No. 879,748.

PATENTED FEB. 18, 1908.

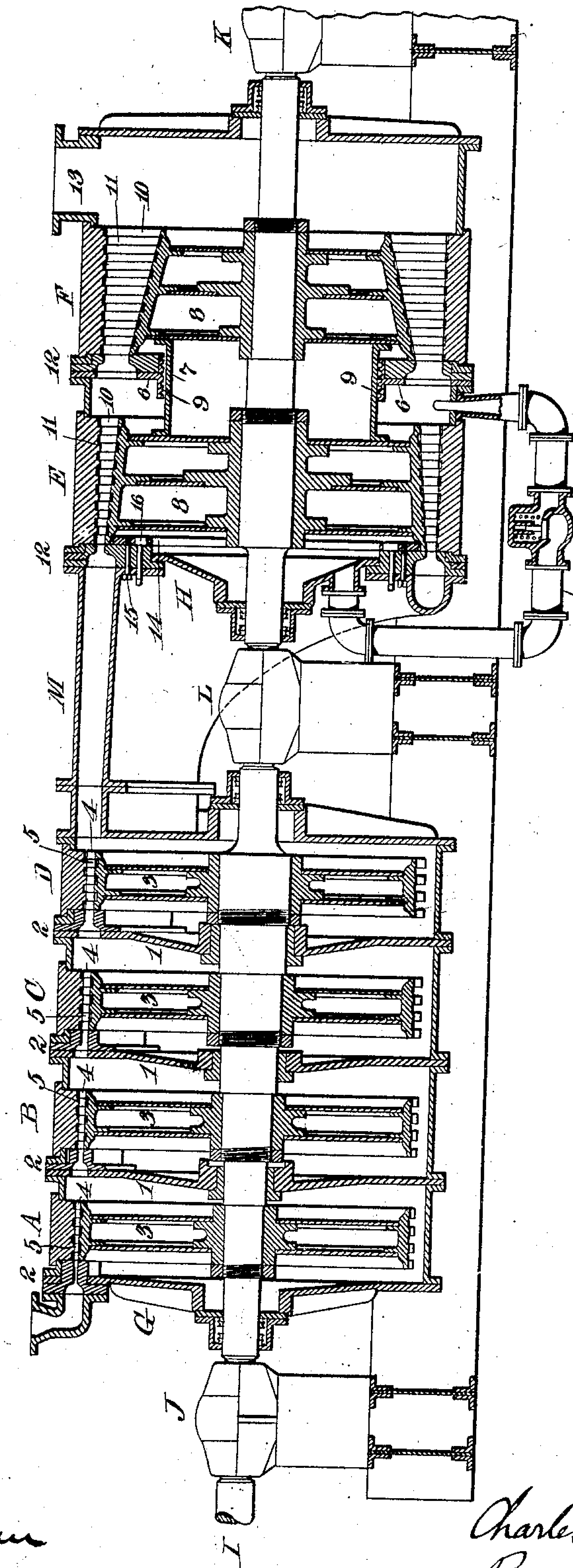
C. G. CURTIS.

ELASTIC FLUID TURBINE.

APPLICATION FILED AUG. 17, 1904.

2 SHEETS—SHEET 1.

Fig. 1



Witnesses:

Jas. F. Coleman

Jno. Robt. Taylor

Inventor

Charles G. Curtis

By Dyer & Dyer

Attorneys.

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2 SHEETS—SHEET 2.

