No. 716,908. Patented Dec. 30, 1902.

T. G. E. LINDMARK.

ELASTIC FLUID TURBINE.

(Application filed Dec. 26, 1901.)

(No Model.) 4 Sheets—Sheet 1.

Fig. 2.

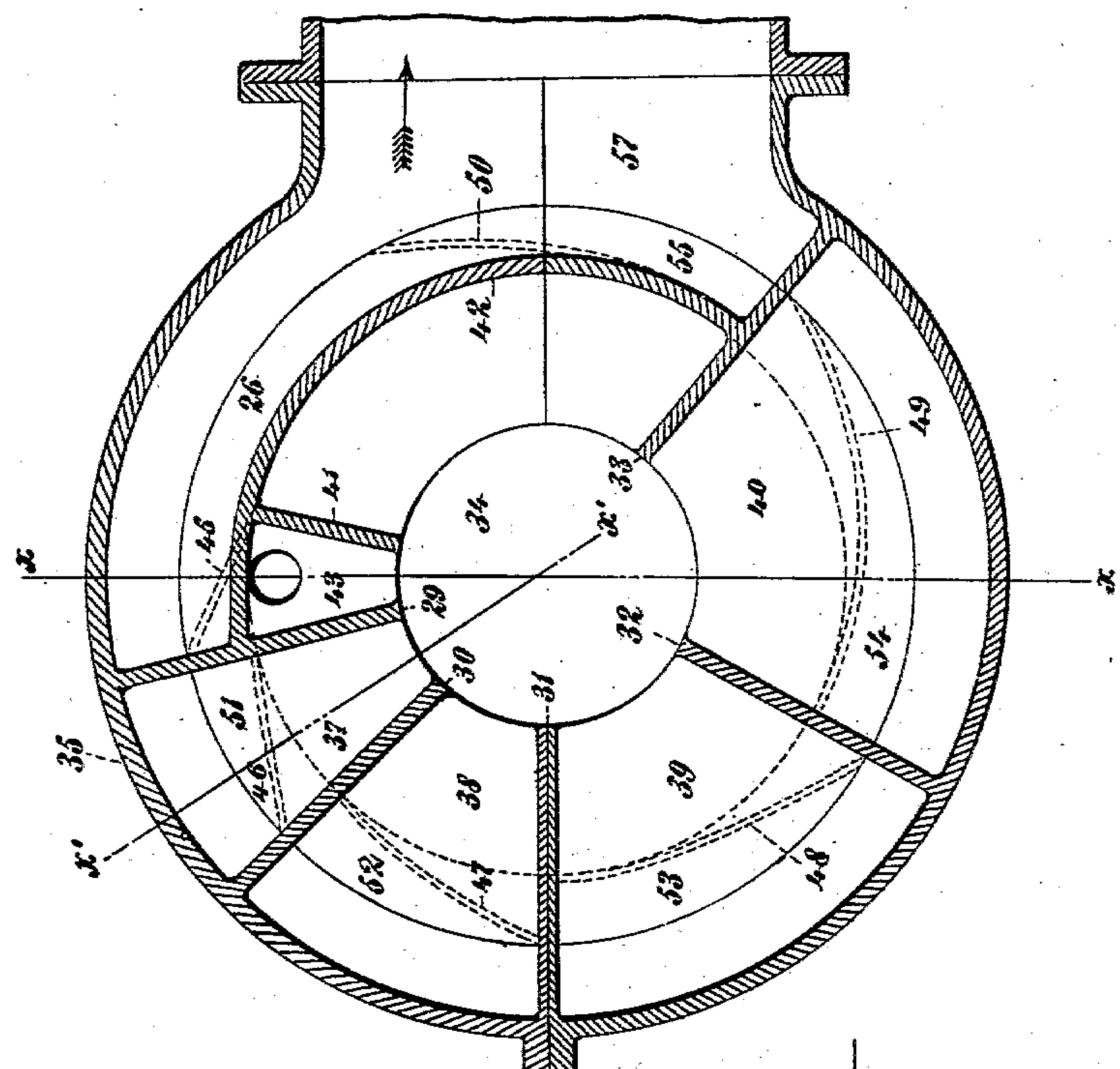


Fig. 1.

