No. 842,211. PATENTED JAN. 29, 1907.

O. KOLB.

ELASTIC FLUID TURBINE.

APPLICATION FILED MAR. 2, 1904.

4 SHEETS—SHEET 1.

Fig. 1.

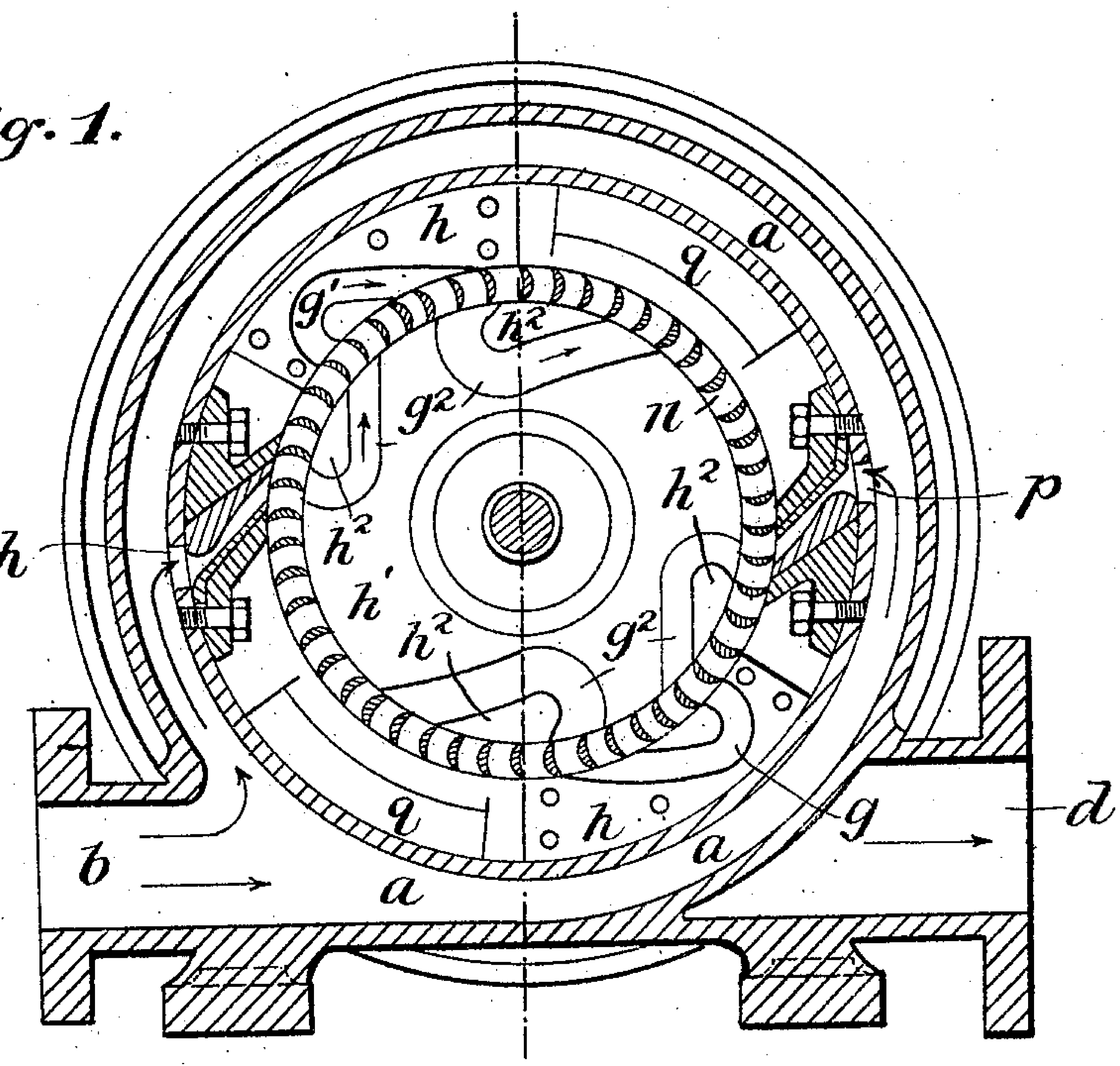
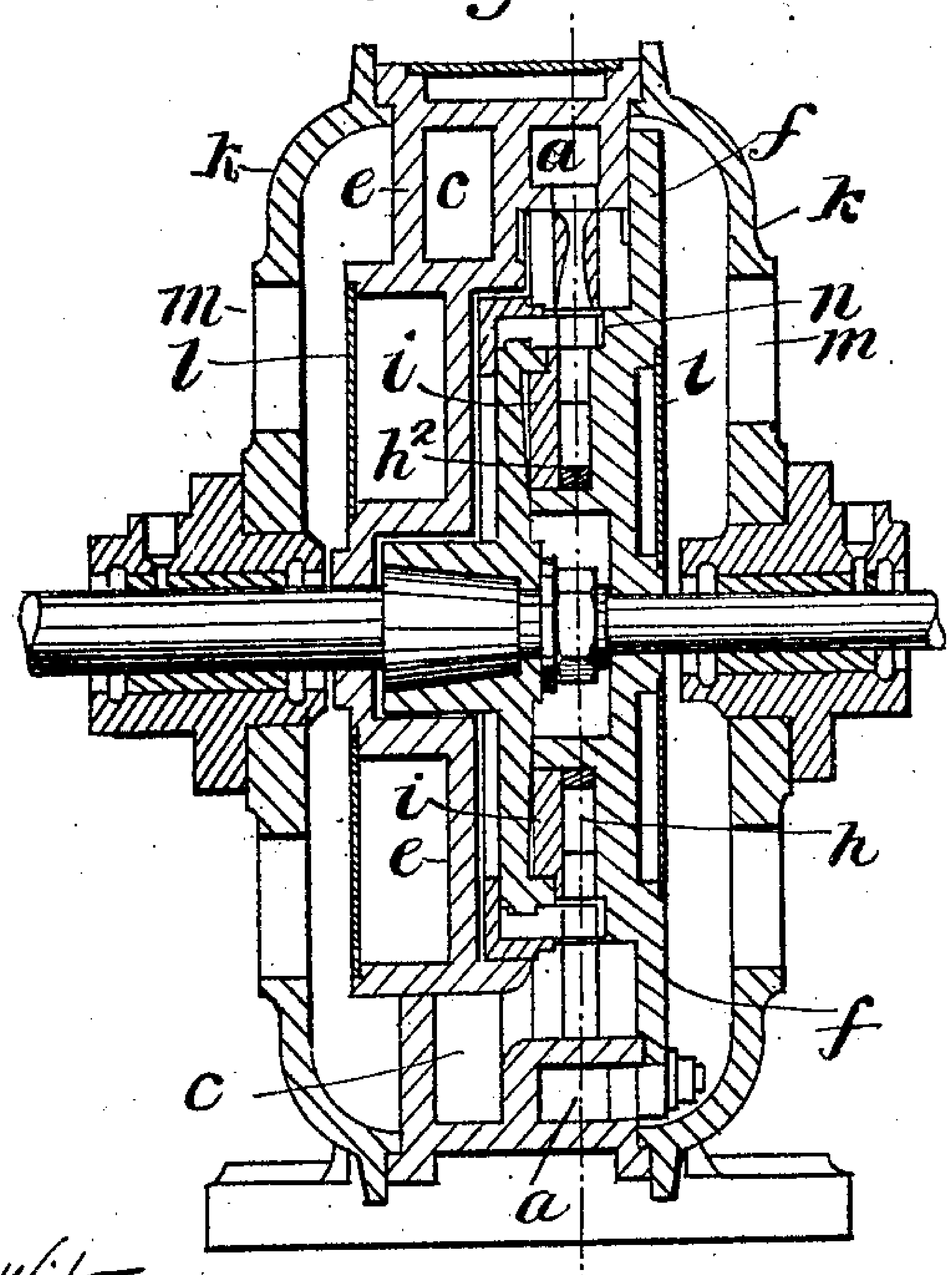


Fig. 2.