Fig. 2

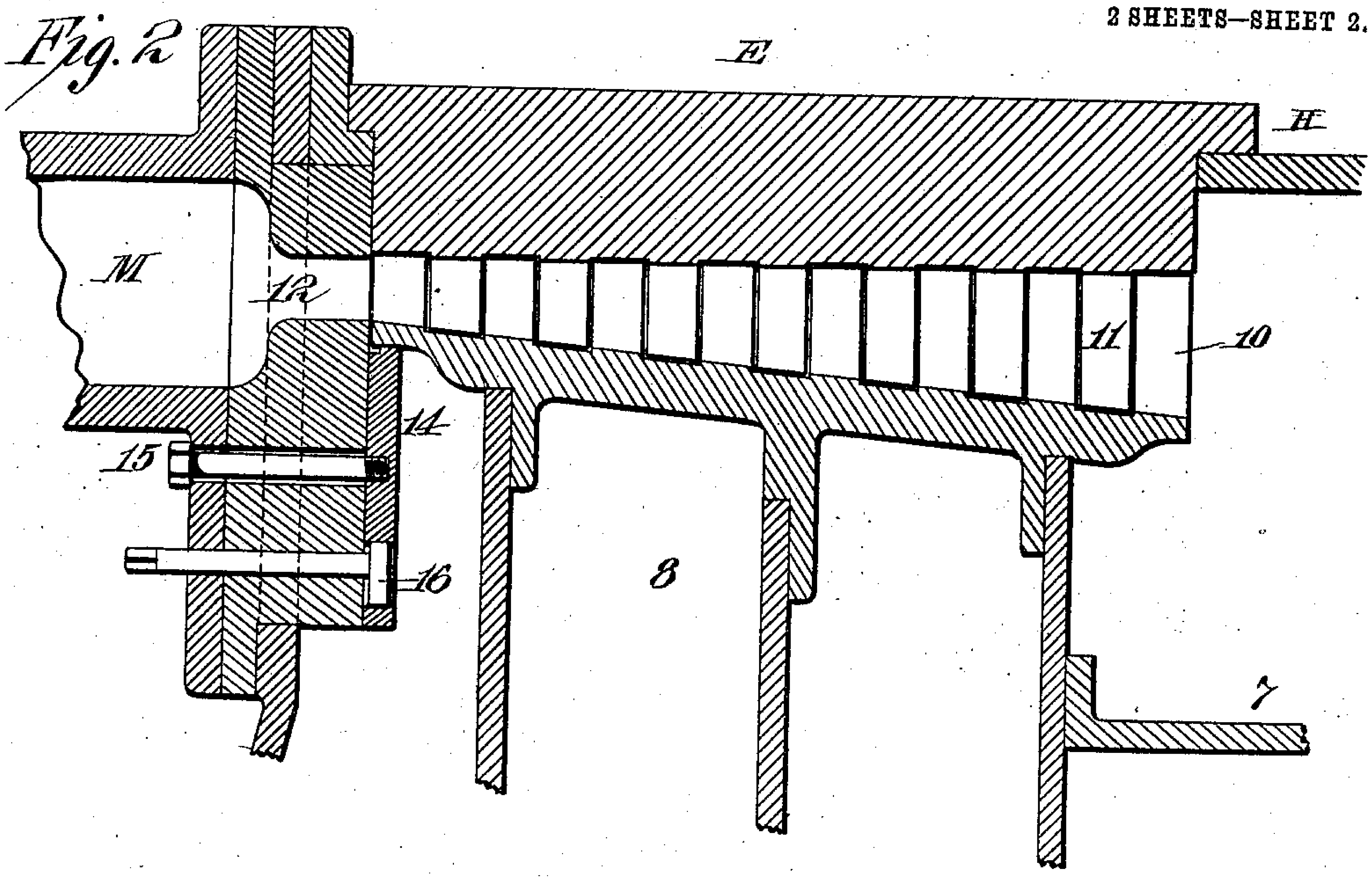


