retain the advantages of each of said types, and generally to improve the construction and operation of engines of this class.

By the term "impulse-turbine" is intended a turbine of the De Laval type, in which the pressure of the motive fluid does not change, but its velocity is reduced in passing or acting upon each series or set of vanes, and by the term "reaction-turbine" is intended a turbine of the Parsons type, in which the pressure of the motive fluid is reduced or falls in passing or acting upon each series or set of vanes.

The invention consists in certain novel features of construction and in the peculiar arrangement and combinations of parts hereinafter particularly described, and defined in the claims.

In the accompanying drawings like characters designate the same or similar parts in the several figures.

Figure 1 is a view, partly in side elevation and partly in vertical axial section, of one form of steam-turbine embodying the invention. Fig. 2 is a view of the same, the left-hand side being an end elevation and the right-hand side a vertical cross-section on the line 2 2, Fig. 1. Fig. 3 is a partial axial section on the broken line 3 3, Fig. 4, of a modified form of the turbine. Fig. 4 is a cross-section of the same on the line 4 4, Fig. 3; and Figs. 5, 6, 7, 8, and 9 are partial axial sections, on a reduced scale, of other modifications also embodying the invention.

Referring to Figs. 1 and 2, *a* designates the casing of the turbine mounted on a base *b* and provided in the ends with stuffing-boxes *c* and *d*. The rotating part of the turbine comprises a shaft *e*, passing through the stuffing-boxes *c* and *d* and supported by bearings *f* and *g*, which are mounted on the base *b*, an impulse-wheel or high-pressure member *h* and a reaction or low-pressure member *m* fixed on said shaft within the casing. The impulse-wheel or high-pressure member *h*, which in the present instance is made in the form of a disk, is provided with two concentric circular series or rows of vanes or buckets *i*, which in the present case are attached to one side of the wheel or disk near its periphery. The reaction or low-pressure member *m*, constructed in the present case in the form of a hollow drum or cylinder, is provided on the outside with several concentric circular series of vanes or buckets *j*, increasing in size from left to right according to the customary practice in turbines of the Parsons or reaction type. The casing is provided with a series of stationary guide-vanes or buckets *k*, arranged between the two series or rows of movable vanes *i* of the impulse wheel or member *h*, but extending only part way around it, as shown in Fig. 2. The casing, which is made to conform approximately with the impulse wheel or disk *h* and with the drum *m* of the reaction or low-pressure member, which is of considerably smaller diameter than said disk, is also provided with several series of fixed vanes or buckets *l*, arranged concentric with and in position to direct the steam or other motive fluid at the proper angle against the successive series or sets of movable vanes *j* of said reaction or low-pressure member. Between the impulse or high-pressure member *h* and the reaction or low-pressure member *m* of the turbine a receiver or chamber *n* is provided to receive steam discharged from the inner series of vanes of the high-pressure member and deliver it at the same pressure to the entire first series of vanes of the low-pressure member, said chamber extending completely around the drum *m* and also communicating with the inclosed space on the opposite side of the wheel or disk *h*. The casing also forms or incloses at the end next to the impulse-wheel a cylindrical piston-chamber *o* and at the opposite end an exhaust-chamber *p* in communication with the delivery end of the low-pressure member. Upon the upper part of the casing, over the impulse-wheel *h*, is mounted a steam-chest *q*, with which the

steam-supply pipe *r* connects. A series of nozzles *s*, arranged in the arc of a circle to deliver steam to the upper part of the outer series of movable vanes *i*, are severally connected by passages *t* with the steam-chest *q*. The nozzles *s* may be conveniently formed, as shown, in a segment of a ring which is fitted and secured in the upper part of the casing *a* adjacent to the periphery of the impulse-wheel, and to this segment the stationary buckets or guide-vanes *k* are attached.

Any suitable form of valve mechanism may be employed to control and regulate the supply of motive fluid from the steam-chest *q* to the impulse or high-pressure member of the turbine. As suitable for the purpose that shown in Figs. 1, 2, and 5 will be briefly described, although no claim thereto is made herein.

In the steam-chest *q* a roller *u* is carried in a swinging frame or forked arm *v*, which is fixed on a shaft *w*, passing through a stuffing-box in one side of the steam-chest and provided at its outer end with a pinion *x* or other suitable means for turning it. The openings or ports through which the passages *t* communicate at their upper ends with the steam-chest are arranged in a curved face concentric with the axis of the shaft *w*, and a flexible band-valve *y*, attached at one end to the periphery of said roller and at the other end to the curved port face, is adapted to close and open said ports one after another, the shaft *w* being turned in the proper direction to unwind or wind said band-valve on said roller. To prevent the band-valve from buckling and to insure it tightly closing the ports opening into the passages *t* from the steam-chest, the roller *u* is provided at one end with a spur-gear or teeth *z*, which mesh with a rack 2 in the steam-chest.