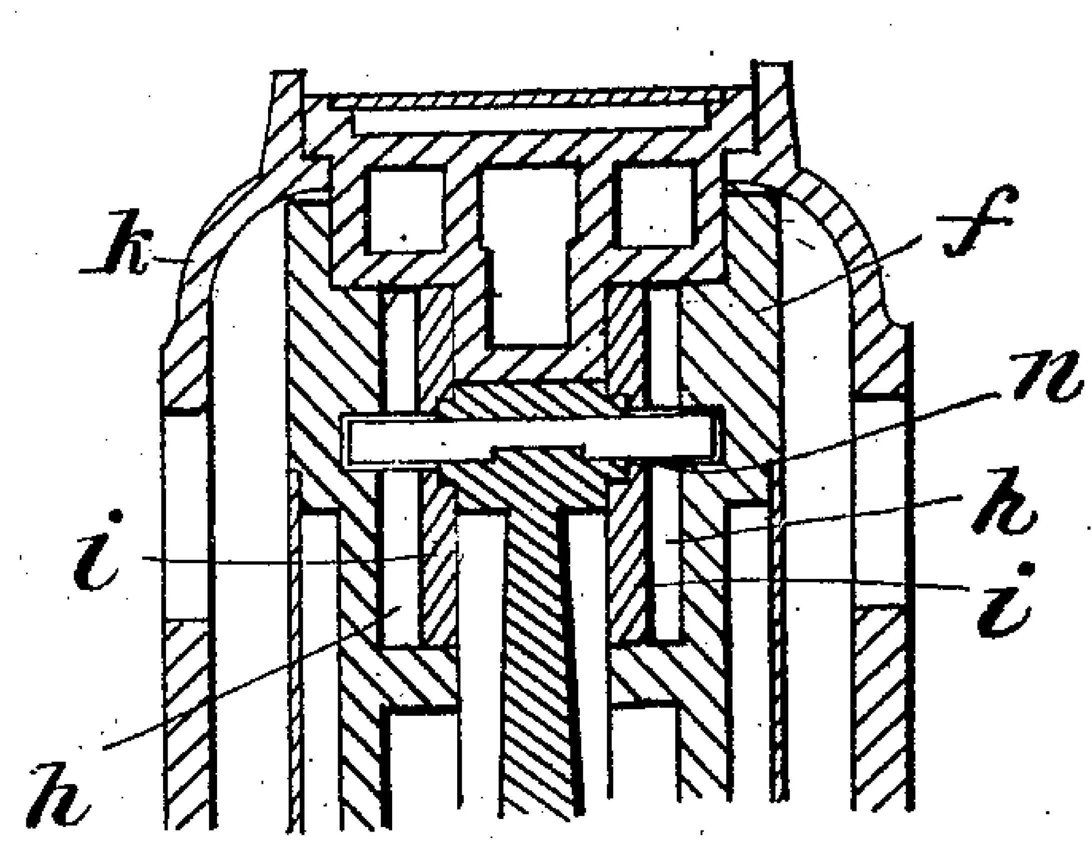


Fig. 3.

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4 SHEETS—SHEET 2.

Fig. 4.

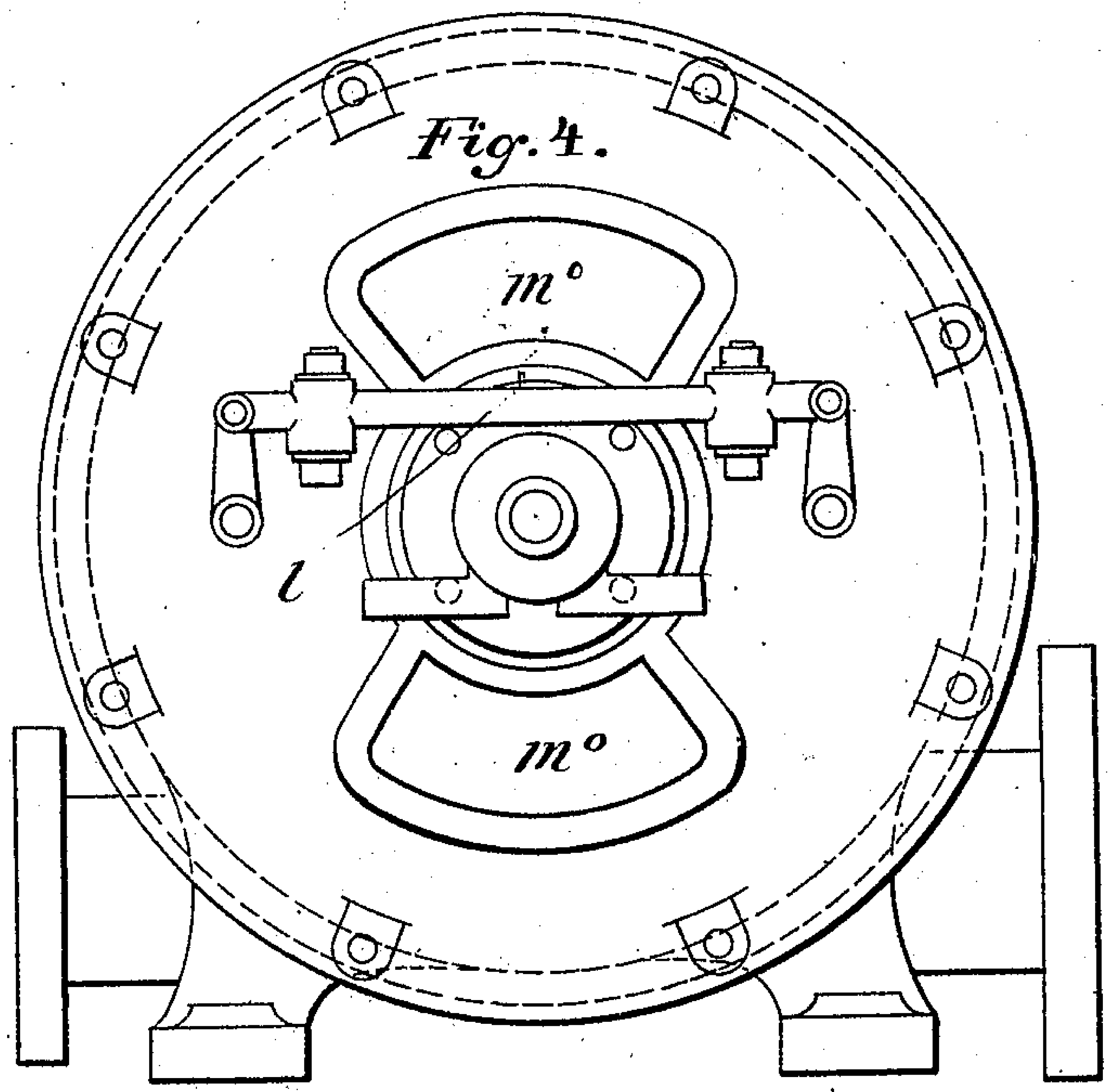


Fig. 5.