Fig. 3

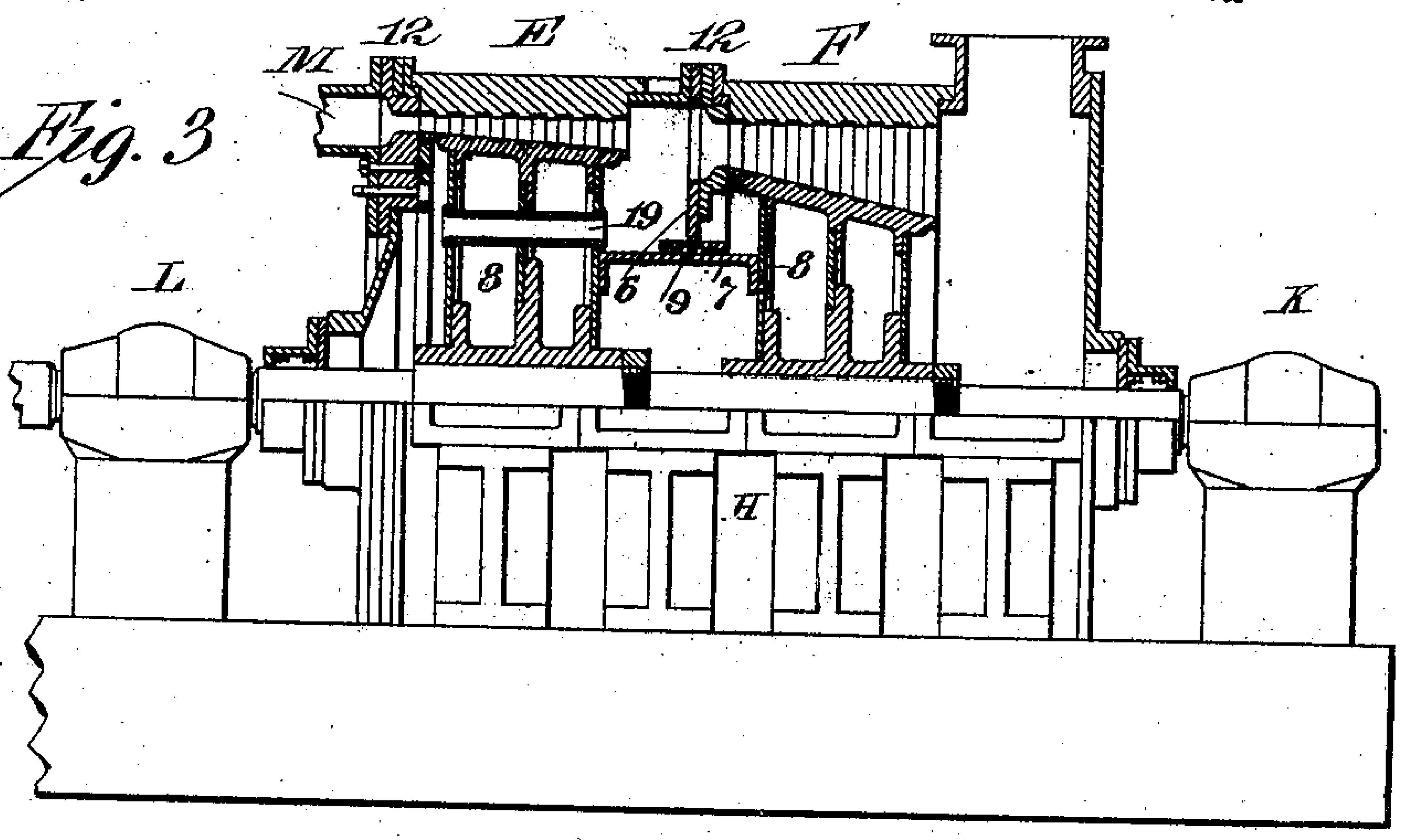