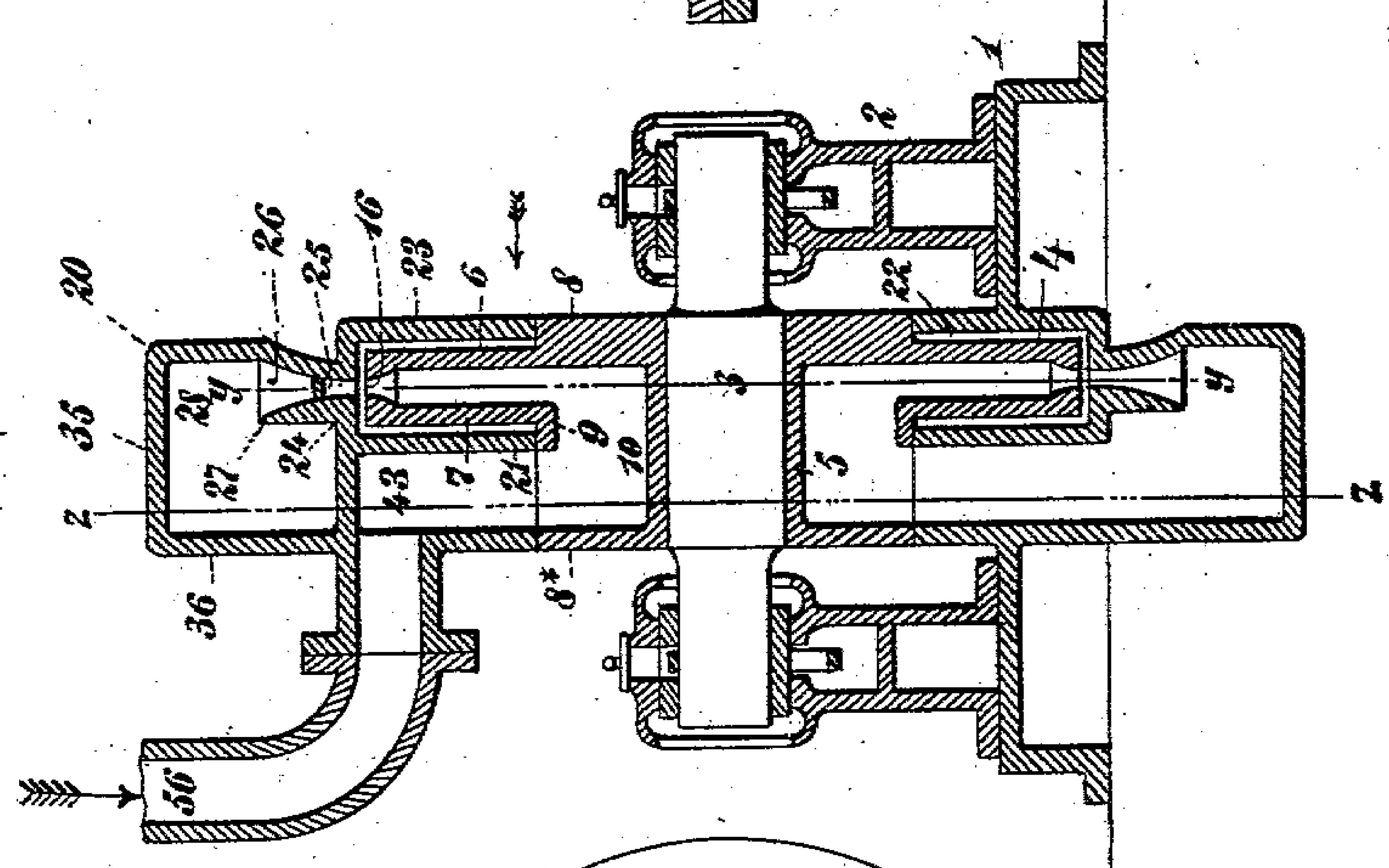
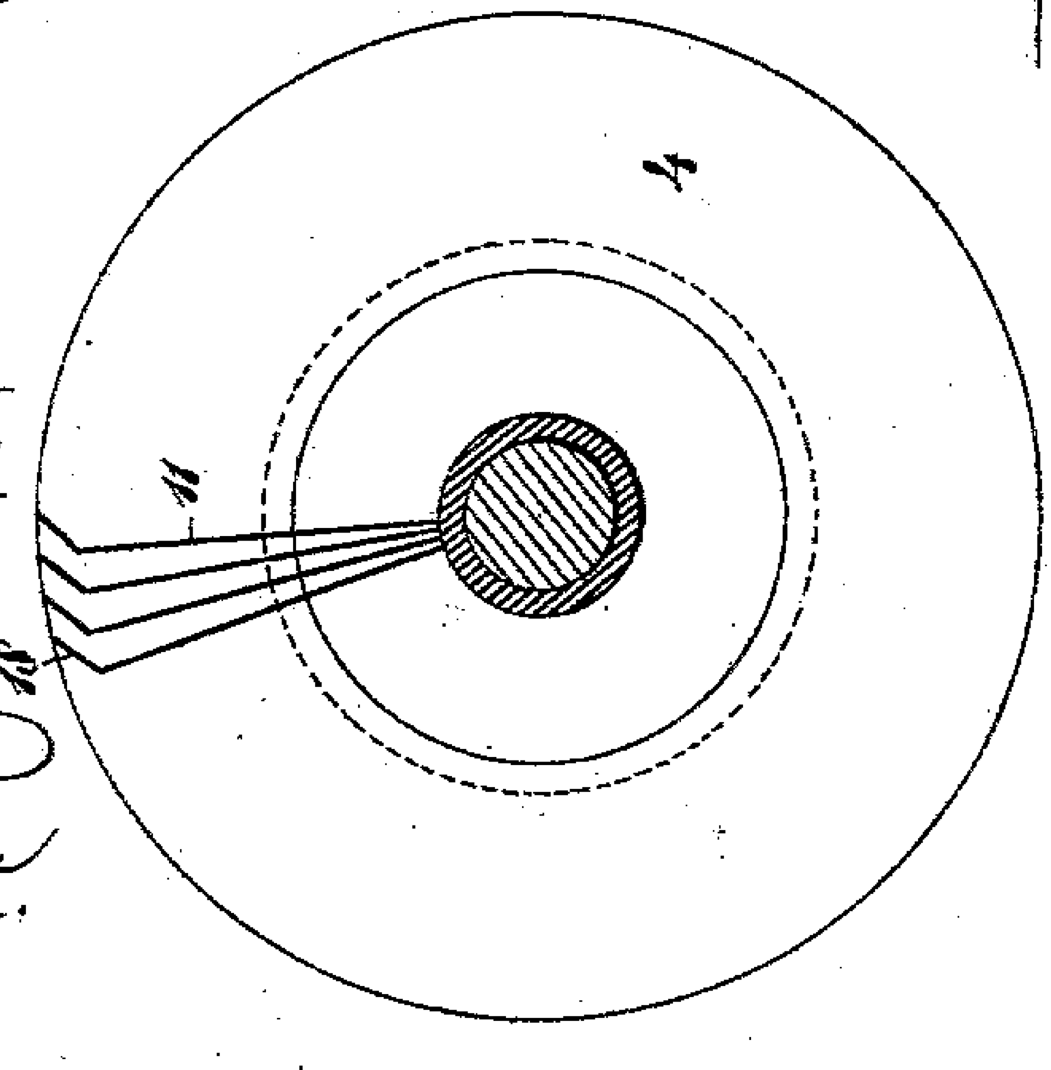


Fig. 3.



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4 Sheets—Sheet 2.

Fig. 8.