The valve mechanism above mentioned may be operated manually for regulating the supply of steam to the turbine for different loads, or it may be operated automatically by a connection through the pinion *x* and a rack 3 with a centrifugal governor 4 of any suitable construction, geared or otherwise connected with the shaft *e*.

To avoid or reduce loss of power on account of the ventilating action of the impulse-wheel running at a high velocity in a body of steam under pressure, the inactive movable vanes *i*, or those which are not supplied by the nozzles *s* with steam, are covered by a stationary plate or shield 5, which separates them from the body of steam in the receiver or chamber *n*.

In a turbine having its parts constructed and arranged as shown in Figs. 1 and 2 there is an end thrust on the reaction or low-pressure member *m* toward the exhaust chamber or passage *p*. To balance this end thrust, the impulse-wheel *h* has a larger area exposed to the pressure in chamber *n* on the side next to the reaction member *m* than on the opposite side, and a piston 6 is attached to the impulse-wheel *h* and fitted to turn and move endwise in the chamber *o*, labyrinthine or other suitable packing being interposed between said piston and the surrounding wall of said chamber, which is connected with the exhaust chamber or passage *p* at the opposite end of the turbine by pipes 7 passing through the drum *m* of the low-pressure member. The unbalanced pressure area of the impulse-wheel *h*, exposed to receiver-pressure, balances the end thrust produced by the action of the steam on the vanes of the reaction member, while the piston 6 balances the end thrust on the drum of the reaction member.

The turbine constructed as hereinbefore described operates as follows: Steam being admitted through the supply-pipe *r* into the steam-chest *q*, passes thence, as indicated by arrows on Figs. 1 and 2, through the open passages *t* to the nozzles *s*, by which it is directed at the proper angle against the outer or first series of movable vanes *i*. In the nozzles a certain amount of the potential energy of the steam is transformed into kinetic energy, which in turn is converted into mechanical work by the movable and fixed guide-vanes of the impulse member of the turbine, the nozzles and vanes being so shaped and proportioned that the steam is expanded as it issues from the nozzles to a pressure producing a velocity which will be spent by its impact against the vanes in doing mechanical work without material change in the pressure of the steam. The steam acting at high pressure on the impact or impulse principle without material change in pressure in the first stage or stages of its operation, the number of series or sets of vanes that can be practicably utilized in connection with the impulse or high-pressure member of the turbine is limited and will not ordinarily exceed two sets of moving vanes to each impulse-wheel with a single intervening series of fixed guide-vanes, which serve simply to change the direction of the flow of steam. The steam entering the receiver or chamber *n* and filling the inclosed space on both sides of the impulse-wheel *h* under the pressure at which it is delivered from the nozzles *s* is delivered at that pressure all around the drum *m* of the low-pressure member to the entire series of fixed and movable vanes *l* and *j* successively from left to right, escaping from the last set of guide-vanes into the exhaust space or passage *p*. All the available energy of the steam remaining after it has acted upon the impulse or high-pressure member of the turbine is thus exerted and spent simultaneously upon the several entire series of vanes of the reaction or low-pressure member, so that the entire energy developed by the drop in pressure or temperature of the steam from its admission to its exhaust from the turbine

is thus utilized to the best advantage with the greatest economy and in the smallest compass.

By substituting for the first part of a reaction-turbine or turbine of the Parsons type, which is wasteful of energy in the initial stages of its operation, an impulse member or members which is only partially supplied with steam, the moving vanes not supplied with steam being covered to prevent losses by ventilation, the length of the reaction or low-pressure member is materially reduced, thus reducing the total size of the engine in proportion to the power developed, besides attaining much greater economy in the application of the steam as well as in the mechanical construction of the engine.

A slight decrease in the speed of the turbine under an increase of load causes the governor 4 to swing the roller *u* toward the fixed end of the band-valve *y*, thereby opening additional passages *t* one after another and admitting steam to more nozzles until the turbine has attained its normal speed under the increased load. Upon a decrease in the load and a corresponding acceleration in the speed of the engine the governor swings the roller *u* in a reverse direction, thereby closing the steam-passages one after another and cutting off the supply of steam to the corresponding nozzles until the speed of the turbine has been lowered to its normal rate. By this mode of regulation throttling of the steam-supply, which is a wasteful and unsatisfactory mode of regulation, is avoided, and more or less nozzles are fully supplied with steam at the pressure for which they are specially designed to operate with the best effect and greatest economy.

