C. G. CURTIS.

ELASTIC FLUID TURBINE.

APPLICATION FILED AUG. 24, 1905.

996,317. Patented June 27, 1911.

5 SHEETS—SHEET 1.

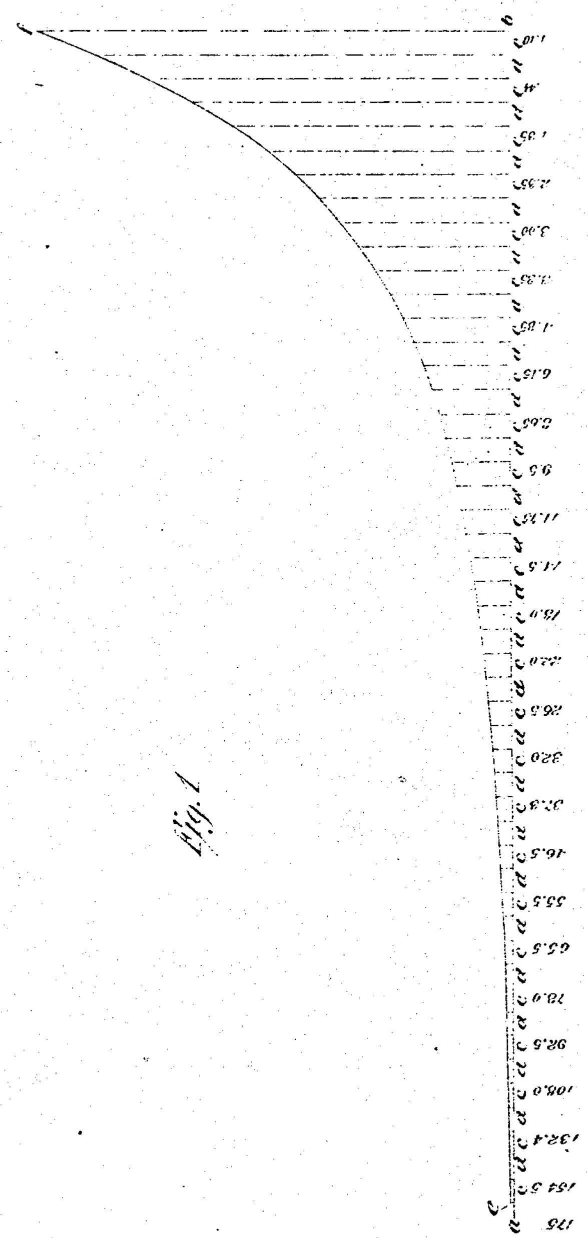

Fig. 1

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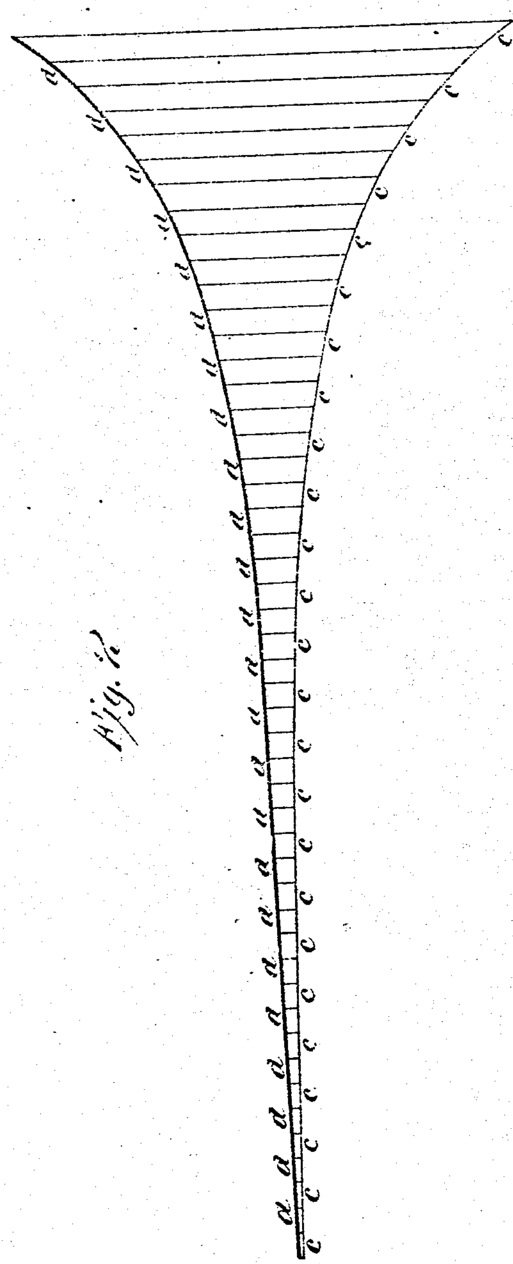