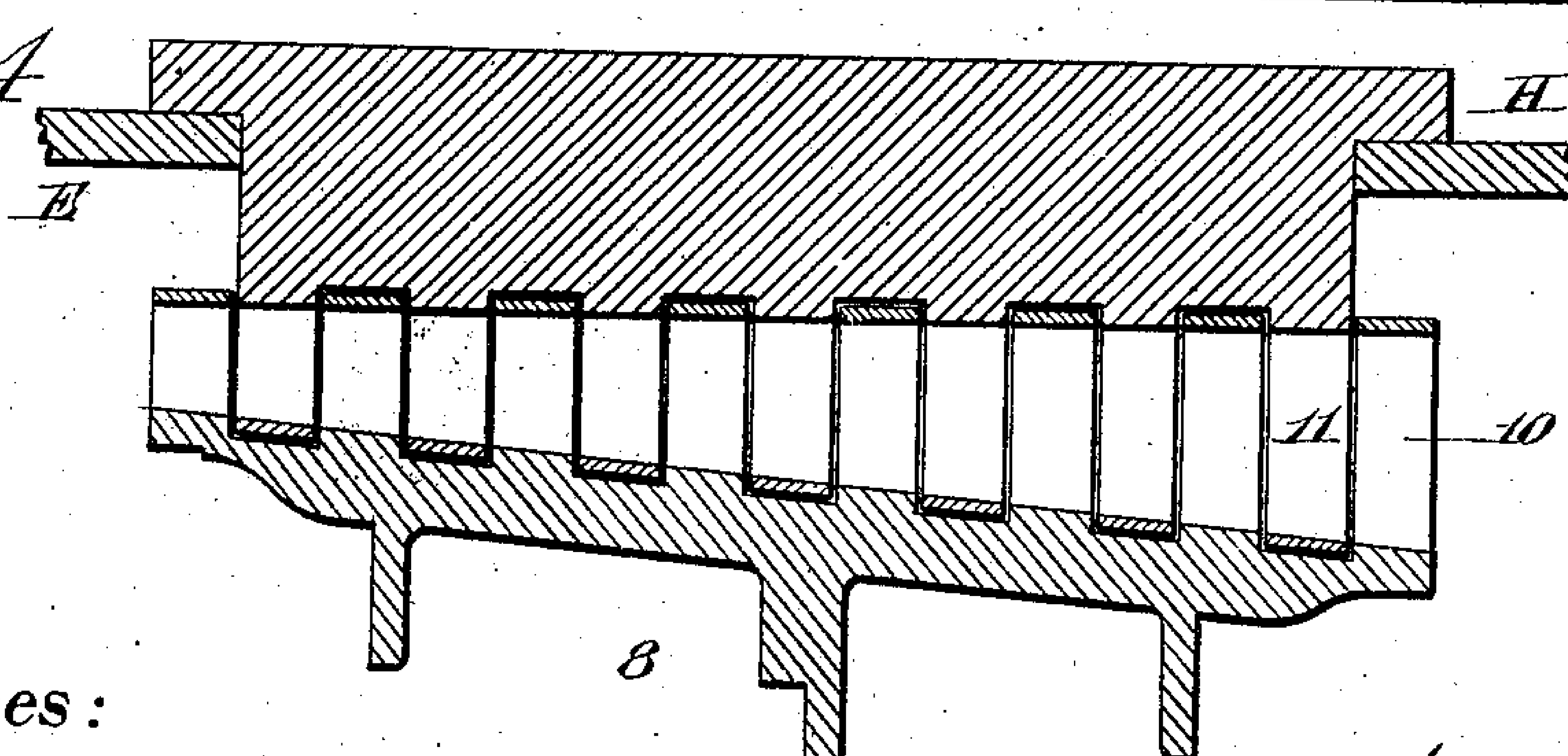