The piston-chamber *o* being connected with the exhaust space or passage *p* at the opposite end of the turbine, the impulse-wheel *h* having a greater area exposed to receiver-pressure on the side next to the reaction or low-pressure member *m* than on the opposite side, and the balance-piston 6 being subjected to exhaust-pressure, the end thrust of the steam on the low-pressure member is equalized, and the turbine is thus balanced under all loads and conditions. The two stuffing-boxes *c* and *d* at opposite ends of the casing are also subjected, by reason of the above-mentioned balancing connections, to the same pressure and working conditions, and this is an important advantage in both the construction and the operation of the turbine.

The essential features of the invention may be embodied in engines varying widely as to details of construction and arrangement of parts. For example, the high and low pressure members may be compounded or made up of one or more elements, the direction of the flow of steam in either the high or low pressure part of the turbine may be radial (inward or outward) or axial, and the balancing of the end thrust on the rotary parts of the turbine may be effected in various ways.

Referring to Figs. 3 and 4, the moving vanes *i i* and the intermediate series of fixed guide-vanes *k*, together with the steam-chest and nozzles, are arranged for the flow of steam in an axial direction with relation to the impulse or high-pressure member, while in place of a cylinder or drum provided on its periphery with several coaxial circular series of vanes, as shown in Figs. 1 and 2, the low-pressure member consisting of a disk *m'*, provided on each of its opposite sides with a number of concentric circular series of vanes *k'* alternating with corresponding series of fixed guide-vanes *l'*, is substituted. In this case the supply of steam from the receiver *n* to the low-pressure member is divided, a part being delivered directly from the receiver to the inner series of vanes on the near side of said disk and a part being delivered by conduits 8, passing through the exhaust-space *p* to the inner series of vanes on the far side of said disk as indicated by arrows on Fig. 3. This form of turbine is balanced without a special piston for the purpose.

Referring to Fig. 5, the turbine is provided with two separate impulse or high-pressure wheels, each furnished with a regulated supply of steam from a steam-chest substantially as shown in Figs. 1 and 2, the steam-chest *q* of the second impulse-wheel or intermediate member being supplied through a passage 9 from the first receiver *n* with steam which has acted on the first impulse-wheel.

Referring to Fig. 6, the vanes of the impulse or high-pressure member of the turbine are arranged for the axial flow of steam substantially as shown in Fig. 3. The low-pressure member is of the drum type; but the drum *m''* is made of larger diameter at the exhaust than at the admission end to admit of locating the balance-piston 6 at the exhaust end of the turbine and connecting the chamber in which it works with the receiver-chamber *n* at the opposite end of the turbine.

Referring to Fig. 7, the low-pressure member of the turbine consists in this case of a disk provided with vanes on one side only. The balance-piston 6 is attached to said disk and works in a chamber which is connected by an outside pipe, as indicated by dotted lines, with the receiver *n*.

Referring to Fig. 8, both the high and low pressure members are constructed for radial flow of steam, the flow being inward with relation to the high-pressure member and outward with relation to the low-pressure member. In this case the balance-piston *e* is attached to the high-pressure member, and the chamber in which it works is connected by a

pipe, as indicated by dotted lines, with the exhaust space or chamber *p* at the opposite end of the turbine.

Referring to Fig. 9, the low-pressure member consists of a disk provided on opposite sides with vanes, substantially as shown in Fig. 3; but in this case the vanes on one side of the disk are supplied through conduits 10, passing through the exhaust space or chamber *p*, with steam which has acted upon and is discharged from the vanes on the other side of the disk.

In the several forms or modifications of the turbine herein shown and described the principles involved and the mode of operation are essentially the same. In each case the impulse or high-pressure member is partially supplied with steam acting against its vanes on the impulse or impact principle without material change in pressure, while the low-pressure member is fully supplied from the high-pressure member with steam, which acts simultaneously on all the vanes of said low-pressure member.

Various changes other than those hereinbefore specifically mentioned may be made in the details of construction and in the arrangement of parts of the turbine without materially affecting its operation and without departing from the principle and intended scope of the invention.

I claim—

1. In an elastic-fluid turbine the combination of coaxial rotary impulse and reaction members each provided with vanes arranged in concentric circular series, a casing inclosing said members and provided with fixed guide-vanes arranged in concentric series to coöperate with the movable vanes of the rotary members, nozzles arranged to deliver motive fluid to the vanes of the impulse member within a part only of their circuit, a chamber arranged to receive the motive fluid from the impulse member and to deliver it to the vanes of the reaction member throughout their entire circuit, and a balance-piston at one end of the rotating part of the turbine connected with the motive-fluid space to which the opposite end of said rotating part is exposed, substantially as described.

