

(No Model.)

6 Sheets—Sheet 1.

C. G. CURTIS.
ELASTIC FLUID TURBINE.

No. 566,969.

Patented Sept. 1, 1896.

Fig. 1,

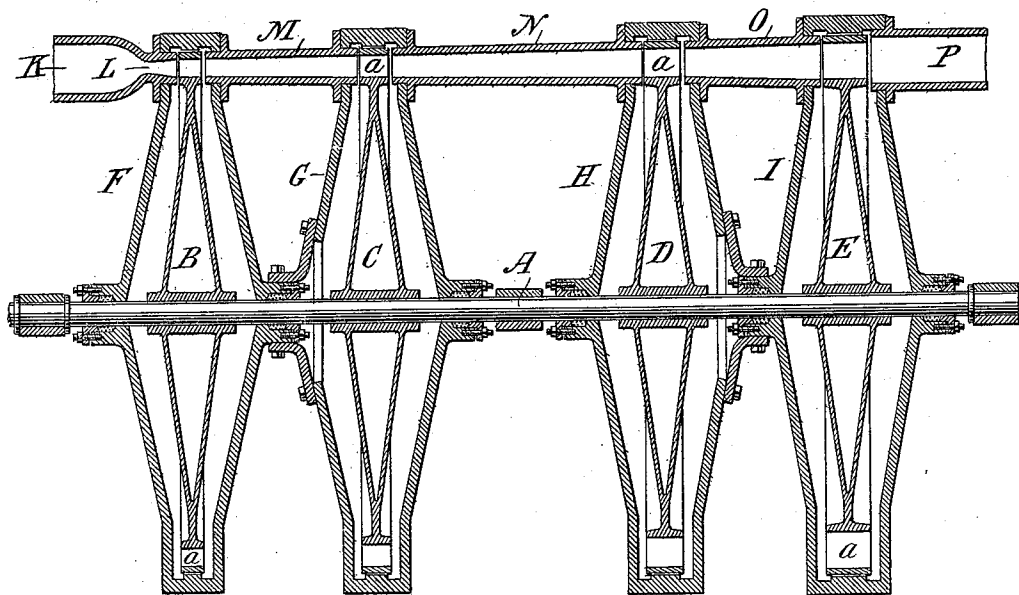
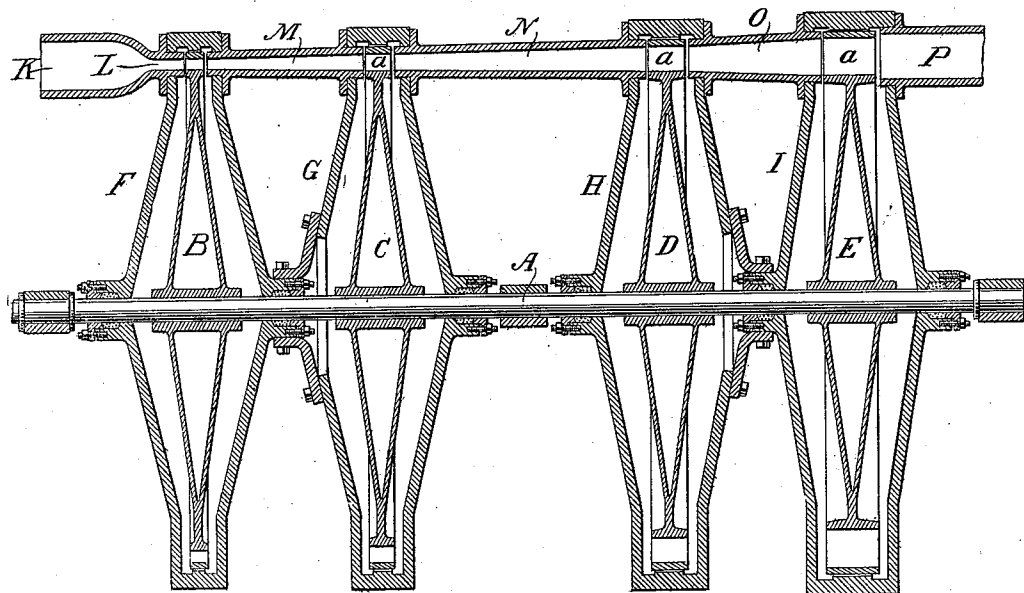


Fig. 2,



WITNESSES:

C. E. Ashley
H. W. Lloyd

INVENTOR:

Charles G. Curtis,
By his Attorneys
Syer & Driscoll.

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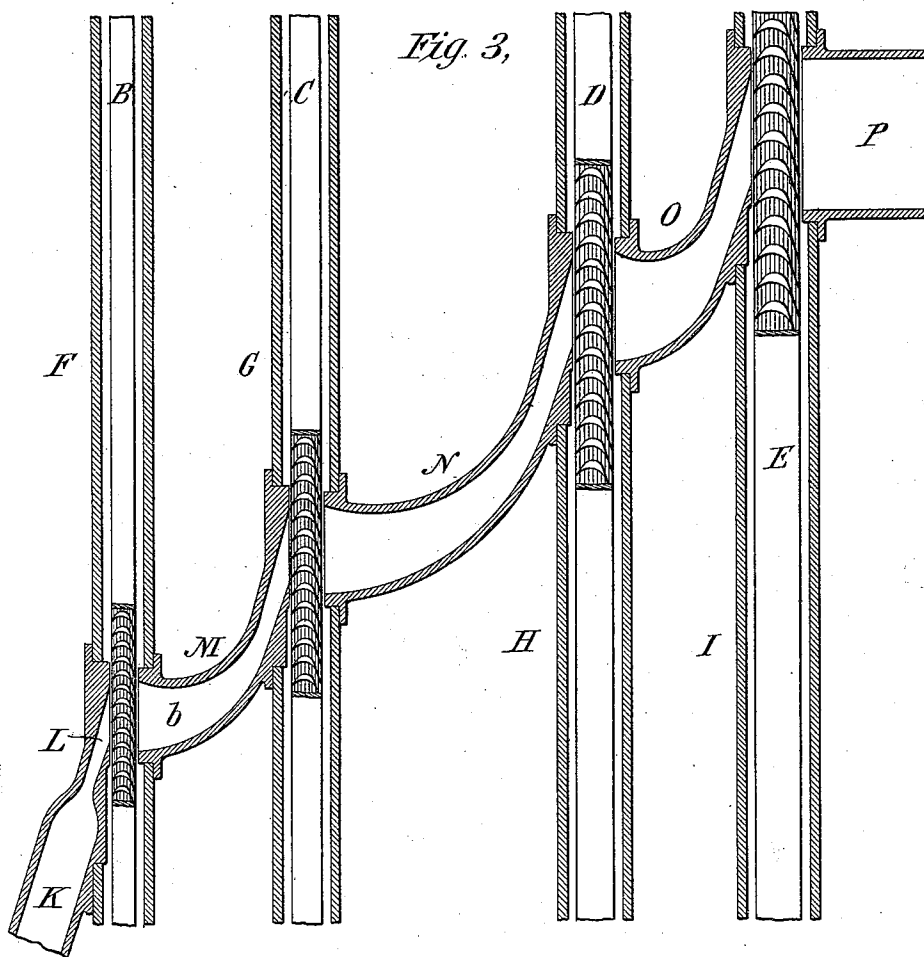
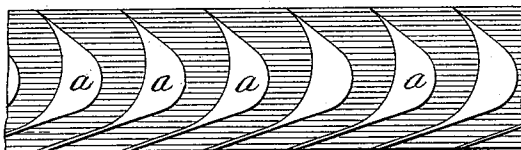