Fig. 4



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Attorneys.

UNITED STATES PATENT OFFICE.

CHARLES G. CURTIS, OF NEW YORK, N. Y., ASSIGNOR, BY MESNE ASSIGNMENTS, TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

ELASTIC-FLUID TURBINE.

No. 879,748. Specification of Letters Patent. Patented Feb. 18, 1908.

Application filed August 17, 1904. Serial No. 221,008.

To all whom it may concern:

Be it known that I, Charles G. Curtis, a citizen of the United States, resident of the borough of Manhattan, city, 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.

The object I have in view is to produce an elastic fluid turbine especially designed as a marine engine of high power, but capable of use for other purposes, to be as simple as possible in construction and occupy as little space as possible, and at the same time have a high efficiency and a relatively low speed.

Another object is to reduce the number of diaphragms separating the stages. Owing to the fact that the high pressure stages use nozzles and fixed intermediates which extend only a portion of the way around the circumference of the casing, it is necessary to have the diaphragms arranged between, for example, every three or four sets of buckets, otherwise the steam would flow around the parts of the casing not covered by the intermediates, but in the low pressure stages owing to the greatly increased volume of the steam, it becomes possible to use nozzles and fixed intermediates which extend all the way round, and therefore diaphragms are not required and the number of sets of buckets and intermediates can be multiplied greatly exceeding those in the high pressure stages, provided the expansion of the steam is properly taken care of, *i. e.*, provided the nozzle end pressure be sufficiently high and suitable expansion be provided passing through the buckets.

Another object of the invention is to reduce or partially relieve the end pressure on the turbine wheels which necessarily results from the conditions existing in the turbine of the annular and pressure character.

In carrying out my invention I construct a turbine having a number of expansion stages in accordance with the principle set forth in my Patent No. 566,969, and I employ for the high pressure stages a jet turbine, preferably compounded in each stage, while for the low pressure stages, I employ the annular form of turbine constructed in one or more stages and highly compounded in each stage.

The high pressure stages are constructed in accordance with the principle of my jet turbine which has been made familiar by my patents. There may be two or more of these high pressure stages, preferably as many as four, each provided with a sectional nozzle made in accordance with my Patent No. 700,744. The nozzle of the first stage is preferably an expansion nozzle, while the nozzles of the succeeding high pressure stages are preferably without expansion. The first stage nozzle is not necessarily an expansion nozzle, as the difference in velocity between the nozzles is relative, therefore all of the high pressure stage nozzles can be non-expansion nozzles, the succeeding high pressure stage nozzles beyond the first passing less than their capacity. Each of these high pressure stages has preferably two or more sets of moving buckets, preferably four sets of moving buckets and three sets of intermediate buckets being used for each stage. The circumferential area occupied by the nozzles and intermediates is progressively greater throughout these high pressure stages and the working passage through the moving and stationary buckets of each stage is expanded in the direction of flow of the elastic fluid. The several high pressure stages are inclosed in a common shell, which is divided into separate compartments, in which progressively lower pressures are maintained, by diaphragms which carry the sectional nozzles. The high pressure jet stages will be utilized to reduce the pressure of the elastic fluid down to a definite point which may be, for illustration, atmospheric pressure.

The wheels of the high pressure stages are mounted upon a common shaft, and this shaft also extends through the shell of the low pressure stage or stages and carries the wheels in such shell. The shaft is preferably supported by end bearings as well as by an intermediate bearing between the shells of the high and low pressure stages. The low pressure stages, which may be two or more in number, are mounted in a common shell, and consist of wheels carrying each a relatively large number of annular rows of moving buckets, there being preferably as many as eight of these rows in each stage, which coöperate with intermediate stationary buckets carried by the shell and extending completely around the circumference. Each of the low pressure stages is provided with a complete annular sectional nozzle made in accordance with the principle of my Patent

No. 700,744, but without expansion between the throats of the nozzle sections and their delivery ends. The moving and stationary buckets are made progressively of greater height so as to give the proper expansion of the working passage through them. The shell containing the low pressure stages is divided into separate compartments corresponding with the number of stages, preferably by means of partitions or diaphragms which extend inwardly from the shell only part way to the shaft. These relatively narrow annular diaphragms carry at their inner openings, rings which make a close fit with drums carried by the wheels of the adjoining stages.