2. In an elastic-fluid turbine the combination of high and low pressure rotary members each provided with vanes arranged in circular series, a casing inclosing said members and provided with fixed vanes arranged in concentric series to coöperate with the movable vanes of the rotary members, a series of nozzles arranged in the arc of a circle to deliver motive fluid to the vanes of the high-pressure member within a part only of their circuit, a chamber arranged to receive motive fluid from the high-pressure member and to deliver it to the vanes of the low-pressure member throughout their entire circuit, and a shield or partition separating the inactive vanes of the high-pressure member from the motive fluid contained in said receiver-chamber, substantially as described.

3. In an elastic-fluid turbine the combination of a casing having stuffing-boxes in the ends, and a piston-chamber at one end connected with the motive-fluid space at the other end, a rotary shaft passing through said stuffing-boxes, high and low pressure members mounted on said shaft within the casing and each provided with vanes arranged in circular series, nozzles arranged to deliver motive fluid simultaneously to a part only of the vanes of the high-pressure member, a chamber arranged to receive the motive fluid from the high-pressure member and to deliver it simultaneously to the entire initial series of vanes of the low-pressure member, and a balance-piston connected with the rotary part of the turbine and fitted in said piston-chamber, substantially as described.

4. In an elastic-fluid turbine the combination of a casing having stuffing-boxes in the ends, an exhaust-chamber in one end and a piston-chamber in the other end connected with said exhaust-chamber, a rotary shaft passing axially through said casing and stuffing-boxes, high and low pressure members mounted on said shaft and each provided with vanes arranged in circular series, nozzles arranged to deliver motive fluid to a part only of the vanes of the high-pressure member, a chamber within said casing arranged to receive the motive fluid from the high-pressure member and to deliver it simultaneously to all the vanes of the first series of said low-pressure member, and a balance-piston fitted in said piston-chamber and attached to one of said rotary members, substantially as described.

5. In an elastic-fluid turbine the combination of a rotary impulse-wheel provided with vanes arranged in circular series, a coaxial reaction-wheel provided on one side with vanes arranged in a number of concentric circular series, a casing inclosing said wheels and provided with guide-vanes arranged to coöperate with the vanes of said impulse and reaction wheels, the guide-vanes for the reaction-wheel being arranged in a number of circular series one within another and concentric with the series of movable vanes on said reaction-wheel, whereby the motive fluid is caused to flow in an approximately radial direction from each inner series to the next outer series, means for supplying motive fluid to a part only of the vanes of the impulse-wheel, and a chamber arranged to receive the motive fluid from the impulse-wheel and to deliver it simultaneously to the entire inner series of vanes of the reaction-wheel, substantially as described.

6. In an elastic-fluid turbine the combination of a rotary part comprising high and low

pressure members each provided with vanes arranged in circular series, a casing inclosing said rotary part with a piston-chamber and a chamber arranged to receive motive fluid from the high-pressure member and deliver it all around to the low-pressure member, said casing being provided with fixed vanes arranged in series concentric with and adjacent to the series of movable vanes, a series of nozzles extending part way around the high-pressure member and adapted to deliver motive fluid to its vanes, and a balance-piston attached to the rotary part and fitted in said piston-chamber which communicates with a part of the turbine in which the motive-fluid pressure is such as acting upon said piston will equalize the otherwise unbalanced end pressure on said rotary part, substantially as described.

7. In an elastic-fluid turbine the combination of coaxial rotary impulse and reaction members, means for supplying motive fluid to the vanes of the impulse member, and a chamber arranged to receive the motive fluid from the impulse member and deliver it to the vanes of the reaction member, the impulse member having an unbalanced pressure area exposed to the motive fluid in said chamber and tending to balance the end thrust on the reaction member, substantially as described.

8. In an elastic-fluid turbine the combination of coaxial rotary impulse and reaction members each provided with vanes arranged in circular series, a casing inclosing said members and provided with guide-vanes arranged to coöperate with the vanes of the rotary members, means for supplying motive fluid to the vanes of the impulse member, a chamber arranged to receive the motive fluid from the impulse member and to deliver it to the vanes of the reaction member, and a balancing-piston attached to one end of the rotating part of the turbine and working in a chamber which is connected with the motive-fluid space to which the opposite end of said rotating part is exposed, substantially as described.

In witness whereof I hereto affix my signature in presence of two witnesses.

WILLIAM A. NUSSBAUMER.

Witnesses:

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A. F. WEST.