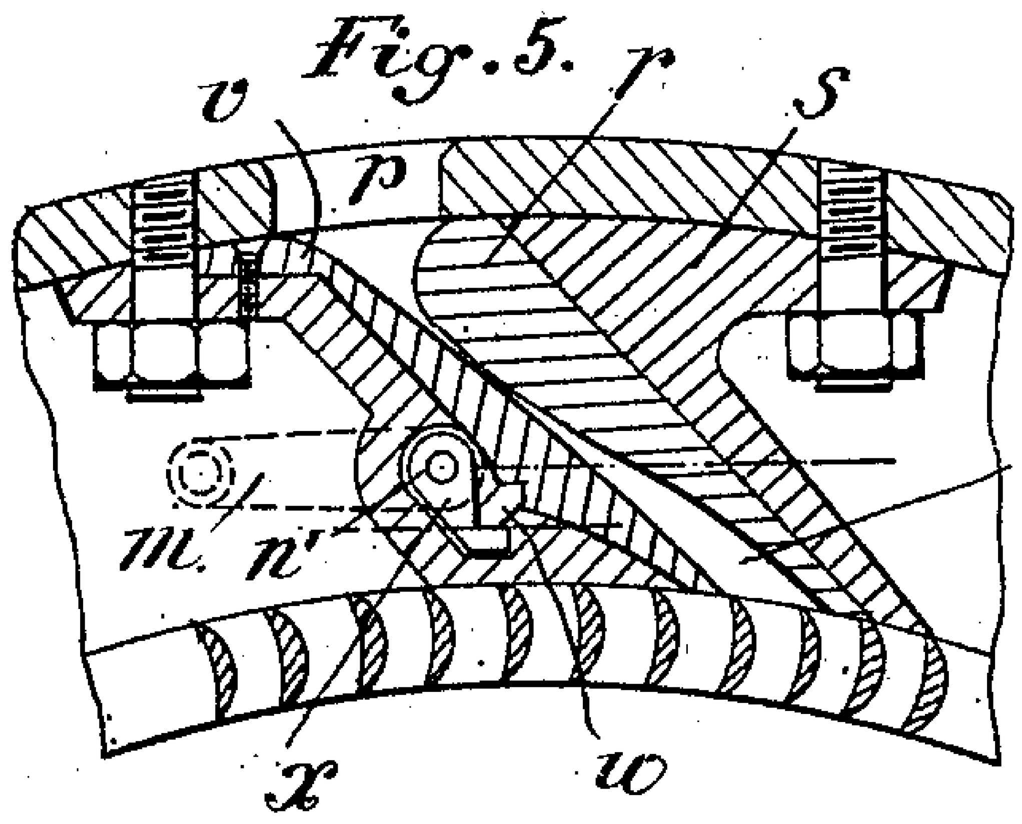


Fig. 6.

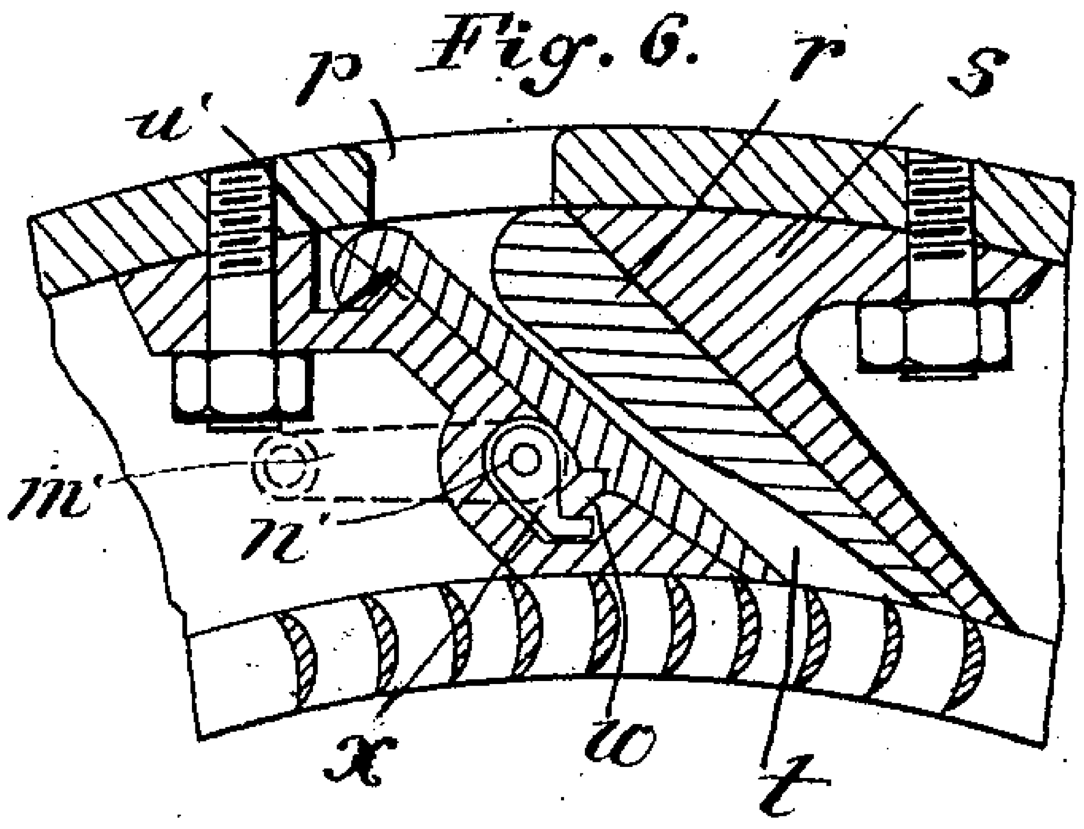
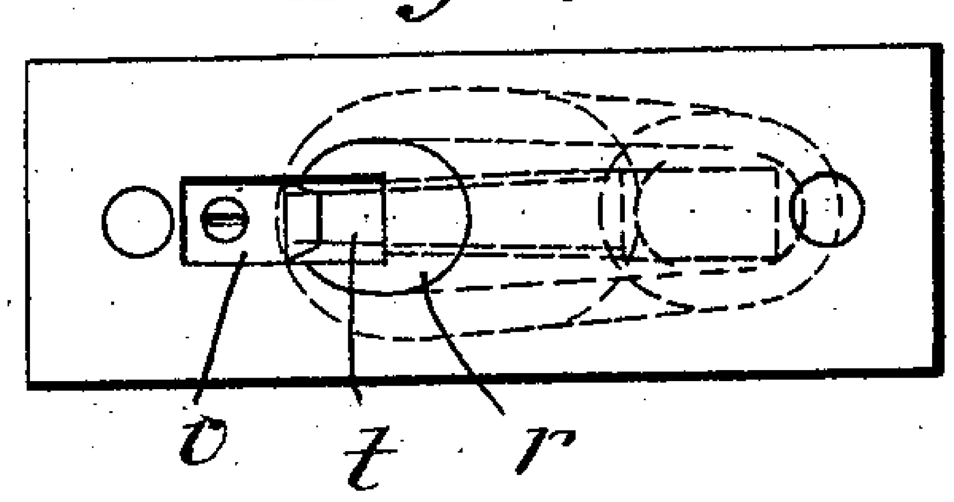


Fig. 7.