The moving buckets of the low pressure stages may be made without bands or coverings on their outer ends and move in close contact with finished surfaces upon the shell, and the rows of stationary intermediate buckets may also be made without covers on their inner ends, these buckets working close to finished annular surfaces on the wheels between the rows of moving buckets. Both the moving and stationary buckets of these low pressure stages may, however, be provided with bands or covers. To prevent as far as possible the escape of the elastic fluid at the clearance between the nozzle end of the first low pressure stage and the first set of moving buckets in that stage inwardly into the space around the shaft and between the head of the shell and the first wheel, I provide lateral projections, lips or ring segments in accordance with the construction disclosed in my Patent No. 726,032, which project laterally from the nozzle end over the inner surface of the wheel so as to transfer the clearances from the radial to the cylindrical surfaces. These lips extend entirely around the circumference and are preferably made adjustable radially so as to reduce to the minimum the clearance between the lips and the wheel rim, the latter being finished with a true circular surface over which the lips project. These laterally projecting lips or ring segments not only serve to reduce the leakage inwardly from the clearance between the nozzle and the first set of moving buckets, and tend to restrict the leakage to that which takes place around the outer ends of the moving buckets where the elastic fluid will rejoin the stream flowing through the successive sets of stationary and moving buckets. I may also employ the laterally projecting lips at the end of the nozzle for the second low pressure stage although it is not so important to prevent the inward leakage at this point on account of the lower pressure.

I propose to employ relatively high pressures at the nozzle ends of the low pressure annular stages. As for illustration, if the elastic fluid is delivered to the nozzle of the first low pressure stage at atmospheric pressure or 15 lbs. absolute, the elastic fluid may be delivered to the nozzle of the second low pressure stage as 5 lbs. absolute, while the pressures at the nozzle ends of the first and second low pressure stages may be approximately 10 or 11 lbs. absolute for the nozzle of the first stage and 3 or 4 lbs. absolute for the nozzle of the second stage. The working passage through the moving and stationary buckets of each stage will be sufficiently expanded to cause the desired gradual decline in pressure and the resultant production of velocity. The effect at full loads will be therefore to cause the elastic fluid to act by impulse and reaction in the low pressure annular stages. At less than full loads, the pressure difference between the nozzle end and the stage in any given stage will be less than at full loads, and the fluid will therefore operate more by impulse than by reaction, the reactive effect decreasing as the load decreases, but not necessarily in the same proportion. The inward leakage at the end of the nozzle for the first low pressure stage will on account of the relatively high pressure at the nozzle end, produce considerable pressure upon the wheel o the first low pressure stage exerting a thrust towards the exhaust end of the machine. I propose to relieve this pressure by providing a channel for the flow of the elastic fluid from the space between the head of the shell and the wheel of the first low pressure stage into the exhaust space of the first low pressure stage. This channel may be a pipe connecting the head of the shell and extending outwardly around the shell to a connection through its side with the exhaust chamber of the first low pressure stage and in this pipe may be located a relief valve set for a definite pressure so that the pressure upon the wheel of the first low pressure stage may be relieved to any desired extent; or, if desired, openings of suitable size to give the proper relief of pressure may extend directly through the webs of the wheel connecting the space between the shell head and the wheel with the exhaust chamber of the first low pressure stage. The elastic fluid which is thus delivered to the exhaust chamber of the first stage without passing through the moving and stationary buckets of that stage mingles with the elastic fluid delivered by the buckets of the first low pressure stage and is delivered by the nozzle of the second low pressure stage to the buckets of that stage. The pressure which is produced on the wheel of the second low pressure stage by the inward leakage at the nozzle end of that stage is not sufficiently high to make necessary the relief of the pressure at that point, although, if desired, this can be done, in a similar way.

In the drawings, Figure 1 is a longitudinal sectio illustrating a turbine embodying my present invention. Fig. 2 is a section on a larger scale through one side of the first low pressure stage. Fig. 3 is an elevation and half section of the low pressure stages showing a modification of the manner of relieving the pressure on the wheel of the first low pressure stage; and Fig. 4 is a section through the moving and stationary buckets of one of the low pressure stages illustrating the employment of covers for the ends of such buckets.