Fig. 4,



WITNESSES:

C. E. Ashley
H. W. Lloyd.

INVENTOR:

Charles G. Curtis,
By his Attorneys
Ayer & Dunscomb.

(No Model.)

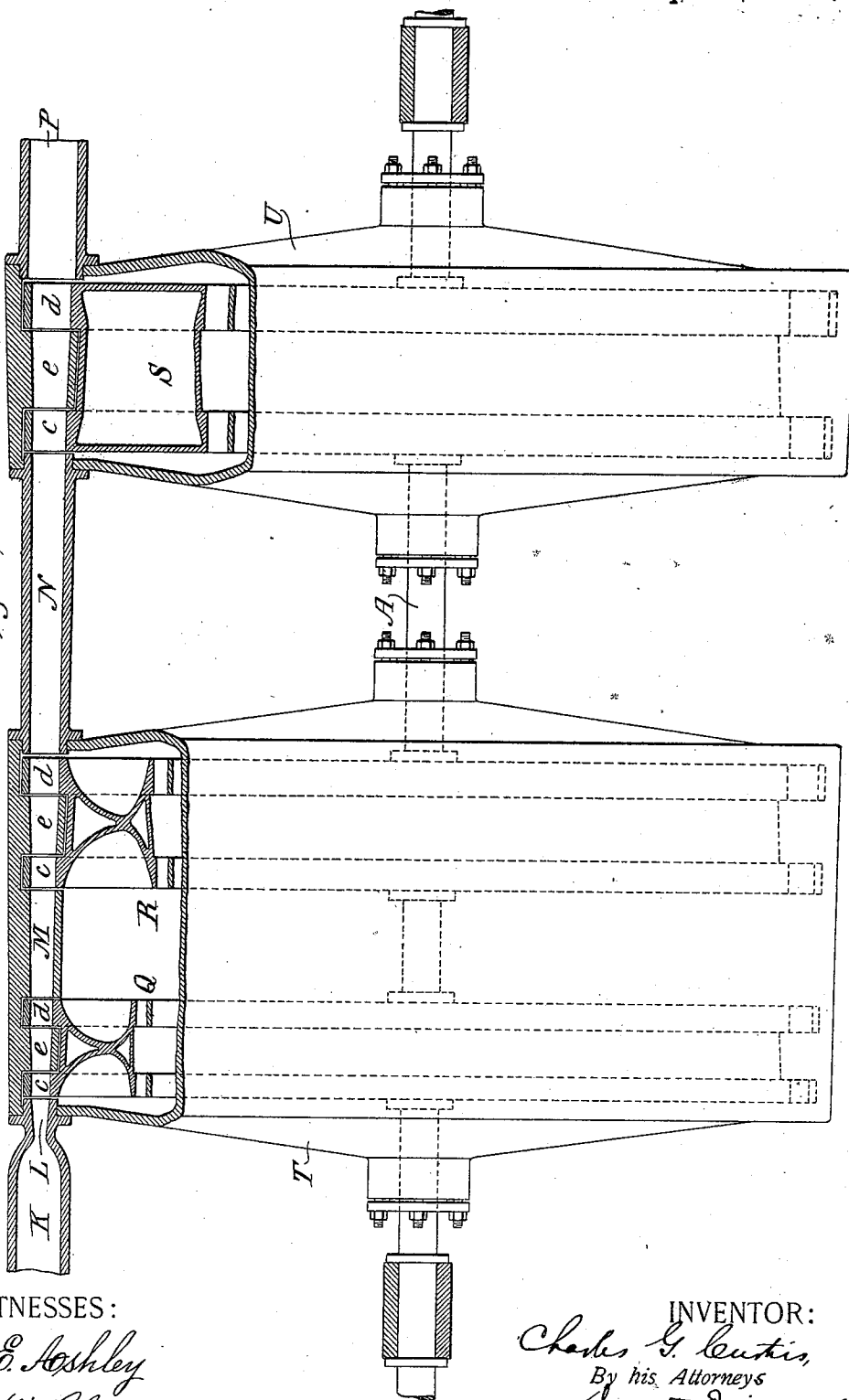
6 Sheets—Sheet 3.

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Fig. 5.



WITNESSES:

C. E. Ashley
H. W. Lloyd.

INVENTOR:

Charles G. Curtis
By his Attorneys
J. & D. Scall

(No Model.)