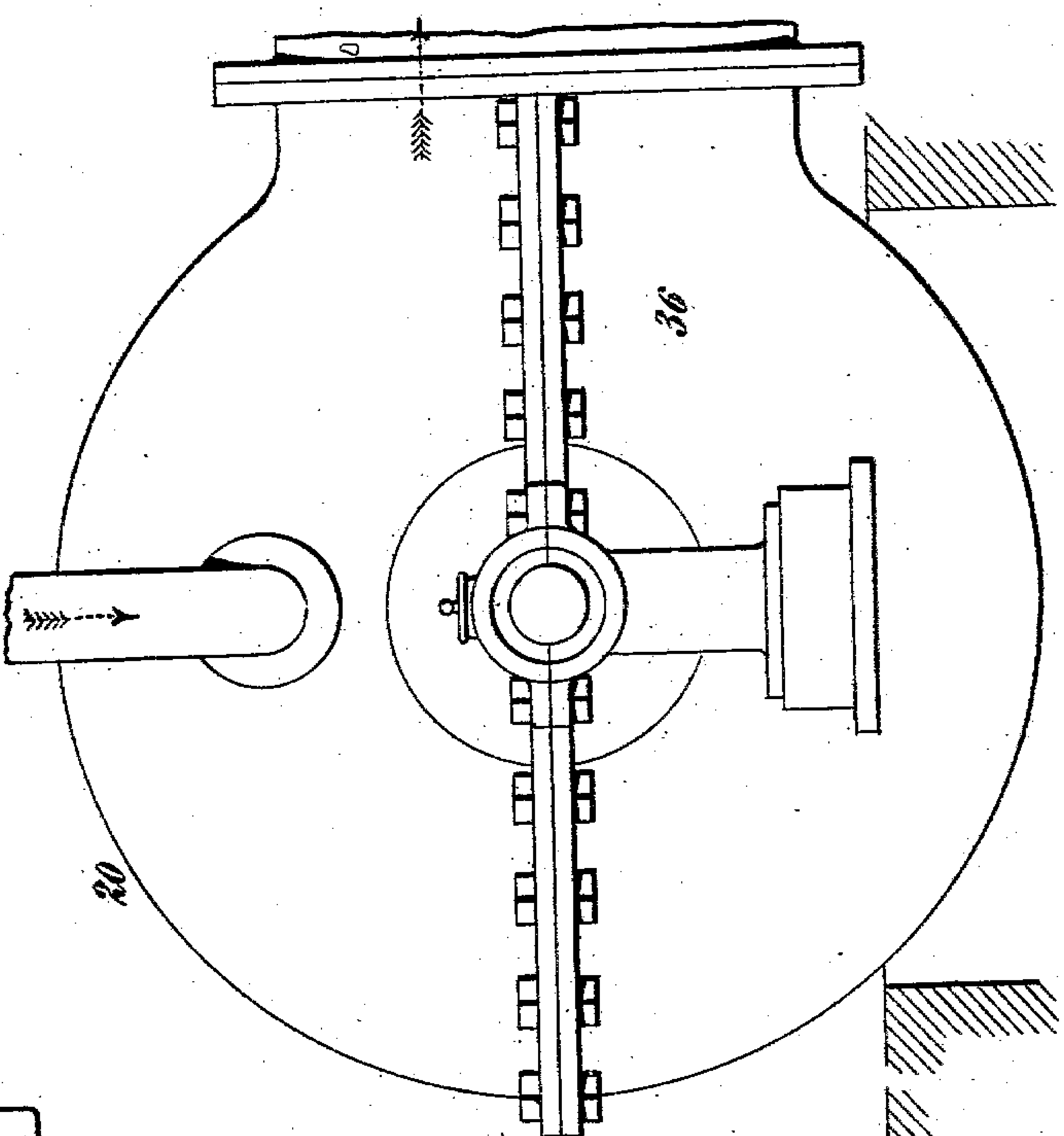


Fig. 4.

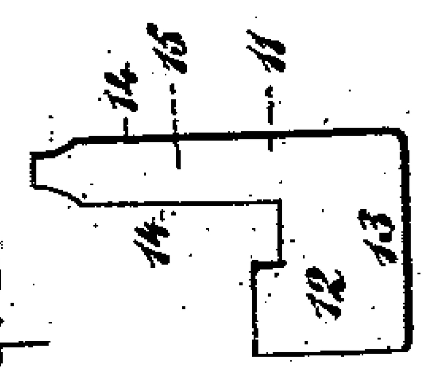


Fig. 7.

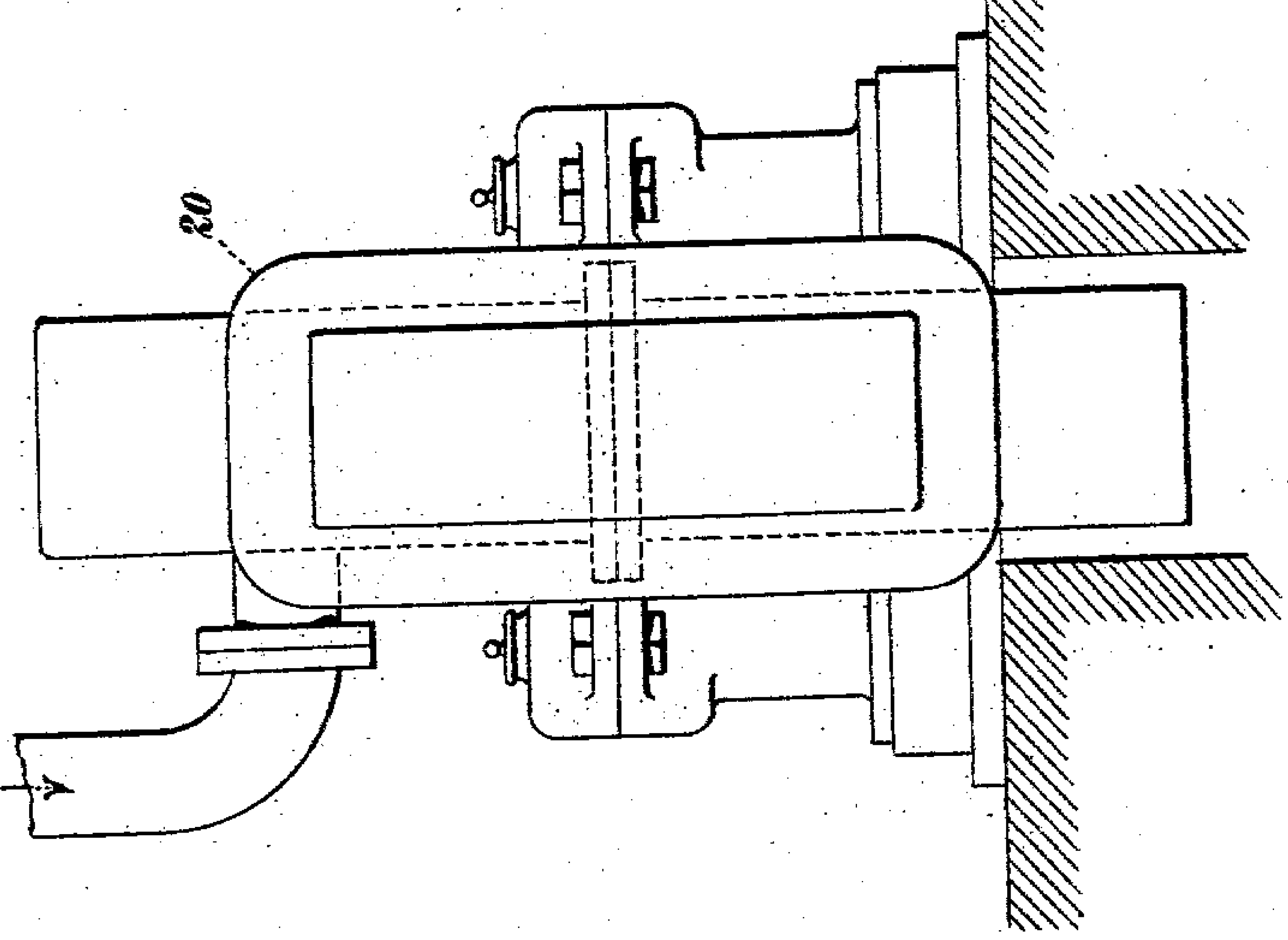
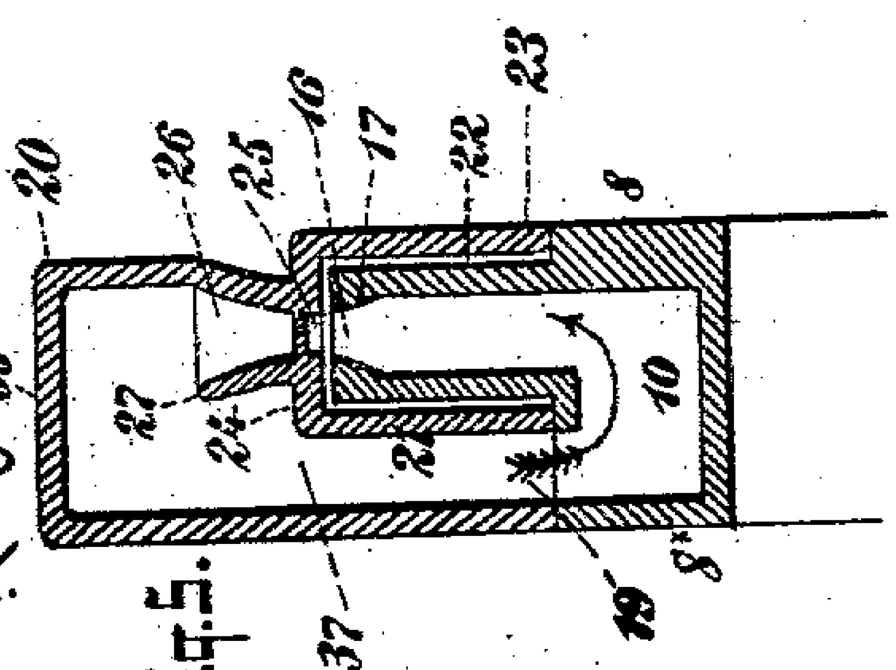


Fig. 5.