A, B, C, D, are the high pressure stages, and E and F, are the low pressure stages. The high and low pressure stages are inclosed in shells G, and H. The shaft I, extends through both shells, and carries the wheels of the several stages. This shaft is supported by outside bearings J, K, and by an intermediate bearing L. The shell G is divided by diaphragms 1 into separate compartments. These diaphragms and the head of the shell carry the nozzles 2. The wheels 3 of the high pressure stages carry two or more annular sets, preferably four, of moving buckets 4 between which in the line of flow opposite the nozzles are the segmental sets of stationary intermediate buckets 5, supported by the shell. The nozzles 2 and the stationary buckets 5 occupy progressively an increasing portion of the circumference as illustrated. The shell H of the low pressure stages is divided into two compartments by a narrow diaphragm 6 extending from the shell to a drum 7 carried by the wheels 8 of the adjoining stages. The diaphragm 6 carries rings 9 on its inner annular edge so as to give an extended surface which is brought as close as possible to the drum 7 to reduce leakage. The wheels 8 of the low pressure stages carry annular sets of moving buckets 10 which coöperate with intermediate sets of stationary buckets 11 carried by the shell. These moving and stationary buckets are preferably without covers on their ends as illustrated in Fig. 2. Each of the low pressure stages is provided with a relatively large number of moving buckets preferably as many as eight rows of such buckets being employed in each stage. The nozzles 12 of the low pressure stages are sectional nozzles which extend around the entire circumference and deliver the elastic fluid to the entire set of moving buckets opposite them. The nozzle for the second low pressure stage is carried by the diaphragm 6 while the nozzle for the first low pressure stage is carried by the head of the shell H. The exhaust of the last high pressure stage D is connected with the nozzle of the first low pressure stage by a channel M, which widens out into a complete annulus where it joins the nozzle 12. The elastic fluid delivered by the second low pressure stage F passes out at the exhaust 13. The end of the nozzle 12 of the first low pressure stage carries the plate 14 which is held by bolts 15 and made adjustable by a cam 16 as illustrated in my Patent No. 726,032. A number of plates 14 will be employed to permit of adjustment. These plates overlap the clearance between the nozzle end and the wheel so as to reduce the leakage inwardly at the clearance between the nozzle end and the first set of moving buckets. The pipe 17 provided with a relief valve 18 connects the head of the shell H with the chamber into which the elastic fluid is delivered by the first low pressure stage E and from which it is taken by the nozzle 12 of the second low pressure stage F. Instead of employing the pipe 17 extending around the shell, for the relief of the pressure on the wheel of the first low pressure stage E, channels 19 may be formed directly in the wheel as illustrated in Fig. 3. While I prefer to leave the ends of the moving and stationary buckets of the low pressure stages uncovered, these buckets may be provided with covers as illustrated in Fig. 4.

What I claim is:—

1. In a stage expansion elastic fluid turbine, the combination of high pressure jet stages and low pressure annular stages, operating at low velocity and high pressure at the nozzle end, substantially as set forth.

2. In a stage expansion elastic fluid turbine, the combination of two or more high pressure jet stages having moving buckets and provided with nozzles and stationary intermediate buckets occupying a part only of the circumference, with two or more low pressure annular stages each having a greater number of annular buckets than the high pressure stages, and provided with nozzles and stationary intermediate buckets occupying the entire circumference, substantially as set forth.

3. In a stage expansion elastic fluid turbine, the combination of two or more high pressure jet stages having each two or more sets of moving buckets and provided with nozzles and stationary intermediate buckets occupying a part only of the circumference, with two or more low pressure annular stages each having a greater number of annular buckets than the high pressure stages and provided with nozzles and stationary intermediate buckets occupying the entire circumference, substantially as set forth.

4. In an elastic fluid turbine, the combination with an annular nozzle and an annular set of moving buckets to which the nozzle delivers the elastic fluid, of a lateral projection extending across the inner clearance between the nozzle end and the moving buckets and transferring the clearance from radial to cylindrical surfaces, substantially as set forth.