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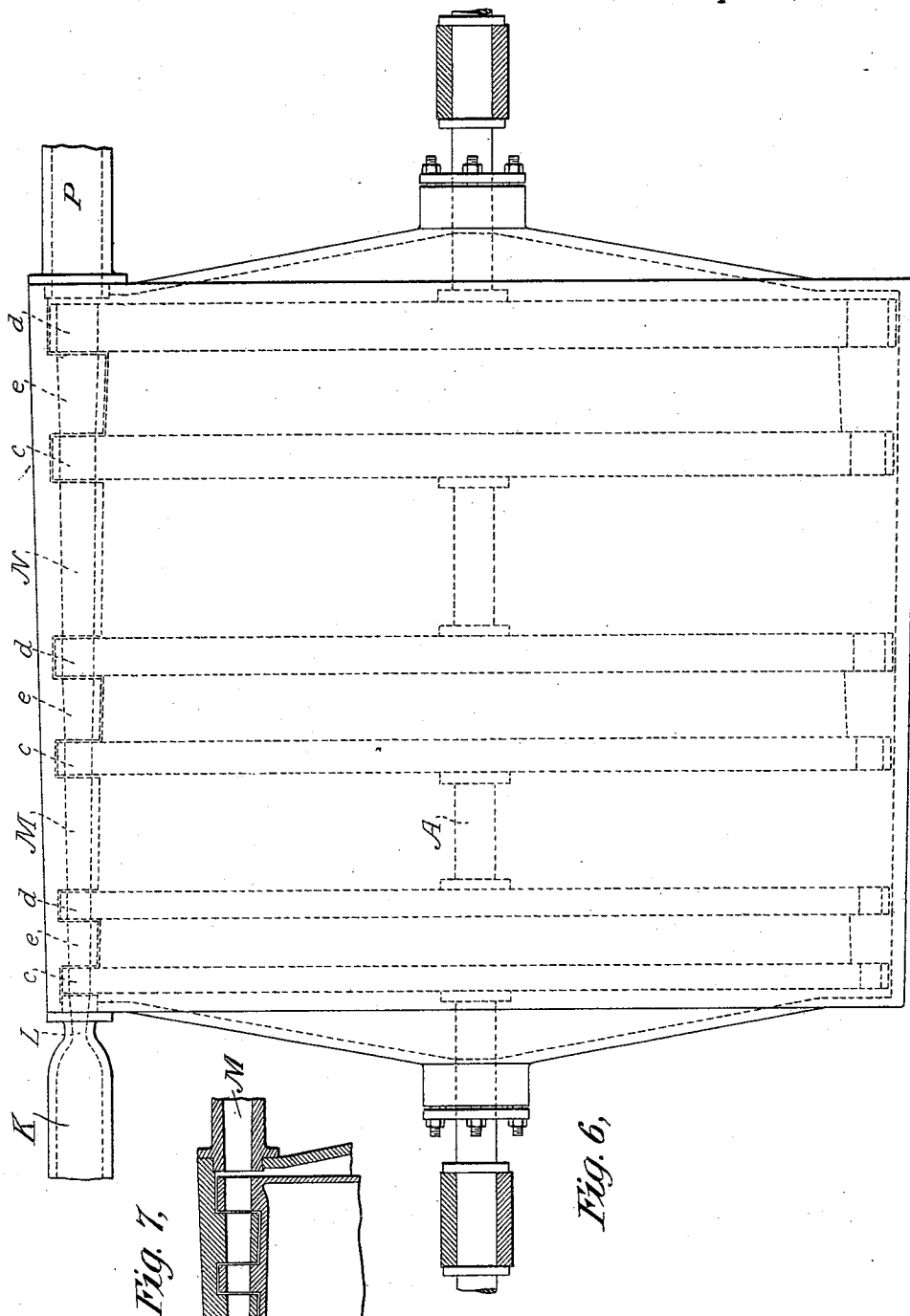


Fig. 7.

Fig. 6.

WITNESSES:

C. E. Nashley
H. W. Lloyd.

INVENTOR:

Charles G. Curtis,

By his Attorneys

Syer & Driscoll.

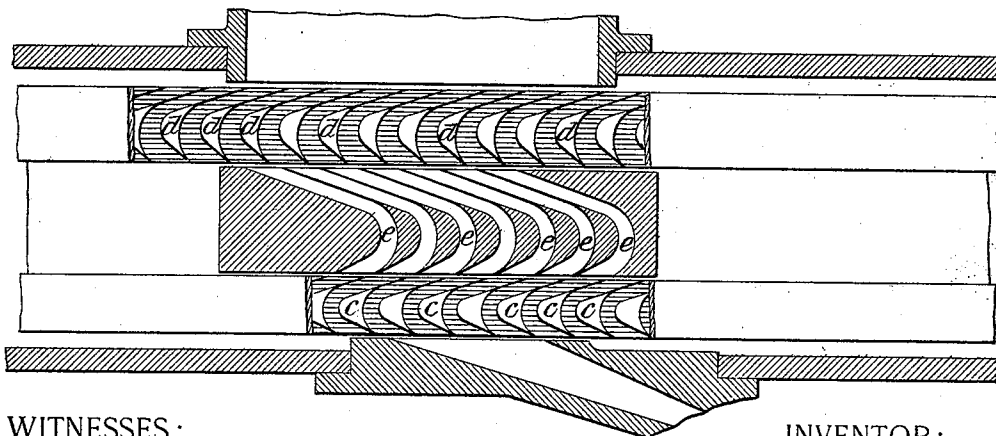
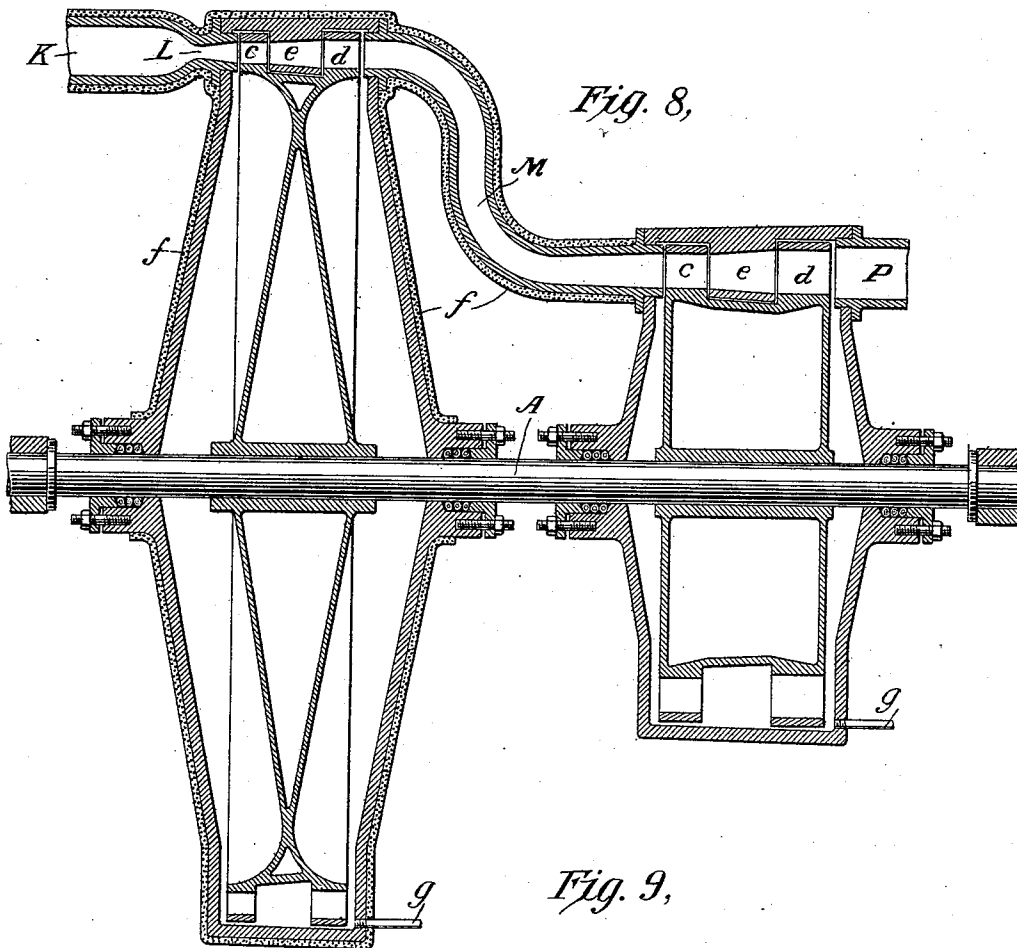
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Patented Sept. 1, 1896.