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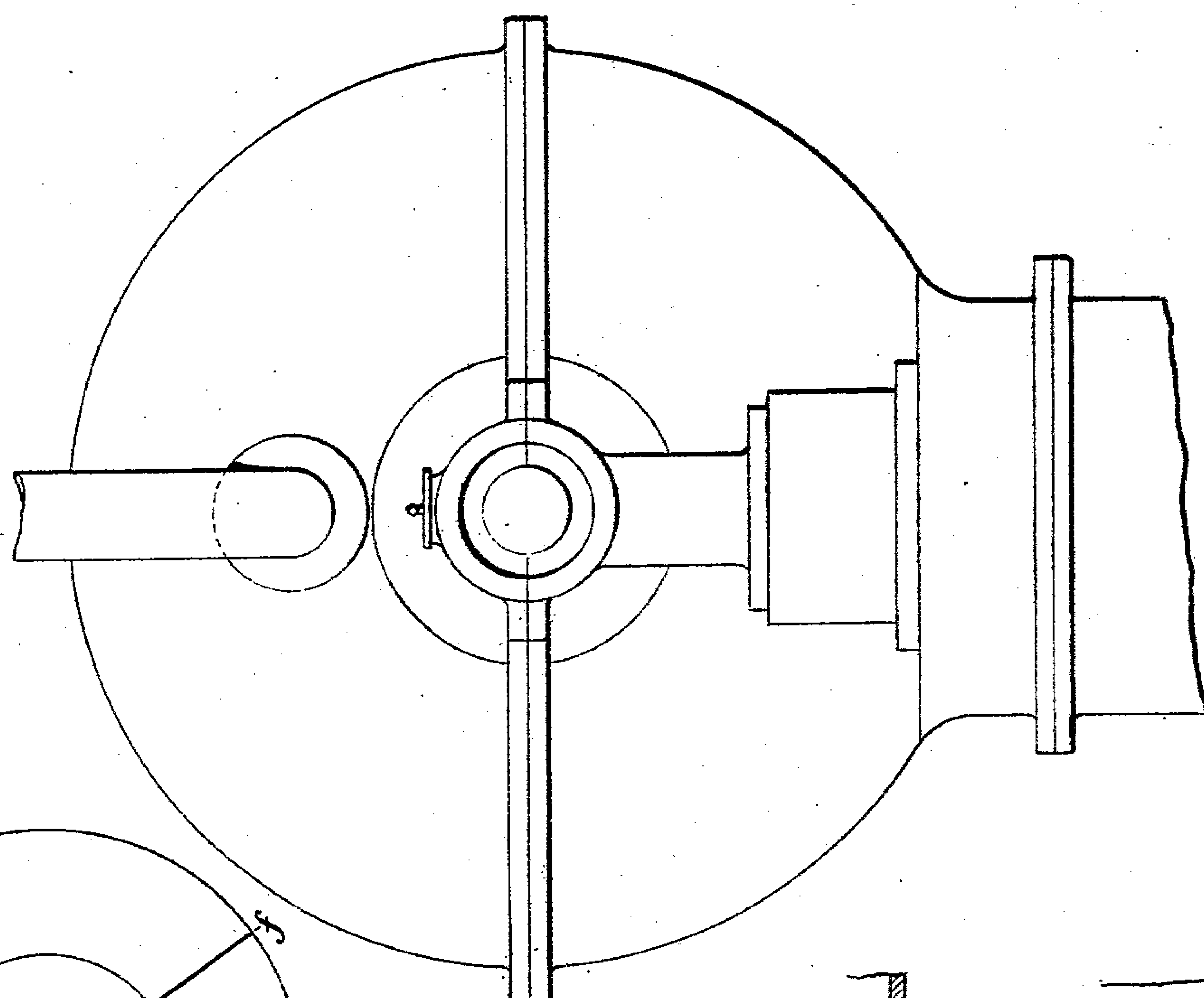

Fig. 12.

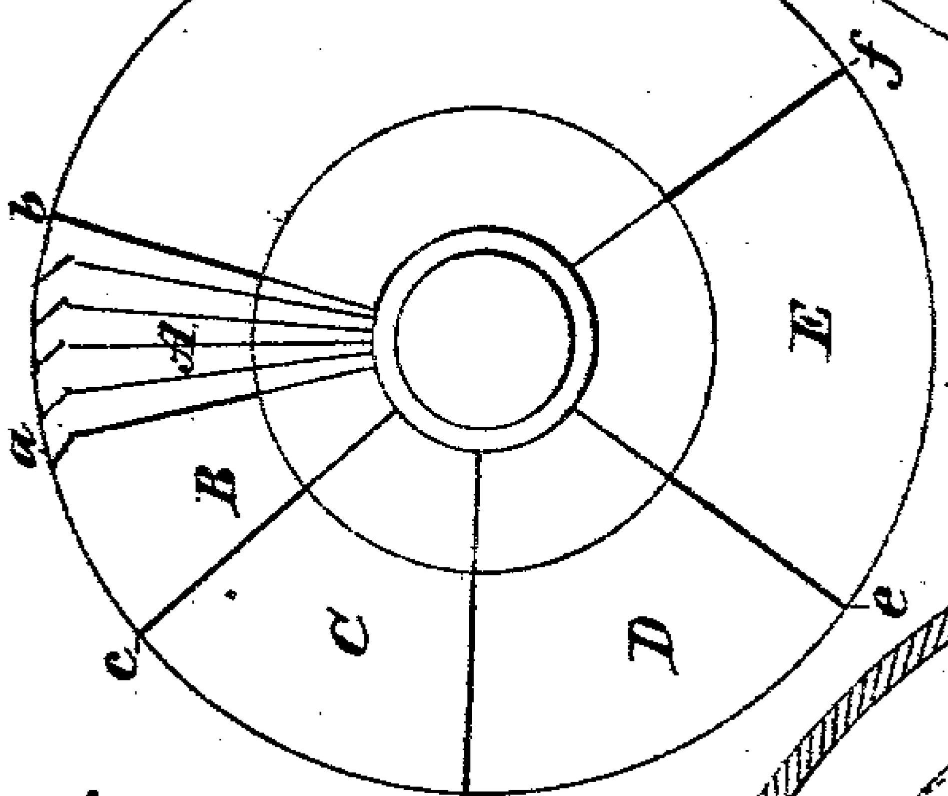

Fig. 6.