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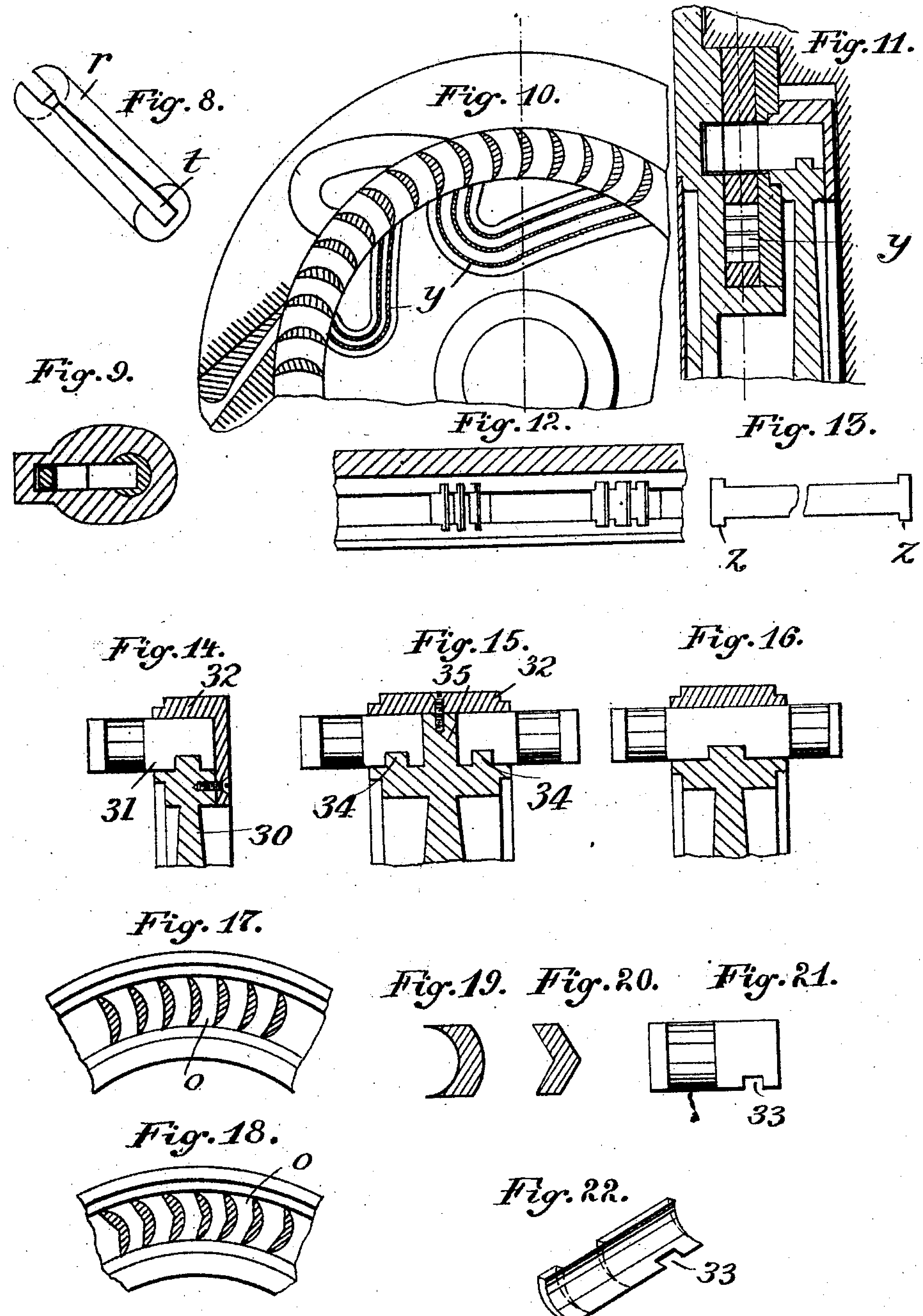
4 SHEETS—SHEET 3.



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4 SHEETS—SHEET 4.

Fig. 23.

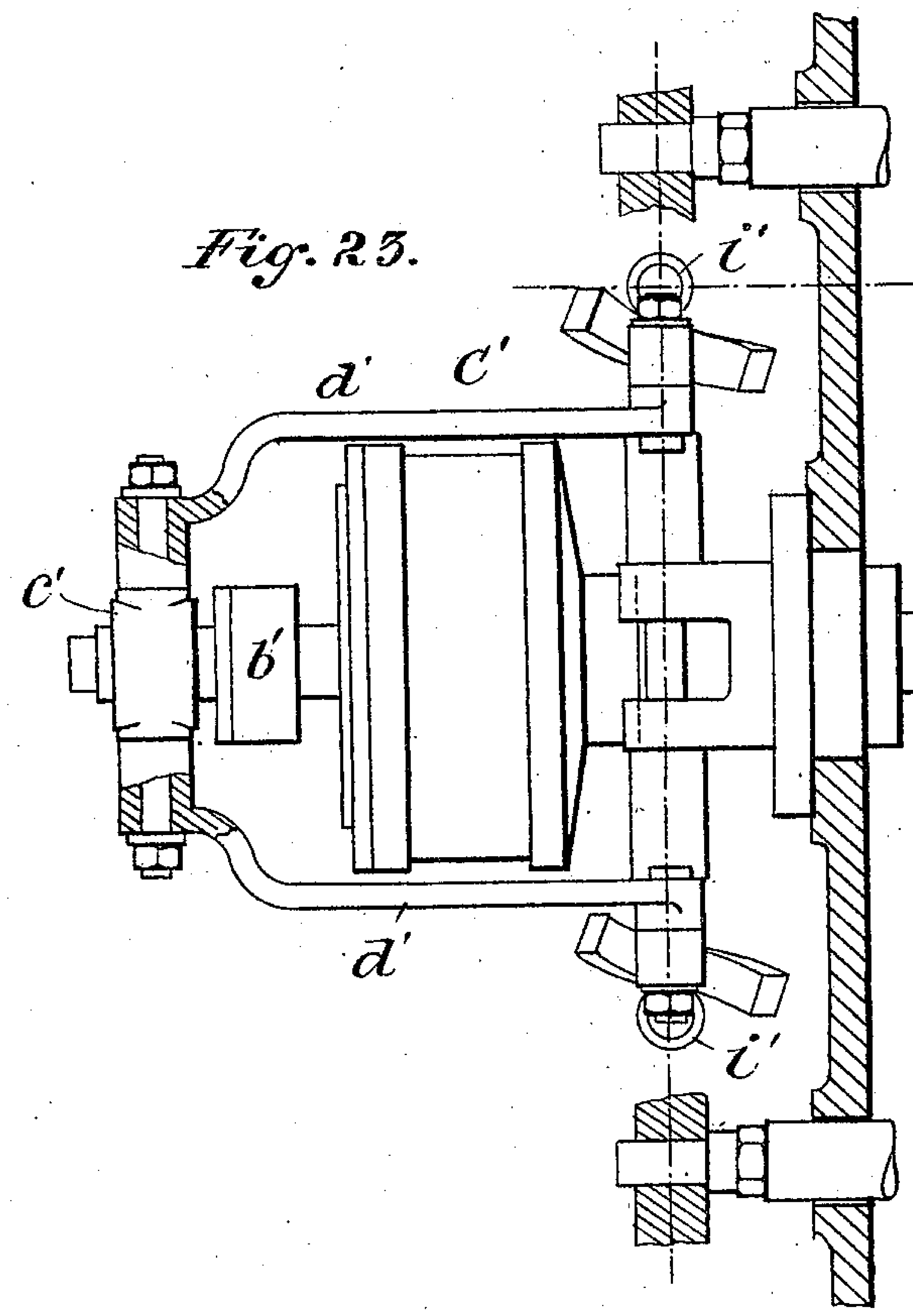


Fig. 24.