WITNESSES:

C. E. Ashley
H. W. Lloyd.

INVENTOR:

Charles G. Curtis,
By his Attorneys
Dyer & Driscoll.

(No Model.)

6 Sheets—Sheet 6.

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Fig. 10,

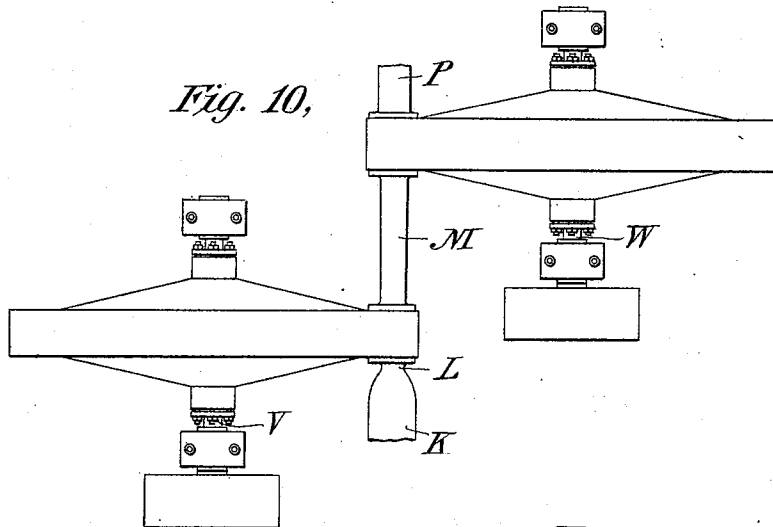
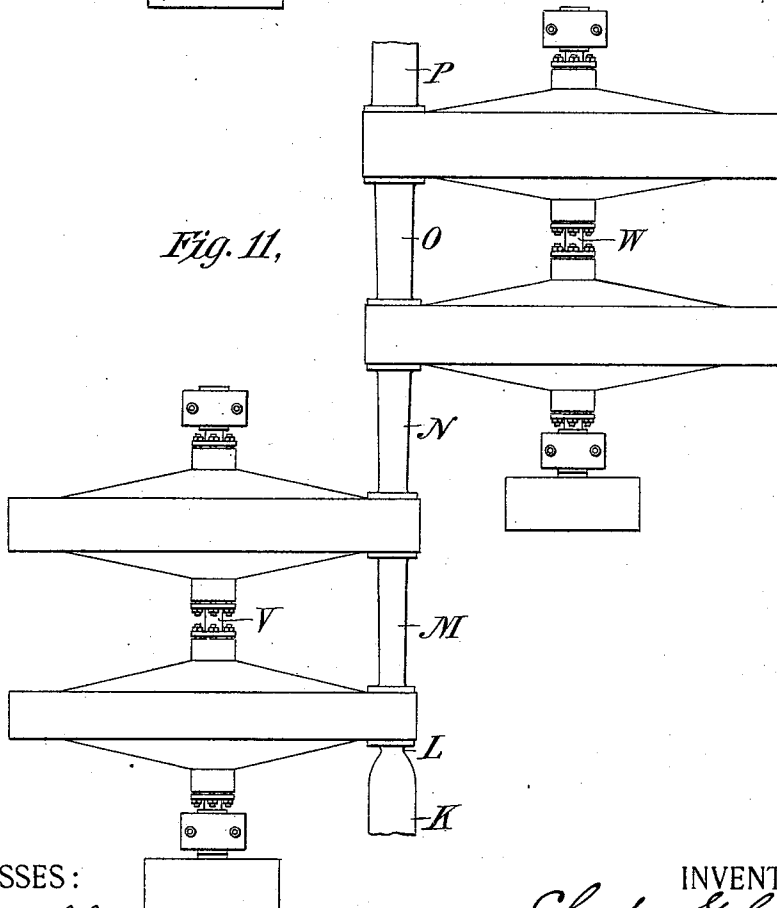


Fig. 11,



WITNESSES:

C. E. Ashley
H. W. Lloyd.

INVENTOR:

Charles G. Curtis,
By his Attorneys
Syer & Oriscall.

UNITED STATES PATENT OFFICE.

CHARLES G. CURTIS, OF NEW YORK, N. Y., ASSIGNOR TO THE CURTIS COMPANY, OF SAME PLACE.

ELASTIC-FLUID TURBINE.