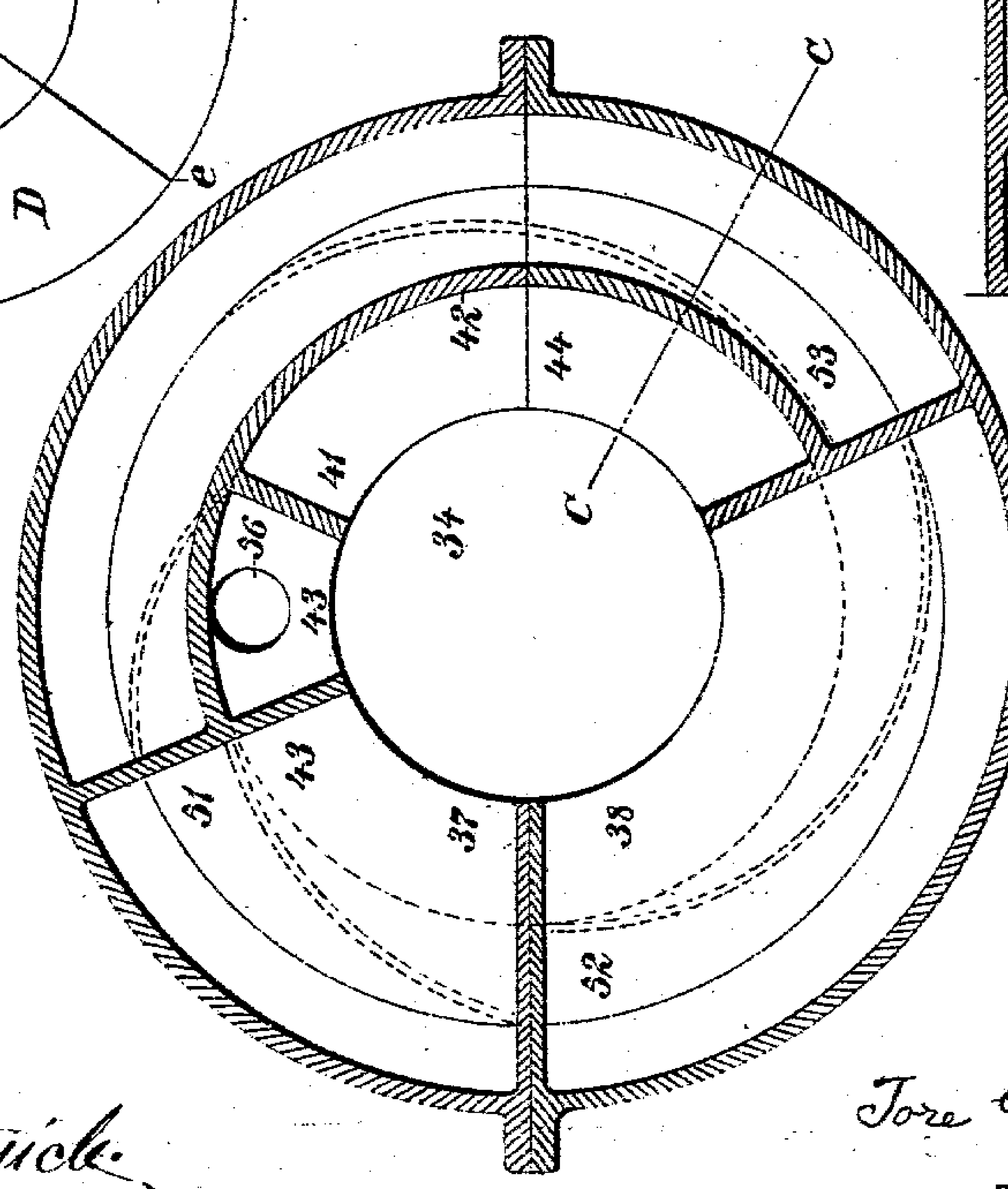

Fig. 9.

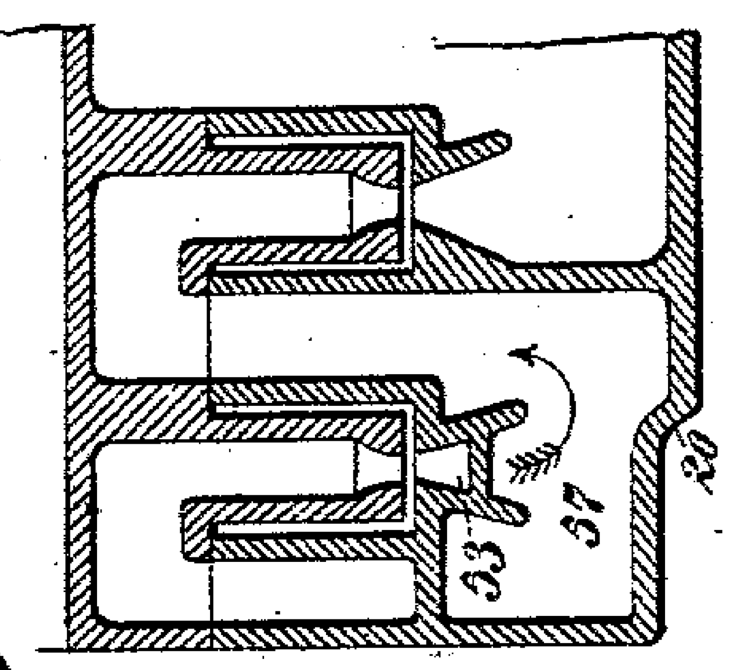

Fig. 11.

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Fig. 13.