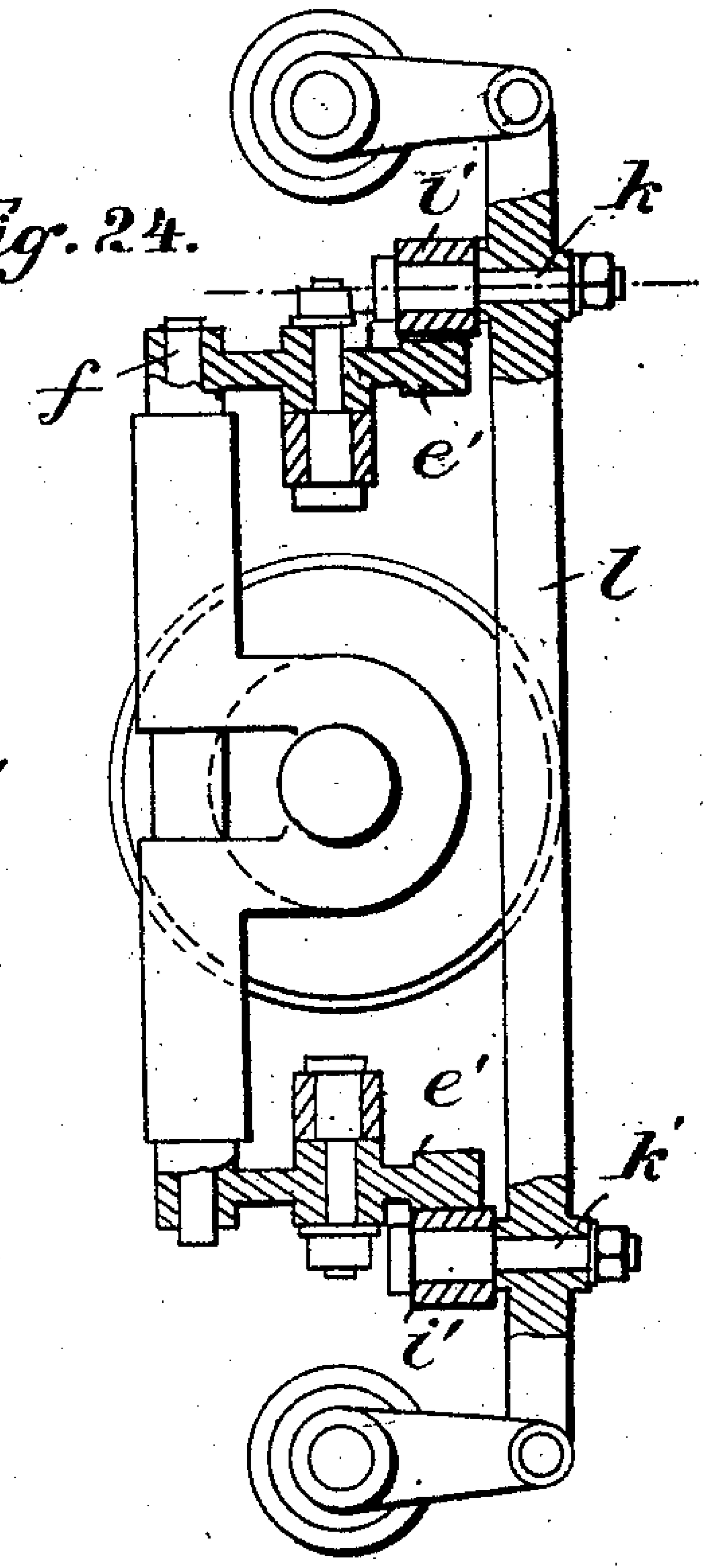
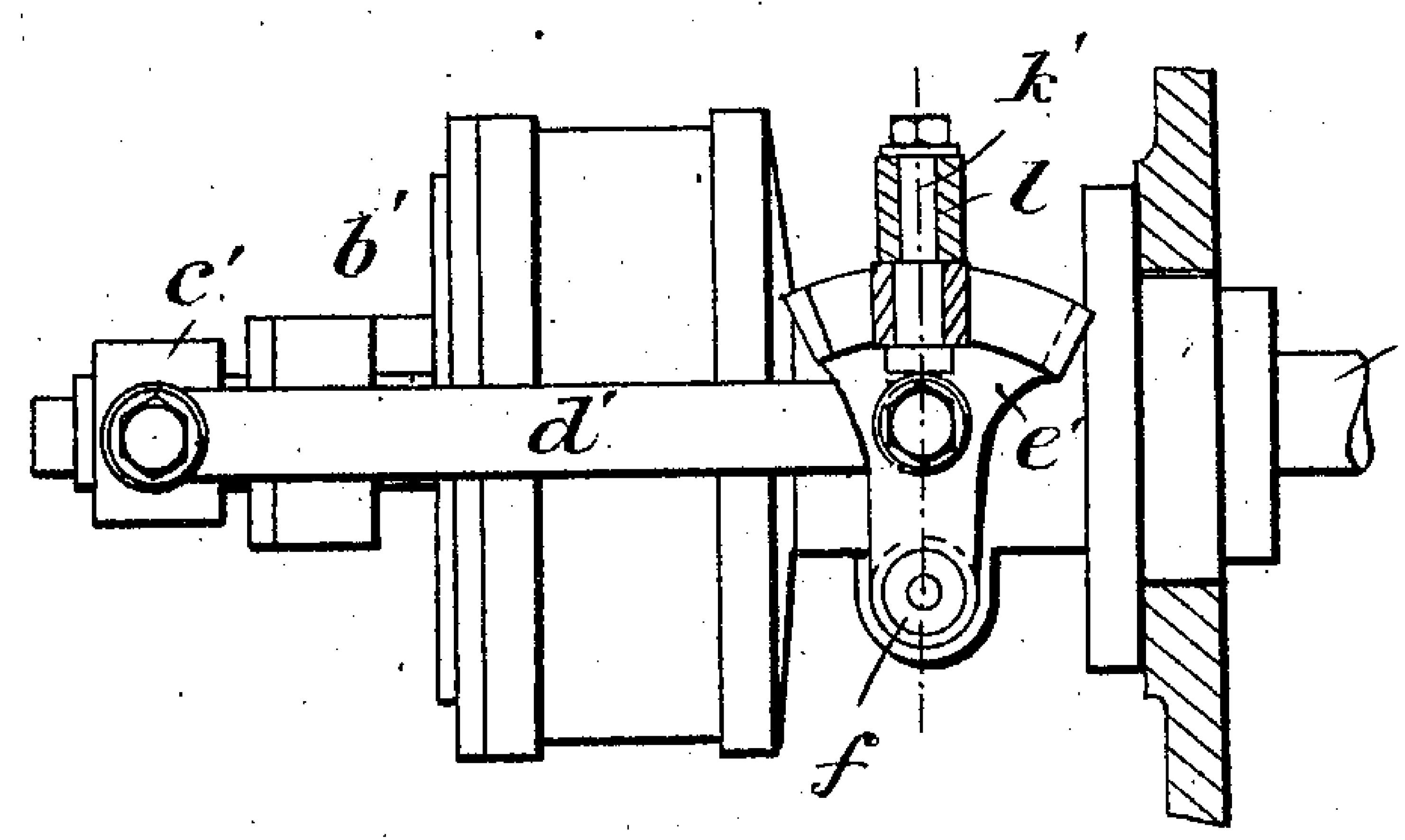


Fig. 25.



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OTTO KOLB, OF KARLSRUHE, GERMANY.

ELASTIC-FLUID TURBINE.

No. 842,211. Specification of Letters Patent. Patented Jan. 29, 1907.

Application filed March 2, 1904. Serial No. 196,171.

To all whom it may concern:

Be it known that I, OTTO KOLB, a subject of the German Emperor, residing and having my post-office address at Karlsruhe, Baden, Germany, Rankestrasse 18, have invented certain new and useful Improvements in Elastic-Fluid Turbines, of which the following is a specification.

Hitherto various attempts have been made to construct elastic-fluid turbines of such a kind that the number of the revolutions is reduced to a minimum by conducting the driving medium, be it steam or gas or air, several times through the turbine-wheel. Although this principle has already been pronounced to be theoretically correct and advantageous, yet no useful turbine of this kind has been introduced so far. In my opinion the chief reasons of the failures of the sundry attempts are the following:

First. The driving fluid was distributed in such a manner from the first nozzle to the following nozzles on both sides of the turbine-wheel constructed as a so-called "reaction-wheel" that the pressure of the compressed fluid consecutively decreased from the first nozzle down to that of the expanded fluid in the last nozzle. This arrangement required the tightening between the rotatory turbine-wheel and the stationary nozzles, also between the said parts and the casing, to be as perfect as possible. Owing to the principle of the reaction-wheel, however, it was impossible to fulfil this condition, since the different pressures in the various nozzles produced differences in the temperature of the turbine-wheel and the parts surrounding the same, which in turn produced unequal expansions of the materials of all the said parts, so that the clearances or spaces left between them required to be excessively large. These clearances or spaces caused heavy losses by the escapement of the fluid, so that a reasonable useful effect of the turbine was rendered impossible. Moreover, there were considerable losses of heat, owing to the fact that at every revolution the turbine-wheel was alternately passed through by colder and warmer jets of fluid, so that it was impossible to heat the turbine-wheel and the parts surrounding it uniformly.