SPECIFICATION forming part of Letters Patent No. 566,969, dated September 1, 1896.

Application filed January 16, 1896. Serial No. 575,679. (No model.)

To all whom it may concern:

Be it known that I, CHARLES G. CURTIS, a citizen of the United States, residing at New York city, in the county and State of New York, have invented a certain new and useful Improvement in Elastic-Fluid Turbines, of which the following is a specification.

My object is to develop mechanical power from steam or other elastic fluid under pressure by utilizing a large proportion of its *vis viva* in a turbine whose speed of rotation shall be low.

The method by which the turbine of my present invention operates consists in converting the pressure of the fluid into *vis viva* by stages and utilizing the *vis viva* developed at each stage by passing the fluid through rotating vanes the speed of revolution of which is adapted to abstract substantially all or a large portion of the velocity. In practicing this method I first convert a definite amount of the initial pressure of the fluid into *vis viva* by passing a jet of fluid through a nozzle or passage properly proportioned to give the desired result, and I deliver the flowing jet to a movable element of the apparatus consisting of one or more circular ranges of vanes forming passages through which the jet passes and in which its direction of flow is changed, so as to extract its velocity wholly or largely, whereby the *vis viva* developed in the nozzle or passage is wholly or largely converted into mechanical rotation. The fluid issues from this movable element into a stationary passage, which is so proportioned as to convert a further definite amount of the pressure remaining in the fluid into *vis viva*, and which delivers the fluid in a jet to the second movable element consisting of one or more circular ranges of vanes, by which the direction of the flow of the jet is changed, and its velocity is again wholly or largely extracted, whereby the *vis viva* developed in the intermediate passage is converted wholly or largely into mechanical power. The energy of the fluid may be converted into mechanical power in two or more such steps or stages, but it is essential that the various stages be so coördinated that the flow through the apparatus shall be continuous. To this end the successive working passages to which the jet is ad-

mitted in the movable elements of the apparatus are enlarged in cross-section and correspond in size with the discharging ends of the successive stationary passages, and in each element in which *vis viva* is developed provision is made for carrying the same mass of fluid as is admitted to the first nozzle or passage having regard to the volume and velocity. The pressure of the fluid-jet is not reduced during its passage through the utilizing-vanes, except to the extent necessary to supply what may be called the "frictional consumption of energy" in the passage through the vanes. The passage must be enlarged in proportion thereto.

The movable elements of the apparatus in which the *vis viva* developed at each stage is utilized may consist of single sets of rotating vanes, or of two or more such sets with intermediate stationary vanes or passages, or of two or more sets of rotating vanes connected to different shafts. The velocity developed and utilized at each stage may be the same, in which case the speed of the several movable elements will also be the same, or the former may not be the same, in which case the latter will also vary. The movable elements may be mounted on the same or different shafts. If they are mounted on the same shaft but have different rates of motion, their diameters should be different, so that the speed at the shaft may be the same.

Certain constructional features of my apparatus are applicable to an apparatus operating by the special method referred to, but may also be applied to an apparatus in which the steam or other elastic fluid has a considerable velocity after passing through each movable element of the apparatus except the last, as described in an application for patent already filed by me, Serial No. 575,244. The more important of these constructional features are as follows: The movable elements of the apparatus are divided between two or more separate fluid-tight shells or casings connected together by suitable stationary passages. Within each of the shells the movable element may be single or compound. The effect of this construction is to maintain different pressures in the two or more fluid-tight shells, which pressures will approximate

the pressures existing in the working passages at the clearances between the movable and stationary parts in each shell. This reduces the leakage at the clearances. Such leakage as does take place, however, into any shell except the last shell of the series does not result in a waste of power, since the excess fluid reenters the working passages of the turbine at the clearance between the exit-
 10 passage and the movable vanes and is utilized in the succeeding set of vanes. This construction is particularly useful in the form of apparatus in which a considerable portion of the pressure is still retained by the fluid when it enters the first movable element of the apparatus, but it is a desirable construction in any compound elastic-fluid turbine, even in one where the entire useful or available pressure is converted into *vis viva* by the delivery-nozzle which delivers the fluid to the first set of movable vanes, because in a compound apparatus more or less pressure must exist even at the end of the delivery-nozzle in order to overcome friction
 25 in the working passages. I also intend that my apparatus shall not be subject to the loss in efficiency arising from the friction of the elastic fluid in passing through the working passages. The friction produces heat in the walls of the passages, which may be considerably greater than the heat of the steam or other elastic fluid. The energy represented by this heat will be lost to a great extent if the working passages are allowed to cool off.
 30 To prevent this, I cover the working passages with a heat-non-conducting material. To do this effectually, the delivery-nozzle, the intermediate stationary passages when employed, and the shell or shells must all be covered.
 40 The covering of the nozzle and the intermediate stationary passages secures the result so far as those parts of the apparatus go, and the covering of the shells prevents the cooling of the movable vanes as they move through the atmosphere within the shells, the heat of such atmosphere being maintained by the heat insulation of the shells themselves. The result of this heat insulation of the working passages is to cause such passages to be heated by the friction of the fluid to such an extent above the heat of the fluid itself that a point of equilibrium will be reached where a definite temperature will be maintained, and the heat produced by friction will react upon the fluid-jet and be reconverted into energy within the jet. The heat insulation of the shells has also the additional result of preventing loss by condensation within the shells.
 50 It is the design of my present invention, as of the apparatus of my prior application referred to, to employ at the delivery end of the nozzle and in the working passages a "jet" of steam or other elastic fluid, i. e., a practically solid stream of fluid having an oblong form in cross-section, whose thickness bears a considerable proportion to its width,

so that its cross-sectional area will be large compared with its perimeter as distinguished from an annular film of elastic fluid, whose cross-sectional area is small compared with its perimeter. By this means the frictional retardation is greatly reduced and the efficiency is largely increased.