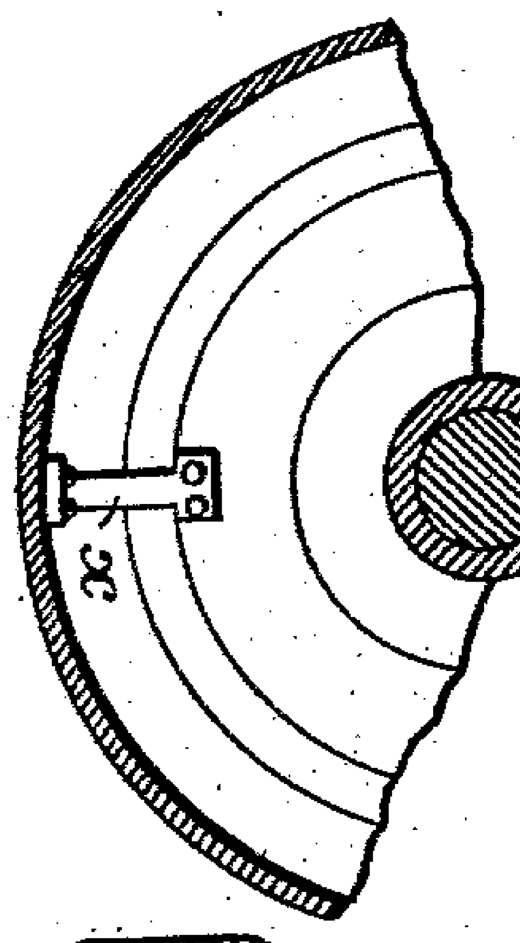
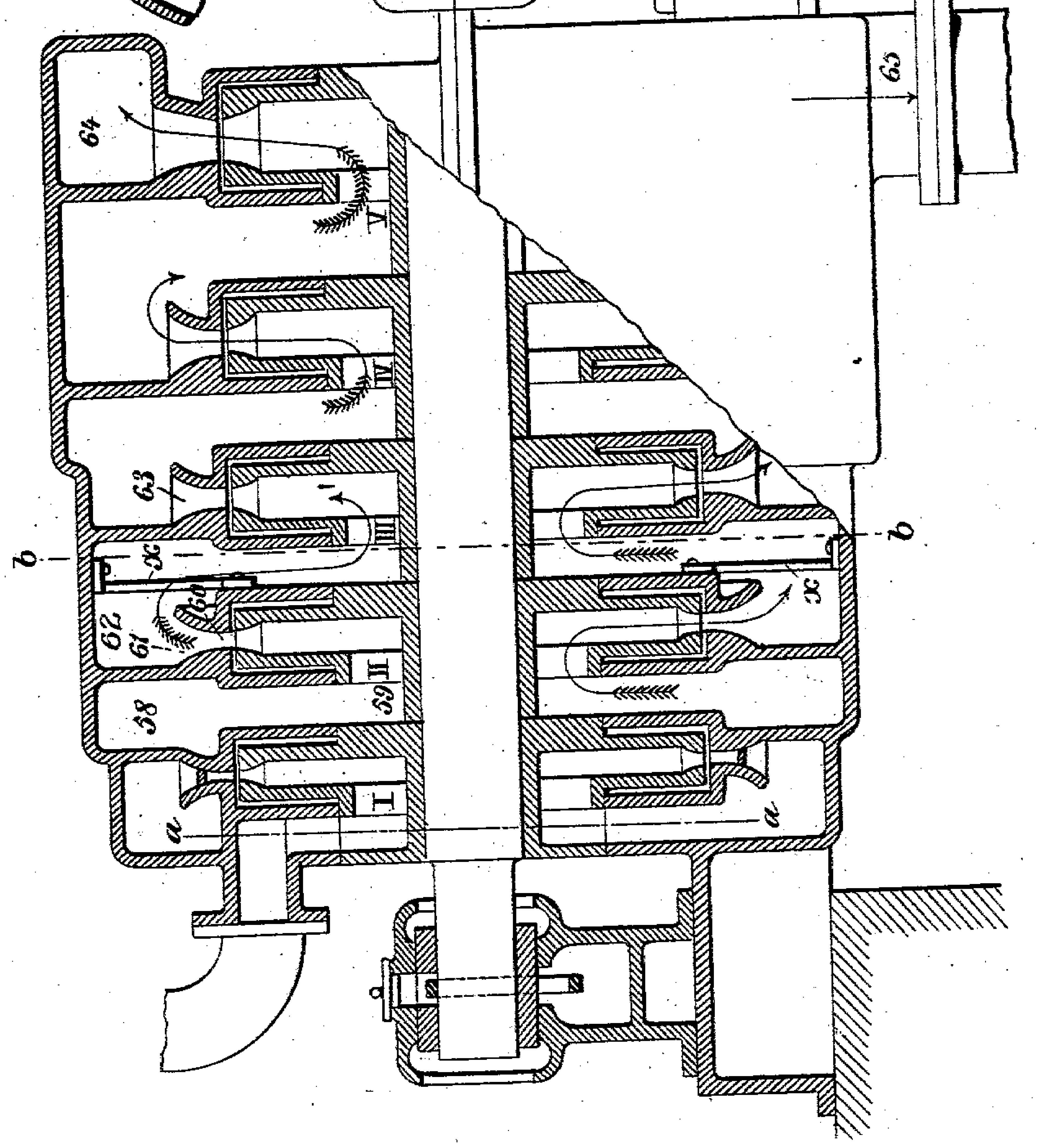


Fig. 10.



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UNITED STATES PATENT OFFICE.

TORE GUSTAF EMANUEL LINDMARK, OF STOCKHOLM, SWEDEN.

ELASTIC-FLUID TURBINE.

SPECIFICATION forming part of Letters Patent No. 716,908, dated December 30, 1902.

Application filed December 26, 1901. Serial No. 87,346. (No model.)

To all whom it may concern:

Be it known that I, TORE GUSTAF EMANUEL LINDMARK, a subject of the King of Sweden and Norway, residing at Stockholm, Sweden, have invented a new and useful Improvement in Elastic-Fluid Turbines, of which the following is a specification.

My invention relates to an elastic-fluid motor in which the said fluid is repeatedly utilized.

My invention consists in the combination, with an elastic-fluid motor, of means for transforming the velocity energy of the exhaust from said motor into pressure and means for reconducting said exhaust to said motor, in the construction of said motor with a plurality of working compartments wherein the fluid is successively utilized and means also for increasing the pressure of said fluid prior to such utilization, in the construction of an elastic-fluid turbine embodying successive compartments for the above purpose, in the combination of such a turbine with a second motor actuated by the exhaust thereof, and in the various other combinations and instrumentalities more particularly set forth in my claims.

In the accompanying drawings, Figure 1 is a vertical section of my engine on the line *x x* of Fig. 2. Fig. 2 is a vertical section of the casing on the line *z z* of Fig. 1, the wheel being omitted and looking into the same in the direction of the arrow, Fig. 1. Fig. 3 is a section of the wheel and of its supporting-shaft and hub on the line *y y* of Fig. 1, showing but four of the buckets. Fig. 4 is a side elevation of one of the wheel-buckets. Fig. 5 is a partial section of wheel and casing on the line *x' x'* of Fig. 2. Fig. 6 is a diagram illustrating the parts of the wheel into which steam enters successively. Fig. 7 is a side and Fig. 8 an end elevation. Figs. 9, 10, 11, and 12 show the arrangement of my improved turbine in compound relation with a series of other turbines, Fig. 9 being a section on the line *a a* of Fig. 10, Fig. 10 a vertical longitudinal section, Fig. 11 a section on the line *c c* of Fig. 9, and Fig. 12 an end elevation. Fig. 13 is a partial cross-section on the line *b b* of Fig. 10.

Similar characters of reference indicate like parts.

1 is the bed of the engine, carrying the standard 2, in which the main shaft 3 is journaled. The wheel 4, fast upon said shaft, has a hub 5, having flanges 8 and 8. Said hub carries the annular wheel-heads 7 and 6. The head 7 is flanged at 9 and does not extend to the hub, so that an annular inlet-passage 10 is formed between said hub and flange 9. Within the wheel are secured the buckets 11, one of which is shown in side elevation in Fig. 4. The inner wider portion 12 of each bucket lies between the hub-flanges 8 and 8, and hence in the annular inlet-passage 10. The outer and narrow portion 15 lies between the wheel-heads 6 and 7. The longitudinal inner edge 13 of each bucket is secured to the hub and the radial side edges 14 to the heads 6 and 7. There is an opening 16 in the peripheral wall of the wheel. The inner sides of the passage leading to said opening converge toward said opening, as shown at 17, Fig. 5. The annular passage formed by said converging sides is divided into a number of smaller passages by the wheel-buckets 11. The outer ends of said buckets located in said passage are all inclined in one direction, as shown at 18, Fig. 3. Each small passage formed by the inclined ends of adjacent buckets and the inclined sides 17 of the annular passage is of less area at the periphery of the wheel than elsewhere.