Second. The arrangement of the nozzles following the first nozzles was wrong, because the former nozzles were placed in opposite directions and in opposition to the direction of the revolution of the turbine-wheel, which necessitated a larger angle through which the fluid leaving the turbine-wheel required to be turned before reëntering the turbine-wheel than if the nozzles were all disposed in the direction of the revolution of the turbine-wheel. Thereby larger losses due to friction were produced than would be in the latter case. Besides this several partition-walls of most varying thicknesses were necessary in each of the following nozzles to prevent the formation of whirls, which otherwise would impair the useful effect of the turbine.

Third. It was impossible to so regulate the areas of the nozzles in proportion to the power required as to obtain a reasonably-useful effect of the turbine. The elastic fluid was simply throttled before entering the turbine, which for smaller powers considerably reduced the useful effect.

My invention relates to improvements in elastic-fluid turbines of the class described whereby the various evils and defects are avoided; and the objects of my improvement are, first, to so arrange the first nozzle in the one or several series of nozzles that the fluid on leaving this nozzle is completely expanded and its pressure turned into speed before it enters the turbine-wheel; second, to arrange the inlet and outlet tubes or channels around the periphery of the turbine-wheel for heating the latter uniformly; third, to specially construct the first nozzle proper so as to vary its consecutive areas in proportion and simultaneously either at will or automatically; fourth, to provide means for adjusting the areas of the first nozzle proper; fifth, to so arrange the following nozzles in either series on the internal and external peripheries of the turbine-wheel as to always turn the fluid on the turbine-wheel in the direction of the revolution of the latter; sixth, to arrange, if so preferred, a plurality of boxes or buckets of sheet metal in each of the following nozzles either by inserting or by casting; seventh, to provide the turbine-wheel on the one side or on both sides with a plurality of detachable scoops or buckets made of rolled or drawn or milled rods or cast pieces and mechanically shaped to render their manufacture easy and exact, and, eighth, to provide a governor on the turbine-shaft and means for controlling the first nozzle of each series. I attain these objects by the constructions illustrated in the accompanying drawings, in which—

Figure 1 is a cross-section through the elastic-fluid turbine in a mode of execution on the line A A in Fig. 2. Fig. 2 is a longitudinal section through the same on the line B B in Fig. 1. Fig. 3 is a part of a longitudinal section similar to Fig. 2 through a double turbine. Fig. 4 is an elevation of a turbine similar to that shown at Figs. 1 and 2 and provided with a governor (not shown) and means for controlling the first nozzles of the two series. Fig. 5 shows, on an enlarged scale, a section through a first nozzle and a part of the turbine-wheel of the turbine shown at Fig. 4 on the line C C in Fig. 7. Fig. 6 is a similar section to show a modified form of the first nozzle. Fig. 7 is a plan of the first nozzle shown at Fig. 5. Fig. 8 is a perspective view of the first nozzle proper. Fig. 9 is a section through the first nozzle in Fig. 5 on the broken line D D. Fig. 10 is a cross-section through a part of a modified turbine on the line E E in Fig. 11. Fig. 11 is a longitudinal section through the same on the line F F in Fig. 10. Fig. 12 is a plan of the internal nozzles in Fig. 10, a part of the casing being shown in section. Fig. 13 is a view of one of the partition-walls in the smaller nozzle in Fig. 10 when evolved. Fig. 14 shows, on an enlarged scale, a part of the turbine-wheel in Fig. 2 on its periphery, (the wheel being assumed to be inversed.) Fig. 15 is a similar section through part of a modified turbine-wheel. Fig. 16 shows, on an enlarged scale, a part of the turbine-wheel in Fig. 3. Fig. 17 is a section through the buckets in Fig. 14 on the line G G. Fig. 18 is a section through the buckets in Fig. 15 on the line H H. Fig. 19 is a cross-section through a rolled or drawn or milled metal rod out of which the buckets can be made. Fig. 20 is a cross-section through a similar modified rod. Fig. 21 is an elevation of a scoop or bucket. Fig. 22 is a perspective view of the same. Fig. 23 is a plan, on an enlarged scale, of the governor applied to the turbine shown at Fig. 4, part of the external cover being shown in section. Fig. 24 is a section through the same on the line I I in Fig. 23; and Fig. 25 is an elevation of the same, part of the external cover being shown in section.

Similar characters of reference refer to similar parts throughout the several views.

The casing *e* of the turbine shown at Figs. 1 and 2 is cast in one piece with the inlet *b*, the annular inlet-channel *a*, the annular outlet-channel *c*, and the outlet *d*. The internal wall of the inlet-channel *a* is provided with two opposed openings *p p*, leading to two first nozzles secured on their internal sides and constructed about in the same manner as the nozzles shown at Figs. 5 to 9, which will be described later on. The only difference is that the areas of these nozzles are invariable.

The cover *f* of the casing *e* has secured on its internal side two opposite cast pieces *h h*, formed with bent channels *g′ g′*. The latter serve as intermediate nozzles and are covered by plates *i*, Fig. 11, of the size of the pieces *h h*. On the internal side of the cover *f* also a star-like disk *h′* and four pieces h^2 are secured and covered by an annular disk *i′*, so that four bent channels g^2 are thereby formed. Between the two first nozzles and the two cast pieces *h h* there are two spaces and two openings *q q* for permitting the spent fluid to escape into the outlet-channel *c*.

The turbine-wheel consists of a disk 30, a plurality of detachable scoops or buckets 31, Fig. 14, and a rim 32. The buckets 31 are pieces cut from rolled or drawn or milled metal rods of the cross-section according to either Fig. 19 or Fig. 20 and so milled as to form the scoops or buckets 31 proper, which when the buckets are assembled side by side upon the wheel leave closed channels between them, as is clearly shown at Figs. 17, 18, 21, and 22. They are formed into a ring and being secured in this position by any suitable device they are turned and provided with a groove 33, (see Fig. 14,) after which the device is opened to release the finished scoops or buckets, which are then assembled on the periphery of the disk 30 and fastened thereon by a rim 32, pressed or put over them in the hot state and secured by screws or otherwise. The rib on the periphery of the disk 30 prevents the scoops or buckets from getting loose. Where so preferred, the scoops or buckets 31 may be cast separately and conveniently milled, so as to attain the shape shown at Figs. 17, 21, and 22 or Fig. 18. The essential point is that the manufacture of the scoops or ladles is thereby rendered easy, cheap, and exact, and that, as experiments have proved, the turbine-wheel is made strong, durable, and capable of withstanding the centrifugal force when running at a high speed.

The turbine-wheel is in a convenient known manner affixed on its shaft, and the casing *e* and the cover *f* are so formed as to leave just sufficient space for the turbine-wheel, and more particularly an annular space *n* for the bucket-crown. The turbine shaft is mounted to turn in suitable bearings secured in two external covers *k k*. Preferably the casing *e* and the internal cover *f* are covered with two sheet disks *l l*, so that the air inclosed in the two spaces serves as an insulating material to protect the two bearings from excessive heat. Moreover, two or more openings *m m*, similar to those m° m° in Fig. 4, are provided in each external cover *k* to permit the air to freely circulate and to cool the bearings.

The two nozzles in Fig. 1 are so formed that they first converge and then diverge and in such a manner that the compressed fluid during its passage through the nozzles is completely expanded before it enters the turbine-wheel.