In the accompanying drawings, forming a part hereof, Figure 1 is a vertical section of one form of the apparatus with the nozzle and intermediate stationary passages brought into the same vertical plane for clearness of illustration. Fig. 2 is a view similar to Fig. 1, showing a nozzle with parallel walls instead of diverging walls. Fig. 3 is a horizontal section through the nozzle and intermediate stationary passages of the apparatus of Fig. 1, these parts being brought into the same horizontal plane and the vanes of the movable elements of the apparatus being partly developed in the same horizontal plane. Fig. 4 is a plan view, on a larger scale, of some of the movable vanes developed. Fig. 5 is a side view and partial vertical section with the nozzles and stationary passages brought into a vertical plane, showing a modified form of the apparatus. Fig. 6 is a side elevation of a further modification. Fig. 7 is a vertical section of one movable element employing three sets of movable vanes. Fig. 8 is a vertical section similar to Fig. 1, illustrating elements of different diameters mounted on the same shaft. Fig. 9 is a horizontal section, with the passages brought into the same horizontal plane, of the second element of the apparatus of Fig. 8, the movable vanes being partly developed. Fig. 10 is a plan view showing an apparatus of two elements delivering the power to two different shafts, the nozzle and intermediate stationary passage being brought into a horizontal plane; and Fig. 11 is a similar view showing an apparatus of four elements working on two shafts.

Referring particularly to Figs. 1, 2, and 3, A is the shaft, upon which are mounted four disks or wheels B, C, D, and E, each carrying on its periphery a complete circular range of curved vanes *a*, which form the sides of curved passages extending parallel with the shaft from side to side of the disk and closed at their tops and bottoms. The disks are mounted in separate stationary shells F, G, H, and I, which are properly packed about the shaft, so as to prevent leakage. K is a pipe or conduit leading from the steam-boiler or other source for supplying the fluid under pressure. This pipe terminates in a nozzle L, which may have diverging sides, as in Fig. 1, or parallel sides, as in Fig. 2. The end of this nozzle passes through one side of the shell F and approaches closely the receiving ends of the movable vanes *a* of the disk B, to which it delivers the fluid-jet. The nozzle L is placed at an angle, as shown in Fig. 3, while the vanes *a* have the configuration more particularly shown in Fig. 4,

and receive the jet on their concave sides and tend to change its direction of motion over ninety degrees, which change would occur if the vanes were held stationary. Owing, however, to the fact that the speed of the vanes is about half that of the jet, the jet issues from the tails of the vanes at about right angles to the disk B. The jet is then received by the intermediate stationary passage M. This passage is widened out at its receiving end *b*, so as to cover all the vanes to which the nozzle delivers the jet, which, due to "spill" and to the lead, will be greater than those actually covered by the end of the nozzle. The passage M terminates in an expansion-nozzle similar to the nozzle L but larger, so as to carry the increased volume of fluid due to its diminished pressure. This second expansion-nozzle is adapted to convert a further amount of pressure into velocity, and is arranged obliquely with reference to the vanes of the disk C at the proper angle to deliver the fluid-jet to such vanes the same as the nozzle L delivers the fluid-jet to the vanes of the disk B. Back of the expansion-nozzle with which the passage M terminates that passage may be a conduit of any suitable size and shape so long as it is large enough to accommodate the fluid at the increased volume due to its decreased pressure. The vanes of the disk C are larger than those of the disk B, so as to give additional cross-sectional area to the passages between them. Between the disks C and D is a stationary passage N, corresponding with the passage M, and another similar passage O is located between the disks D and E, each of these passages terminating, as does the passage M, in an expansion-nozzle of larger size than the preceding one and adapted to convert pressure into *vis viva*. The exhaust-pipe P, opening into the air or connected with a condenser, opens out of the side of the case I opposite the vanes *a* in the disk E to which the fluid-jet is delivered by the passage O.

The apparatus described and illustrated is proportioned to operate by the method already referred to. The delivery-nozzle L and the nozzles of the successive stationary passages M, N, and O are designed each to produce the same velocity, which is practically or largely extracted by each set of the movable vanes, which receive the fluid-jet in succession. The manner of proportioning the relations between the receiving and discharging ends of the delivering-nozzle and the nozzles of the stationary passages will be understood from the explanation of the delivery-nozzle given in my application already referred to.

In Figs. 1 and 2 the apparatus illustrated is designed, in each instance, to convert in the two or more successively-acting nozzles all the useful or available energy into *vis viva*, each one of these nozzles developing the same velocity in the jet as each of the others, and each set of movable vanes extracting practi-

cally all this velocity and being made successively larger in cross-section to compensate for the increased volume of the fluid-jet. The apparatus of Fig. 1, however, is designed to work under different terminal pressures from that of Fig. 2. For purposes of illustration we will assume that the apparatus of Fig. 1 is designed to work between a boiler-pressure of one hundred and fifty pounds and an exhaust-pressure of two pounds, these pressures being absolute and not by gage, (this exhaust-pressure corresponding to about twenty-six inches of vacuum.) The pressures existing at the discharging ends of the nozzle L and of the nozzles of the intermediate stationary passages M, N, and O will be such as to develop practically equal velocities at the delivery end of each of these nozzles, this velocity being, roughly, seventeen hundred feet per second. The apparatus of Fig. 2 is intended to represent a non-condensing turbine, operating between a boiler-pressure of one hundred and fifty pounds (absolute) and an atmospheric exhaust, say sixteen pounds pressure. In this case the pressures at the discharge ends of the nozzle L and of the nozzles of the intermediate stationary passages M, N, and O will likewise be such as to develop practically equal velocities at each nozzle, and in this case such velocity will be, roughly, thirteen hundred feet per second.

In Fig. 5 is illustrated a form of apparatus having three movable elements, each of which is compounded once, or has two series of movable vanes. The movable elements are wheels or drums Q, R, and S, having on their peripheries two sets of vanes *c d*, which are separated by a stationary passage *e*, carried by the casing. The construction of these movable vanes and stationary passages and their relations to each other will be understood from Fig. 9, which will be presently described. Although each movable element may be inclosed in a separate casing, as in the apparatus of Figs. 1 and 2, in the form of apparatus shown in Fig. 5 the first two movable elements and the intermediate connecting-passage M are inclosed in the shell T, while the third movable element is inclosed in the shell U, the intermediate passage N connecting the two shells. In this apparatus the delivery-nozzle L and the nozzles of the stationary passages M and N are designed to develop the same velocity in the jet, which is, in each case, one-third of the total velocity utilized in all the movable elements combined. Each of the movable elements is compound, having two sets of movable vanes and an intermediate stationary passage *e*, which is not designed to develop additional velocity but is expanded in the direction of flow to compensate for the reduced velocity produced by the movable vanes *c* and for increased volume required to overcome frictional retardation, as described in my application already referred to. It is the especial design of the apparatus of Fig. 5 that the pressure in the