5. An elastic fluid turbine comprising a plurality of stage compartments working at different pressures, a nozzle for a high pres-

sure stage which converts the available pressure thereof into velocity, and whose end pressure is substantially the same as that of the exhaust from the stage compartment, wheel buckets coöperating therewith to abstract the velocity, an annular nozzle for a low pressure stage which partially converts the available pressure of the stage into velocity and has an end pressure considerably in excess of that of the exhaust from the stage compartment, a wheel having rows of buckets, all of which are active, and a complete annular row of intermediate buckets, the said rows of intermediate and wheel buckets alternately converting the pressure of the fluid into velocity and abstracting it as the fluid flows through the stage compartment.

6. An elastic fluid turbine comprising a plurality of stage compartments working at different pressures, a nozzle which converts the available pressure of a high pressure stage into velocity, wheel and intermediate buckets which fractionally abstract the velocity of the fluid received from the nozzle, a wheel for the buckets which is balanced as to fluid pressures, an annular low pressure nozzle which converts only a certain percentage of the available stage pressure into velocity, wheel and intermediate buckets arranged in rows, all of which are active and coöperate with the nozzle to abstract the velocity from the fluid due to the nozzle and also to alternately create velocity and abstract it as the fluid flows toward the exhaust.

7. An elastic fluid turbine comprising a plurality of stages working at successively decreasing pressures, nozzles for the high pressure stages that convert the available pressure of each of the high pressure stages into velocity, wheel buckets coöperating therewith which abstract the energy of the fluid without imparting velocity thereto, annular nozzles for the low pressure stages which convert only a limited portion of the available pressure of each stage into velocity, wheel and intermediate buckets arranged to abstract the velocity of the fluid as received from the annular nozzles and also to create velocity and abstract it by successive steps as the fluid flows through the stage, wheels for the buckets, and supports for the low pressure intermediate buckets, the wheels and supports coöperating to prevent the fluid from flowing from a point of high to a point of low pressure without passing through the bucket spaces.

8. An elastic fluid turbine comprising a casing, high and low pressure diaphragms for dividing the casing into stage compartments, bucket wheels for the high pressure stage compartments, bucket wheels for the low pressure stage compartments having a greater number of rows of buckets than those of the high pressure stages, expanding nozzles for high pressure stages, intermediate buckets therefor, the nozzles and buckets covering less than the full circumference of the wheel, annular nozzles for the low pressure stages which convert a portion only of the available stage pressure into velocity, and intermediate low pressure buckets, the wheel and intermediate buckets of the low pressure stages being constructed and arranged to work by impact of the motive fluid under certain load conditions and to work by impact and reaction under other load conditions.

9. An elastic fluid turbine comprising a plurality of high pressure stages working on the partial flow plan, low pressure stages working on the total flow plan, nozzles for the high pressure stages, rows of wheel buckets therefor, nozzles for the low pressure stages, and rows of wheel buckets therefor which alternately convert the pressure of the fluid into velocity and extract it, the number of rows of wheel buckets being greater in the low pressure stages than in the high.

10. In an elastic fluid turbine, the combination with a turbine wheel and a nozzle delivering the elastic fluid to the wheel throughout its entire circumference, of a channel connecting the wheel chamber on opposite sides of the wheel so as to relieve the pressure produced upon the wheel by the inward leakage at the nozzle end, and a relief valve in said channel to maintain a definite difference in pressure between the opposite sides of the wheel, substantially as set forth.

11. In an elastic fluid turbine, the combination with an inclosed shell, of a turbine wheel therein and a nozzle delivering the elastic fluid to the entire circumference of the wheel, of a lateral projection on the shell across the inner clearance between the nozzle end and the wheel, and a channel connecting the chambers on opposite sides of the wheel, substantially as set forth.

12. In an elastic fluid turbine, the combination with two annular stages each provided with a number of sets of moving buckets and with a nozzle delivering the elastic fluid throughout the entire circumference, of means for reducing the inward leakage at the nozzle end of the first stage, and means for discharging the pressure on the first wheel produced by inward leakage at the nozzle end into the nozzle chamber of the second stage, substantially as set forth.

This specification signed and witnessed this tenth day of August, 1904.

CHARLES G. CURTIS.

Witnesses:

JNO. ROB'T TAYLOR,

LEONARD H. DYER.