The manner in which the turbine is operated is obvious. The compressed fluid is conducted from the source through the inlet b to the annular channel a, from whence it passes through the two nozzles while being expanded, so that on entering the scoops or buckets it drives the wheel by means of its live force due to its great speed. On leaving the scoops or buckets the fluid enters the channels g^2, and is thereby turned on the inner periphery of the wheel in the direction of the revolution of the latter. The fluid passing through the scoops or buckets once more drives the wheel, whereupon it enters the external bent channels g', and is thereby again turned on the external periphery of the wheel. The fluid then for the third time drives the wheel while passing through the scoops or buckets, whereupon it passes through the last nozzle g^2, in which it is again turned on the internal periphery of the wheel, so that it passes for the fourth time through the scoops or buckets and drives the wheel. On leaving the latter the spent fluid passes through the openings q and the annular channel c and escapes through the outlet d into the atmosphere or a condenser, as the case may be.

To prevent the formation of whirls in all or some of the nozzles g' g^2, a convenient number of partition-walls y y (see Figs. 10 to 12) may be inserted in the nozzles. These partition-walls are according to my invention strips of sheet metal cut in the shape shown at Fig. 13, so as to have four lugs z z at the corners. They are suitably bent to leave between them and the walls of the nozzles channels of about uniform width. Their lugs z z are embedded in suitable recesses cut into the cover f and the disk i to prevent the partition-walls from shifting. (See Fig. 12.) The sheet partition-walls y y may also be secured by casting, if so preferred, in which case of course they are made wider.

Where so preferred, the nozzles g' g^2 may be cast in one piece with the cover f either as open or closed channels, the plates i and the annular disk i' being retained in the former case.

The turbine-wheel may be provided on both sides with a plurality of scoops or buckets, in which case the casing and the part connected therewith will have to be modified accordingly. An example is shown at Fig. 3, which requires no further explanations, since the parts corresponding to those shown at Fig. 2 are marked with the same letters of reference.

The scoops or buckets on both sides of the double turbine-wheel may be made in one piece, as is shown at Figs. 3 and 16, in which case the disk 30 is on its periphery provided with a rib similar to that in Fig. 14 for engaging in the grooves 33 of the scoops or buckets, or the scoops or buckets on both sides may be made separate in a similar manner as those in Fig. 14, as is clearly shown at Fig. 15. In this case the disk is on its periphery provided besides the two ribs 34 with a central rib 35, on which rim 32 may be fastened by means of screws or otherwise.

The double wheel may be so arranged that the scoops or buckets on the one side are arranged for the one direction of revolution and those on the other side for the opposite direction of revolution. Then the turbine-wheel, and with it the turbine-shaft, can be made to run in either direction at will.

For varying powers of the elastic-fluid turbine the first nozzle of each series requires to be adjusted. This can be effected in the following manner: The nozzle proper, r, Figs. 5 to 9, inclusive, is preferably made in the shape of a slightly-tapering truncated cone cut obliquely on both end faces and provided with an open channel t of rectangular cross-section. This nozzle r is fitted tightly into a cast block s of the shape shown. Its channel t may be closed by a movable tongue v, which in Figs. 5 and 7 is assumed to be fastened with its external end on the block s by means of a screw u' and made to spring in either direction, it being made thinner on the point u. Preferably it is so arranged as to normally close the channel t, so that it will only be opened by the pressure of the fluid in the annular chamber a, provided that it is not checked in a manner to be hereinafter described. Then the adjustment of the tongue will require the less power. The channel t (see Fig. 5) is so shaped that from the opening p it first converges for a small part of its length and afterward diverges toward the scoops or buckets of the turbine-wheel and that for any position of the tongue v the several areas remain in the same relative proportions. Thereby the result is insured that for any position of the tongue v—*i. e.*, for any power of the turbine—the compressed fluid is always fully expanded during its passage through the channel t before entering the scoops or buckets of the wheel at a velocity which exactly corresponds to the pressure of the fluid in the annular channel a. In Fig. 6 the tongue v is assumed to turn around an edge u' in the block s, while it is prevented from longitudinally shifting by its thicker end v' engaging in a suitable recess. For adjusting the tongue v a lever x is preferably affixed on a shaft n', which latter is mounted to turn in the casing e and an external cover k and carries a lever m'. A link w is inserted between the tongue v and the lever x and prevented from getting off by its sharp ends engaging in suitable recesses. In case the turbine is provided with two opposite nozzles the two corresponding levers m' m', Fig. 4, are preferably connected by a rod l', and the one lever m' is formed to a hand-lever, (not shown,) and a suitable known bow is secured on the external cover. Then the two tongues v v can be adjusted by suitably moving the hand-lever and securing the latter in its position on the bow.

The construction described of the first nozzle in each series renders any lubrication of the parts unnecessary, which is of special advantage when employing superheated steam or gas or air.

Where it is so preferred, a governor C', Figs. 23 and 25, of any known and approved construction may be placed on the turbine-shaft a' for automatically controlling the two nozzle-tongues v v in the following manner: The sleeve b' of the governor C' carries a cross-head c', which is pivotally connected with two levers e' e' by two rods d' d'. In suitable bearings h^3 h^3, Fig. 24, cast in one piece with the one bearing for the turbine-shaft a', shaft f is mounted to turn, on the two ends of which the said two levers e' e' are fastened. The latter are connected to two helical segments, which are made to work with two rollers i' i' on two pins k' k', secured on the rod l'. (See also Fig. 4.)

It will now be evident that on the speed of the turbine increasing or decreasing the governor C' will in the usual manner shift its sleeve b' in either direction, so that by the rods d' d' the two levers e' e' will be turned in the corresponding direction, and by means of the two rollers i' i' working with their helical segments the rod l is moved in the respective direction to adjust the two nozzle-tongues v v by means of the two levers m' m' and shafts n' n'.

The elastic-fluid turbine described presents the advantage that on the whole periphery of the turbine-wheel the pressure and temperature are uniform, so that the expansion of the parts due to the heat remains stationary, and no packings are required with the exception of those between the first nozzles and the inlet channel or channels. The losses through leakages between the scoops or buckets and the casing and cover are reduced to a minimum. The construction of the turbine-wheel renders it possible to replace its scoops or buckets should any of them get broken or defective.

The constructions of the elastic-fluid turbine described so far may be varied in many respects without deviating from the spirit of my invention. The number of the series of nozzles may be increased or decreased, also the number of the nozzles in each series. These nozzles may be shifted in their relative positions shown in the drawings to insure a good working of the turbine. In case more than two first nozzles are employed the transmission from the governor to their tongues will of course require to be suitably altered, as will be evident to every skilled man versed in the art to which this invention appertains.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. In an elastic-fluid turbine of the class described, the combination with a turbine-wheel having a crown of scoops, of a casing, an annular channel in said casing in the plane of and concentric with the crown of said turbine-wheel, an inlet communicating with said annular channel, a primary nozzle communicating with said annular channel and adapted to fully expand the compressed fluid before discharging it to the external periphery of the crown of said turbine-wheel, a plurality of consecutive secondary nozzles of increasing areas arranged in said casing alternately on the external and internal peripheries of the crown of said turbine-wheel and adapted to receive and to turn the fluid on the latter in the direction of the revolution of the same, a space in said casing and adapted to receive the spent fluid from the crown of said turbine-wheel, a second annular channel in said casing near and concentric with said annular channel and communicating with said space by an opening, and an outlet communicating with said second annular channel.

2. In an elastic-fluid turbine of the class described, the combination with a turbine-wheel having a crown of scoops, of a casing, an annular channel in said casing in the plane of and concentric with the crown of said turbine-wheel, an inlet communicating with said annular channel, a plurality of primary nozzles communicating with said annular channel and adapted to fully expand the compressed fluid before discharging it to the external periphery of the crown of said turbine-wheel, a plurality of series each comprising a plurality of consecutive secondary nozzles of increasing areas arranged in said casing alternately on the external and internal peripheries of the crown of said turbine-wheel and adapted to receive and to turn the fluid on the latter in the direction of the revolution of the same, a plurality of spaces in said casing and adapted to receive the spent fluid from the crown of said turbine-wheel, a second annular channel in said casing near and concentric with said annular channel and communicating with said plurality of spaces by a plurality of openings, and an outlet communicating with said second annular channel.