first shell T should be approximately atmospheric pressure, while that in the second shell U should be the condenser-pressure, or, say, twenty-six inches of vacuum. Assuming
 5 terminal pressures of one hundred and fifty pounds and two pounds, (absolute,) the pressures at the discharge ends of the nozzle L
 10 and of the nozzles of the passages M and N will be adapted accordingly, and the velocity at each of those points will be practically nineteen hundred feet per second. The pressure
 15 at the receiving end of the passage N will be approximately atmospheric pressure, and that will be approximately the pressure of the elastic fluid within the shell T, which pressure will be determined by the pressure existing at the clearance between the receiving end of the
 20 passage N and the movable vanes *d* of the element R, through which clearance the excess of steam within the shell T will be drawn into the working passages and utilized. The difference between the pressure existing at this clearance and that existing at the clearances
 25 between the nozzle L, the passages *e* and passage M, and the vanes *c d* will be such that there may be considerable leakage into the shell, but this leakage will not be a wasteful one, because the fluid will be again introduced into the working passages of the apparatus at the entrance of the passage N.

In Fig. 6 is illustrated an apparatus in which three elements, each compounded once, are introduced into a single shell. The delivery-nozzle and the nozzles of the intermediate stationary passages are designed to secure the successive conversion of pressure into velocity, and the movable vanes convert the velocity into mechanical motion, as in the case of the apparatus of Fig. 5.

40 In Fig. 7 is shown a sectional view of one element of an apparatus compounded twice, or having three series of movable vanes. This movable element is inclosed in its own casing or shell, from which leads a stationary
 45 passage, terminating in an expansion-nozzle connecting with another movable element, the apparatus being one of two or more movable elements with connecting-passages having expansion-nozzles designed to convert
 50 the pressure into velocity.

In Fig. 8 an apparatus with two movable elements is shown, the movable elements being mounted upon the same shaft and each element being compounded once. In this
 55 apparatus the velocity produced by the expansion-nozzle L is intended to be greater than that produced by the expansion-nozzle of the passage M. For illustration, assuming terminal pressures of one hundred and
 60 fifty pounds and two pounds, (absolute,) the pressures at the discharging ends of the nozzle L and of the nozzle of the stationary passage M may be arranged so that the velocity at those two points may be, respectively, approximately three thousand and fifteen hundred feet per second. The velocity of the fluid-jet as it is discharged by the nozzle of

the passage M being only one-half of the velocity at the delivery end of the nozzle L, the speed of the vanes of the second movable
 70 element will be only one-half that of the vanes of the first movable element. To compensate for this difference in speed, the diameter of the second movable element is made one-half, so that the proper speed at the shaft will be
 75 the same for the two elements. In this figure is also illustrated a heat-non-conducting packing *f*, which covers the nozzle L, the passage M, and the shell of the first movable element, and may also cover the shell of the second
 80 movable element. This heat-non-conducting packing prevents the loss of energy by friction in the working passages to a great extent, as already explained, and also reduces the condensation in the shell to a minimum. A pipe
 85 *g* with a suitable valve is employed to draw off any water of condensation which may collect in the shell.

Fig. 9 is a horizontal section and plan view indicating the vanes and connecting-passages
 90 of the second element of the apparatus of Fig. 8. This view equally well illustrates the same parts of the second element of the apparatus of Fig. 5. The special feature illustrated by this figure (not shown in the other
 95 figures of the drawings) is the employment, for the stationary passage *e* between the two sets of movable vanes in a compound movable element, of a wide passage divided into a number of separate passages by vanes
 100 corresponding with the movable vanes, but placed in a reversed position. The object of this divided passage is to avoid eddy currents, which might occur if an undivided wide passage were employed at this part of the
 105 apparatus, because the fluid-jet enters this intermediate passage with approximately one-half of the velocity which it had on entering the vanes *c*. The divided passage is also in its nature an adjustable passage, because the fluid will not spread out beyond the special
 110 sections of the passage to which it is delivered, and in this way the increased lead in passing from the state of rest of the movable vanes up to their full speed will be provided
 115 for without increasing the width of that portion of the passage which is occupied by the fluid-jet.

In Figs. 10 and 11 two shafts V W are operated by the same apparatus, the elements
 120 of the apparatus being divided between the two shafts, and these elements being connected together by the stationary passages and nozzles the same as if they were mounted upon one shaft. In Fig. 10 the apparatus is
 125 composed of two elements, one on each shaft, while in Fig. 11 the apparatus has four elements, two being on each shaft.

It is obvious that each rotating element of the apparatus may be mounted upon separate
 130 shafts, in which case there may be as many shafts as there are rotating elements to the apparatus, and it is also obvious that the direction of rotation in each case will depend

upon whether the vanes and the successively-acting nozzles are set to produce rotation in one direction or in the reverse direction, and consequently that the same apparatus may produce rotation in opposite directions on different shafts.

It will be observed that in all the constructions illustrated the successively-acting nozzles deliver the fluid-jet to a part only of the vanes of each set; in other words, the delivery ends of the two or more nozzles occupy only a small portion of the peripheries of the wheels. This is an important feature of the apparatus, because, as distinguished from an apparatus in which the fluid is delivered simultaneously to the entire circular range of vanes, the diameters of the wheels may be increased without decreasing the height of the vanes, as is necessary in apparatus where the fluid is delivered to the entire periphery in order to prevent the undue enlargement of the fluid-passage.

It is evident that the constructional features of my apparatus, such as the division of the movable elements of the apparatus into two or more parts located in separate fluid-tight shells, and the heat insulation to secure the reconversion of the heat produced by friction in the working passages into energy in the fluid-jet, are applicable to elastic-fluid turbines operated by the method described in my former application referred to.

What I claim is—

1. In an elastic-fluid turbine, the combination with movable vanes, of a series of passages delivering the fluid to the vanes two or more times in succession, said passages being adapted to convert in successive operations or stages different portions of the pressure of the fluid into *vis viva* and said vanes being adapted to abstract at each passage therethrough substantially all or the principal portion of the *vis viva* developed at the preceding stage, whereby the pressure will be alternately converted into *vis viva* and abstracted in stages, substantially as set forth.