It will be obvious that the wheel described is of the reaction type, the motor fluid entering, as indicated by the arrow in Fig. 5, between the buckets in the inlet-passage 10 and passing through the interior of the wheel to the outlets.

Surrounding the wheel 4 and supported on bed 1 is a cylindrical fixed casing 20, made in two parts, bolted together, as shown in Fig. 8. Through said casing is a circular opening 34, Fig. 2, in which the peripherical edges of the wheel-hub 8 8 are received and have a steam-tight working fit. Within the said casing is a partition 21, through which there is a similar opening, the circumferential edge of which has a working fit on the upper surface of flange 9 of wheel-head 7. The wheel 4 extends into the annular chamber 22, formed by said partition 21 and one head 23 of said casing, Fig. 1, and a circumferential wall 24. In said wall 24 is a continuous opening 25, corresponding in position and in transverse width to the opening 16 in the wheel 4, which opening communicates with an annular passage 26, formed between the inner surface of the casing-head 23 and the inner surface of a flange 27 on said wall 24. These surfaces preferably diverge from the opening 16, so that said annular passage 26 is wedge-shaped in cross-section.

I have now to call special attention to the interior construction of the wheel-casing 20 and the relation of its several compartments to the wheel. From Fig. 2 it will be seen that it has five radially-disposed partitions 29 30 31 32 33, which extend from the peripheral wall 35 of the casing to the opening 34, Fig. 2. Therefore between the casing-head 36, Fig. 1, and the partition 21 there are formed four segmental chambers 37 38 39 40. These is also a radial partition 41, which, however, extends only to an arc-shaped partition 42, and this partition 42, which is practically a continuation of the outer circumferential wall 24 of chamber 22, itself extends between partitions 41 and 33, Fig. 2. A chamber 43 is thus produced between arc-shaped partition 42 and radial partitions 29 and 41 and another chamber 44 between partition 41 and radial partitions 41 and 33. With the chamber 43 the steam-inlet pipe 56 communicates. Each of the chambers 43, 37, 38, 39, and 40 communicates with the annular wheel inlet-opening 10, as illustrated in Fig. 5.

It is to be especially noted that the wedge-shaped annular passage 26 is divided by six inclined partitions 45 46 47 48 49 50 (dotted lines, Fig. 2) into five divisional passages 51 52 53 54 55. The purpose of these passages and chambers in the wheel-casing will be best understood by tracing the course of the steam in the wheel. The steam from the boiler enters by the pipe 56 to chamber 43, Fig. 1, and thence passes by annular opening 10, as already described, to the wheel. Obviously the steam can pass only to those buckets 11 in the annular inlet 10 between said partitions 29 and 41, and these buckets in the space between the wheel-heads 6 and 7 form a segment, such as A, in Fig. 6. Therefore the steam escapes from the wheel from segment A, through the bucket-openings between *a* and *b*, passes to chamber 22, surrounding the wheel, and thence proceeds through the division 51 of the annular passage 26 to the second segmental chamber 37, formed within the casing.

In the divisional passage 51 the velocity energy of the steam from segment A of the wheel becomes transformed into pressure while passing to chamber 37. From chamber 37 (see Fig. 5) the steam now passes through inlet 10 to the buckets in said opening included between partitions 29 and 30, and so to the next ensuing segment B of the wheel. From segment B the steam escapes from the peripherical openings between *a* and *c*, Fig. 6, and then to chamber 22, and thence through the divisional passage 52 in annular passage 26, and so into the next segmental chamber 38 in casing 20. In the same way the steam from chamber 38 enters the wheel, this time passing to segment C, Fig. 6. From C the steam escapes by the orifice between *c* and *d*, traverses chamber 22 and divisional passage 53, and so gets into chamber 39. From chamber 39 in the same way it goes to segment D of the wheel and thence out by the orifices between *d* and *e*, then through chamber 22 and divisional passage 54 to chamber 40. From chamber 40 in the same way it goes to segment E of the wheel and thence out by the orifices between *e* and *f*, then through chamber 22 and divisional passage 55 to the main exhaust-outlet 57. The chamber 44 being completely closed does not receive steam.

From the foregoing description the following facts will be evident: First, the steam is utilized several times in the same wheel; second, it is utilized successively in successive segments or sections of the wheel-buckets of that wheel; third, it is utilized in segments of the wheel progressively increasing in area; fourth, beginning with the second chamber 37 the remaining segmental chambers 38 39 40 of the casing increase in area to the same extent as the corresponding segments *b c d e* of the wheel; fifth, between each utilization of steam in a segment of the wheel, the said steam is received in an intermediate chamber, where it obviously undergoes compression. After leaving any segment of the wheel and before entering any one of the segmental chambers or the exhaust-outlet the steam is compelled to traverse one of the divisional passages 51 52 53, &c., by reason of which its velocity energy is transformed into pressure in the chamber into which it is delivered before it is again utilized in the wheel; sixth, but inasmuch as the pressure energy is always less in each succeeding chamber and segment than in the preceding chamber and segment it is necessary in order to get the same effect to increase the cubic contents of said chambers and the area of the successive segments of the wheel.

The net result is that I have here a single turbine-wheel which nevertheless is a compound wheel, inasmuch as after expansion in one segment of the wheel the steam is reconducted to the next segment, expanded again, and brought to the next segment, and so on successively around the wheel before it is finally allowed to escape at the exhaust-outlet.

In addition to thus compounding the wheel I provide the annular passage 26, divided into separate divisional passages 51 52, &c., whereby, as already stated, the velocity enegy of the exhaust-steam from one segment is changed into pressure before that exhaust-steam is utilized in the next segment. As many casing-chambers 37 38, &c., (and consequently as many segments of the wheel) will be utilized as are requisite to bring the steam down to some desired pressure—say the atmosphere. Therefore I do not limit myself to any particular number of segmental casing-chambers or any particular number of areas of wheel-segments to be utilized.

In another application for Letters Patent, filed by me December 13, 1901, Serial No. 85,747, I have fully described and explained the operation of such passages as 51 52, &c., when interposed between the exhaust of a reaction wheel and a receiving-chamber in changing the velocity energy of steam passing through them into pressure in said chamber. For that reason I do not deem it necessary to enter into any elaborate explanation of the operation of such passages in the present specification. I get the best results by constructing said passages with their inlet-openings 25 of the same width as the exhaust-opening 16 of the wheel, with diverging sides and also wedge-shaped, as already explained, in cross-section and with partitions 45 46, &c., also diverging toward the delivery-opening, so that the said opening of each passage, as 51 52, &c., will be of larger area than the inlet-opening. The necessary dimensions of any such passage in a wheel of this kind must of course depend upon the steam-pressures and wheel dimensions employed. The particular passage in point of dimensions and relative area of inlet and outlet which will give the best results for any particular wheel is easily ascertainable by measuring the steam-pressure in the several segmental chambers.