3. In an elastic-fluid turbine of the class described, the combination with a turbine-wheel having crowns of scoops on both sides, of a plurality of primary nozzles each adapted to fully expand the compressed fluid before discharging it to the one periphery of either crown of said turbine-wheel, a plurality of series each comprising a plurality of consecutive secondary nozzles of increasing

areas arranged alternately on the two peripheries of either crown of said turbine-wheel and adapted to receive and to turn the fluid on the latter in the direction of the revolution of the same.

4. In an elastic-fluid turbine of the class described, the combination with a turbine-wheel having crowns of scoops on both sides, of a casing, two annular channels in said casing in the planes of and concentric with the two crowns of said turbine-wheel, two inlets communicating with said two annular channels, two primary nozzles communicating with said two annular channels and adapted to fully expand the compressed fluid before discharging it to the external peripheries of the two crowns of said turbine-wheel, two series each comprising a plurality of consecutive secondary nozzles of increasing areas arranged in said casing alternately on the external and internal peripheries of each of the two crowns of said turbine-wheel and adapted to receive and to turn the fluid on the latter in the direction of the revolution of the same, two spaces in said casing and adapted to receive the spent fluid from the two crowns of said turbine-wheel, an annular exhaust-channel in said casing between and concentric with said two annular channels and communicating with said two spaces by two openings, and an outlet communicating with said annular exhaust-channel.

5. In an elastic-fluid turbine of the class described, the combination with a turbine-wheel having crowns of scoops on both sides, of a casing, two annular channels in said casing in the planes of and concentric with the two crowns of said turbine-wheel, two inlets communicating with said two annular channels, a plurality of primary nozzles communicating with said two annular channels and adapted to fully expand the compressed fluid before discharging it to the external peripheries of the two crowns of said turbine-wheel, a plurality of series each comprising a plurality of consecutive secondary nozzles of increasing areas arranged in said casing alternately on the external and internal peripheries of each of the two crowns of said turbine-wheel and adapted to receive and to turn the fluid on the latter in the direction of the revolution of the same, a plurality of spaces in said casing and adapted to receive the spent fluid from the two crowns of said turbine-wheel, an annular exhaust-channel in said casing between and concentric with said two annular channels and communicating with said plurality of spaces by a plurality of openings, and an outlet communicating with said annular exhaust-channel.

6. In an elastic-fluid turbine of the class described, the combination with a primary nozzle adapted to fully expand the compressed fluid before discharging it to the one periphery of the turbine-wheel, of a plurality of consecutive secondary nozzles of increasing areas arranged alternately on the two peripheries of the turbine-wheel and adapted to receive and to turn the fluid on the latter in the direction of the revolution of the same, a movable tongue in said primary nozzle and adapted to simultaneously vary its several areas while retaining their relative proportions, a governor on the turbine-shaft and having a moving sleeve, and means for transmitting the movement from the sleeve of said governor to said movable tongue.

7. In an elastic-fluid turbine of the class described, the combination with a primary nozzle adapted to fully expand the compressed fluid before discharging it to the one periphery of the turbine-wheel, of a plurality of consecutive secondary nozzles of increasing areas arranged alternately on the two peripheries of the turbine-wheel and adapted to receive and to turn the fluid on the latter in the direction of the revolution of the same, a tongue mounted in said primary nozzle to swing around an axis at the inlet and adapted to simultaneously vary its several areas while retaining their relative proportions, said tongue being arranged to normally close said primary nozzle, a shaft mounted in the casing to turn, a lever fastened on said shaft, a link inserted between said tongue and said lever, and a hand-lever fastened on said shaft without the casing.

8. In an elastic-fluid turbine of the class described, the combination with a primary nozzle adapted to fully expand the compressed fluid before discharging it to the one periphery of the turbine-wheel, of a plurality of consecutive secondary nozzles of increasing areas arranged alternately on the two peripheries of the turbine-wheel and adapted to receive and to turn the fluid on the latter in the direction of the revolution of the same, a tongue mounted in said primary nozzle to swing around an axis at the inlet and adapted to simultaneously vary its several areas while retaining their relative proportions, said tongue being arranged to normally close said primary nozzle, a shaft mounted in the casing to turn, a lever fastened on said shaft, a link inserted between said tongue and said lever, a second lever fastened on said shaft without the casing, a governor on the turbine-shaft and having a moving sleeve, and means for transmitting the movement from the sleeve of said governor to said second lever.

9. In an elastic-fluid turbine of the class described, the combination with a plurality of primary nozzles adapted to fully expand the compressed fluid before discharging it to the peripheries of the turbine-wheel, of a plurality of tongues mounted in said plurality of primary nozzles to swing around axes at the inlet and adapted to simultaneously vary their several areas while retaining their rela-

tive proportions, a plurality of shafts mounted in the casing to turn, a plurality of levers fastened on said plurality of shafts, a plurality of links inserted between said plurality of tongues and said plurality of levers, a plurality of external levers fastened on said plurality of shafts without the casing, a governor on the turbine-shaft and having a moving sleeve, and means for transmitting the movement from the sleeve of said governor to said plurality of external levers.

10. In a primary nozzle of the class described, the combination with a block adapted to be secured on a wall in the turbine-casing and having a tapering hole, of a nozzle proper tightly fitted into the tapering hole of said block and having an open channel of rectangular cross-section and of varying area, an elastic tongue fitted into the open channel of said nozzle proper for varying its areas and secured with its one end on said block at the inlet and arranged to normally close said nozzle proper, a shaft mounted in said block to turn, a lever fastened on said shaft within a recess of said block, a link inserted between said elastic tongue and said lever, and means for turning said shaft from without.

11. In a primary nozzle of the class described, the combination with a block adapted to be secured on a wall in the turbine-casing and having a tapering hole, of a nozzle proper tightly fitted into the tapering hole of said block and having an open channel of rectangular cross-section and of varying area, a tongue fitted into the open channel of said nozzle proper for varying its areas and mounted to turn around an edge of said block at the inlet, a shaft mounted in said block to turn, a lever fastened on said shaft within a recess of said block, a link inserted between said tongue and said lever, and means for turning said shaft from without.

12. In an elastic-fluid turbine, the combination with the primary nozzle, of buckets adapted to receive the fluid therefrom, and a secondary nozzle adapted to receive the fluid from the buckets, the said secondary nozzle consisting in a detachable cast portion having a channel, and a plurality of partition-walls extending longitudinally of said channel, the said partitions being formed of sheet metal cast into the said detachable portion, whereby a plurality of channels of nearly uniform width is formed.

13. In an elastic-fluid turbine of the class described, a secondary nozzle comprising a plurality of partitions of sheet metal, each suitably bent and provided with four lugs on the corners which engage in suitable recesses whereby they are secured and a plurality of channels of nearly uniform width is formed.

14. In a turbine-wheel of the class described the combination with a disk having a locking-rib on its periphery, of a plurality of pieces cut from rods of a cross-section of a general shape corresponding to the finished piece and so cut out and turned, that their full parts can be closely assembled to a ring on the periphery of said disk and be locked by the locking-rib of the disk engaging in their recesses, and that their projecting parts are partly shaped as scoops, so that closed channels between them are formed, and a peripheral ring securing said plurality of pieces on said disk.

15. In a turbine-wheel of the class described, the combination with a disk having a central dividing-rib and locking-ribs on both sides along the periphery, of a plurality of pieces cut from rods of a cross-section of a general shape corresponding to the finished piece and so cut out and turned, that their full parts can be closely assembled to two rings on the periphery of said disk on both sides of its central dividing-rib and locked by its two locking-ribs engaging in their recesses, and that their projecting parts are partly shaped as scoops, so that closed channels between them are formed, and a ring securing said plurality of pieces on said disk.

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

OTTO KOLB.

Witnesses:
D. H. KREBS,
C. GUNDEL.