2. In an elastic-fluid turbine, the combination with movable vanes, of a series of expansion-passages delivering the fluid to the vanes two or more times in succession, said expansion-passages being adapted to convert in successive operations or stages different portions of the pressure of the fluid into *vis viva* and said vanes being adapted to abstract at each passage therethrough substantially all or the principal portion of the *vis viva* developed at the preceding stage, whereby the pressure will be alternately converted into *vis viva* and abstracted in stages, substantially as set forth.

3. In an elastic-fluid turbine, the combination with movable vanes to which the fluid is delivered two or more times in succession, of an expansion-nozzle and one or more intermediate expansion-passages, said expansion-nozzle and one or more intermediate expansion-passages being adapted to convert in

successive operations or stages different portions of the pressure of the fluid into *vis viva* and said vanes being adapted to abstract at each passage therethrough substantially all or the principal portion of the *vis viva* developed at the preceding stage, whereby the pressure will be alternately converted into *vis viva* and abstracted in stages, substantially as set forth.

4. In an elastic-fluid turbine, the combination with two or more sets of rotating vanes (each set being single or compound), of a series of passages delivering the fluid to the sets of vanes in succession, each of the said passages being adapted to convert in successive operations or stages different portions of the pressure of the fluid into *vis viva* and said vanes being adapted to abstract at each passage therethrough substantially all or the principal portion of the *vis viva* developed at the preceding stage, whereby the pressure will be alternately converted into *vis viva* and abstracted in stages, substantially as set forth.

5. In an elastic-fluid turbine, the combination with two or more sets of rotating vanes (each set comprising movable vanes through which the fluid-jet is passed two or more times in succession), of an expansion-nozzle and one or more stationary intermediate expansion-passages, substantially as set forth.

6. In an elastic-fluid turbine, the combination with two or more sets of rotating vanes, each set composed of two or more series of vanes and one or more intermediate stationary passages, the vanes and passages of each set being constructed to extract the *vis viva* from the fluid without materially decreasing its pressure, of an expansion-nozzle delivering a fluid-jet to a part of the vanes of the first set and constructed to convert a part only of the pressure into *vis viva*, and one or more intermediate stationary expansion-passages connecting the sets of vanes and constructed each to convert a definite portion of the pressure into *vis viva*, substantially as set forth.

7. In an elastic-fluid turbine, the combination with two or more sets of rotating vanes, each set being single or compound, and two or more fluid-tight shells or casings inclosing the said sets of vanes (one or more within each shell), of a nozzle delivering a fluid-jet to a portion of the vanes within the first shell, and one or more intermediate passages connecting the different shells together and delivering the fluid-jet to a portion of the vanes of the different sets in succession, whereby different pressures will be maintained in the shells approximating those at the clearances, and any leakage into any shell other than the last will be returned to the working passages, substantially as set forth.

8. In an elastic-fluid turbine, the combination with two or more sets of rotating vanes, each set being single or compound, and two or more fluid-tight shells or casings inclosing

the said sets of vanes (one or more within each shell), of a series of passages delivering the fluid to the two or more sets of rotating vanes in succession, each of the said passages being adapted to convert substantially such a definite portion of the pressure into velocity as the vanes to which it delivers the fluid are capable of abstracting, whereby the pressure will be alternately converted into *vis viva* and abstracted in stages and whereby different pressures will be maintained in the shells approximating those at the clearances, and any leakage into any shell other than the last will be returned to the working passages, substantially as set forth.

9. In an elastic-fluid turbine, the combination with two or more sets of rotating vanes, each set being single or compound, and two or more shells or casings inclosing the said sets of vanes (one or more within each shell), of an expansion-nozzle, and one or more expansion intermediate passages delivering the fluid to the sets of rotating vanes in succession, whereby the pressure will be converted into *vis viva* and abstracted in stages and whereby different pressures will be maintained in the shells approximating those at the clearances, and any leakage into any shell other than the last will be returned to the working passages, substantially as set forth.

10. In an elastic-fluid turbine, the combination with two or more sets of rotating vanes, each set being composed of two or more series of such vanes, and two or more independent fluid-tight shells, for inclosing the vanes, of a nozzle entering the first shell, and one or more intermediate stationary passages connecting the different shells, said nozzle and passages delivering fluid to a part of the vanes only of each set, whereby different pressures will be maintained in the shells approximating those at the clearances, and any leakage into any shell other than the last will be returned to the working passages, substantially as set forth.

11. The combination of a series of separate fluid-tight shells, each inclosing a set of rotating vanes, and a series of expansion nozzles

or passages converting pressure into velocity and delivering the fluid to the sets of rotating vanes in succession, each succeeding expansion nozzle or passage having an increased cross-sectional area adapted to convey the quantity of fluid received from the previous shell, but at a diminished pressure, and each having a ratio of expansion adapted to convert the desired amount of pressure into *vis viva*, substantially as set forth.

12. In an elastic-fluid turbine, the combination with two or more rotating elements inclosed in two separate fluid-tight shells, of a delivery-nozzle, an intermediate stationary expansion-passage and a vacuum-exhaust, the nozzle, rotating elements and stationary passage being so proportioned that the pressure in the first shell will be approximately atmospheric pressure, and that in the second shell will be the vacuum-exhaust pressure, substantially as set forth.

13. In an elastic-fluid turbine wherein the pressure is alternately converted into *vis viva*, and abstracted by stages, the combination with two or more rotating elements having different rates of peripheral speed and constructed with diameters proportional to such different speeds, of a nozzle, and one or more intermediate stationary passages having the capacity to convert the pressure into different percentages of *vis viva*, substantially as set forth.

14. In an elastic-fluid turbine, the combination with two or more rotating elements and two or more separate fluid-tight shells inclosing said elements, of a series of stationary expansion-passages delivering the fluid to the rotating elements in succession, and two or more shafts upon which the different rotating elements are mounted, substantially as set forth.

This specification signed and witnessed this 11th day of January, 1896.

CHARLES G. CURTIS.

Witnesses:

EUGENE CONRAN,
JOHN R. TAYLOR.