The engine hereinbefore described may be used singly, or it may be employed with other units compounded successively, and especially with a series of reaction wheels in which the steam enters the hollow wheel-body and escapes around the entire circumference between buckets located in a suitable annular opening. Where a number of wheels of the last-named type are disposed successively, the areas exposed to the action of the steam progressively increasing from inlet to outlet of the series, it sometimes is found that the areas of the surfaces in the first wheel are too small to insure a sufficient degree of expansion of the steam passing through it. This difficulty is overcome by using my present wheel as a first unit, because, as is obvious, two or more expansions may be caused in it before the steam is exhausted into the several wheels of the series. This is illustrated in Figs. 9, 10, and 11. I, Fig. 10, is the first unit constructed as already described, containing three expansion-passages 51 52 53, Fig. 9, instead of a greater number. After passing through the passage 53 the steam enters a chamber 57, Fig. 11, in the main casing 20, which casing is here constructed of sufficient size to include all of the wheels, and from thence proceeds to an annular chamber 58, which communicates, through the annular opening 59, with all the buckets in the interior of wheel II. After passing through wheel II the steam escapes around the entire periphery of said wheel into an annular opening 60, which forms the inlet to an annular passage 61, similar to passage 26, but having no internal partitions 46 47, &c. By the action of this passage, as before, the velocity energy of the steam is transformed into pressure energy in the chamber 62, into which said passage conducts it. From chamber 62 the steam in like manner goes to wheel III and passage 63, and thereafter through successive wheels IV and V, until finally it leaves the apparatus by way of annular chamber 64 and outlet 65. Wheels I to V progressively increase in the areas on which the steam acts for the reasons governing the designing of compound engines in general.

I claim—

1. In combination with an elastic-fluid motor, means for transforming the velocity energy of the exhaust from said motor into pressure, and means for reconducting said exhaust to said motor.

2. In combination with an elastic-fluid motor, a receiver for the exhaust thereof, means communicating with said receiver for increasing the pressure of said exhaust therein and means for conducting said fluid at said increased pressure back to said motor.

3. In combination with an elastic-fluid motor, a plurality of working compartments, means for transforming the velocity energy of the exhaust from one working compartment into pressure and means for reconducting said exhaust into another working compartment of said motor.

4. In combination with an elastic-fluid motor, having a plurality of working compartments, means interposed between successive compartments for transforming the velocity energy of the exhaust from each compartment into pressure, and means for conducting the said exhaust into an adjacent compartment of said motor.

5. In combination with an elastic-fluid motor having a plurality of working compartments, arranged successively, a chamber communicating with each compartment and its successor and receiving the exhaust from one compartment, and means in said chamber for augmenting the pressure of said exhaust prior to its passage to the adjacent compartment.

6. In an elastic-fluid turbine, a hollow wheel having a hollow hub projecting from one head thereof, a circumferential inlet surrounding said hub and a circumferential outlet surrounding said wheel, and buckets radially disposed within said wheel and extending longitudinally said hub.

7. In an elastic-fluid turbine, a hollow wheel having a hollow hub projecting from one head thereof, a circumferential inlet surrounding said hub, a constricted circumferential outlet surrounding said wheel, and buckets 11 having outer inclined portions 17, said buckets being radially disposed in said wheel with their inclined portions 17 located in said constricted outlet.

8. An elastic-fluid turbine of the type here-

in described having a plurality of segmental working compartments and means for conducting the exhaust from one compartment back to another compartment.

9. An elastic-fluid turbine of the type herein described having a plurality of segmental working compartments, means for conducting the exhaust from one compartment back to another compartment and means for raising the pressure of said exhaust.

10. An elastic-fluid turbine of the type herein described having a plurality of segmental compartments, means for conducting said fluid to a section composed of a certain number of said compartments, means for reconducting the exhaust to another section similarly composed, and means for increasing the pressure of said fluid while passing from one section to another.

11. An elastic-fluid turbine of the type herein described having a plurality of segmental compartments, means for conducting said fluid to a section composed of a certain number of said compartments, means for reconducting the exhaust from said section to another section composed of a greater number of said compartments, and means for increasing the pressure of said fluid while passing from the first section to the second.

12. The combination of an elastic-fluid turbine-wheel of the type herein described having a plurality of radial partitions, a casing 20 therefor, and in said casing a chamber 43 communicating with a source of elastic-fluid supply and the inlet of said wheel, a chamber 22 inclosing said wheel, a chamber 37 and a passage 51 connecting said chambers 22 and 37; whereby the motor fluid passing from chamber 43 to said wheel-inlet is caused to act upon a certain number of radial partitions and thereafter to pass to chamber 22 and thence through passage 51 to chamber 37 the said passage being constructed and arranged to transform the velocity energy of the exhaust into pressure in said chamber 37.

13. The combination of an elastic-fluid turbine of the type herein described having a plurality of radial partitions, a casing 20 therefor and in said casing a chamber 43 communicating with a source of elastic-fluid supply and the inlet of said wheel, a chamber 22 inclosing said wheel, a chamber 37 communicating with said wheel-inlet, a passage 51 connecting said chambers 22 and 37, a chamber 38 and a passage 58 connecting said chambers 22 and 38; whereby the motor fluid passing from chamber 43 to said wheel-inlet is caused to act upon a certain set of radial partitions and thereafter to pass to chamber 22 and thence through passage 51 to chamber 37, and thence again to said wheel-inlet to act upon a certain other set of radial partitions, and thence to pass to chamber 22 and thence through passage 52 to chamber 38; the said passages 51 and 52 being constructed and arranged to transform the velocity energy of the exhaust into pressure respectively in said chambers 37 and 38.

14. The combination with an elastic-fluid motor having a plurality of working compartments in which said fluid is successively expanded and means interposed between said compartments for transforming the velocity energy of the exhaust into pressure, a second elastic-fluid motor actuated by the final exhaust from said first motor.

15. In combination with an elastic-fluid turbine having a plurality of working compartments in which said fluid is successively expanded, a second elastic-fluid turbine wherein the final exhaust from said first turbine undergoes a single expansion.

16. In combination with an elastic-fluid turbine having a plurality of working compartments in which said fluid is successively expanded, and means interposed between said compartments for transforming the velocity energy of the exhaust into pressure, a second elastic-fluid turbine actuated by the exhaust from said turbine, and a shaft supporting and rotated by said turbines.

17. The combination with an elastic-fluid motor having a plurality of working compartments in which said fluid is successively expanded, and means interposed between said compartments for increasing the pressure of the exhaust, of a plurality of elastic-fluid motors in which the final exhaust from said first motor is successively expanded.

18. The combination with an elastic-fluid motor having a plurality of working compartments in which said fluid is successively expanded, of a plurality of elastic-fluid motors in which the final exhaust from said first motor is successively expanded and means interposed between said motors for increasing the pressure of the exhaust from each motor before said exhaust is utilized in the next motor of the series.

19. The combination with an elastic-fluid motor having a plurality of working compartments in which said fluid is successively expanded and means interposed between said compartments for increasing the pressure of the exhaust, of a plurality of elastic-fluid motors in which the final exhaust of said first motor is successively expanded and means interposed between said motors for increasing the pressure of the exhaust from each motor before said exhaust is utilized in the next motor of the series.

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

TORE GUSTAF EMANUEL LINDMARK.

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