Fig. 2

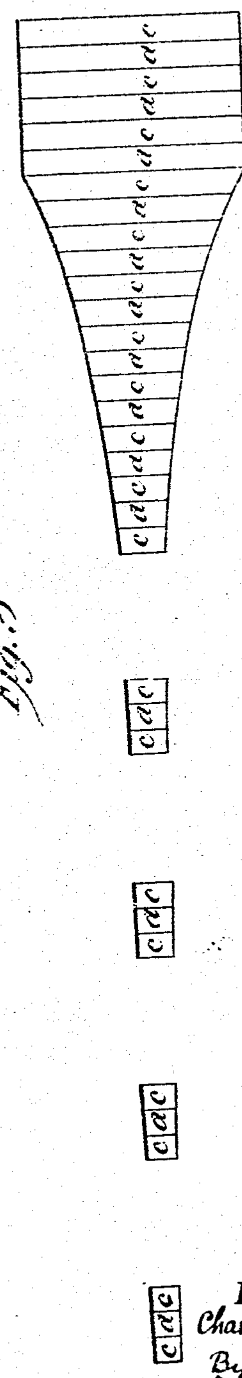

Fig. 3

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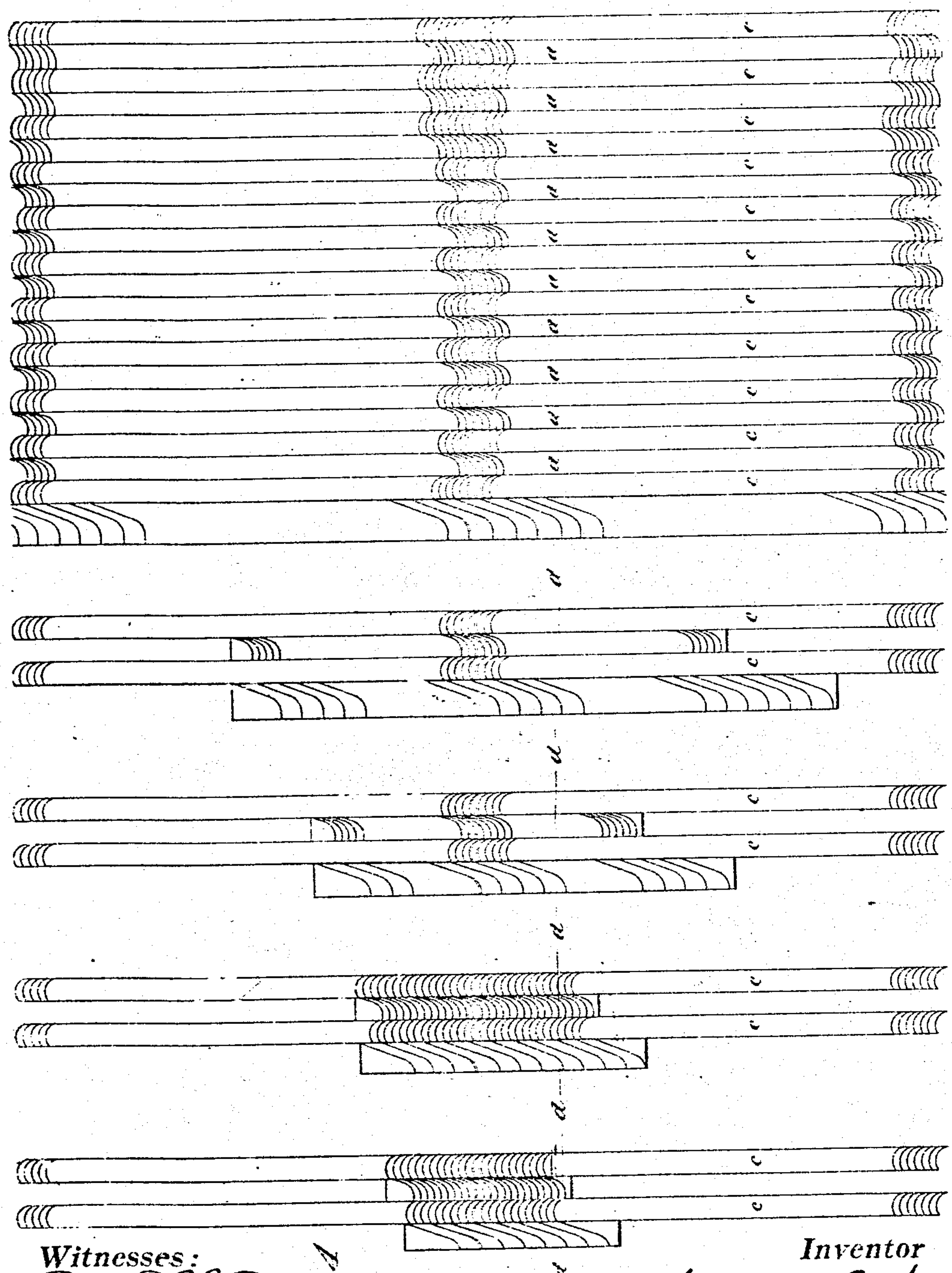

Fig. 4

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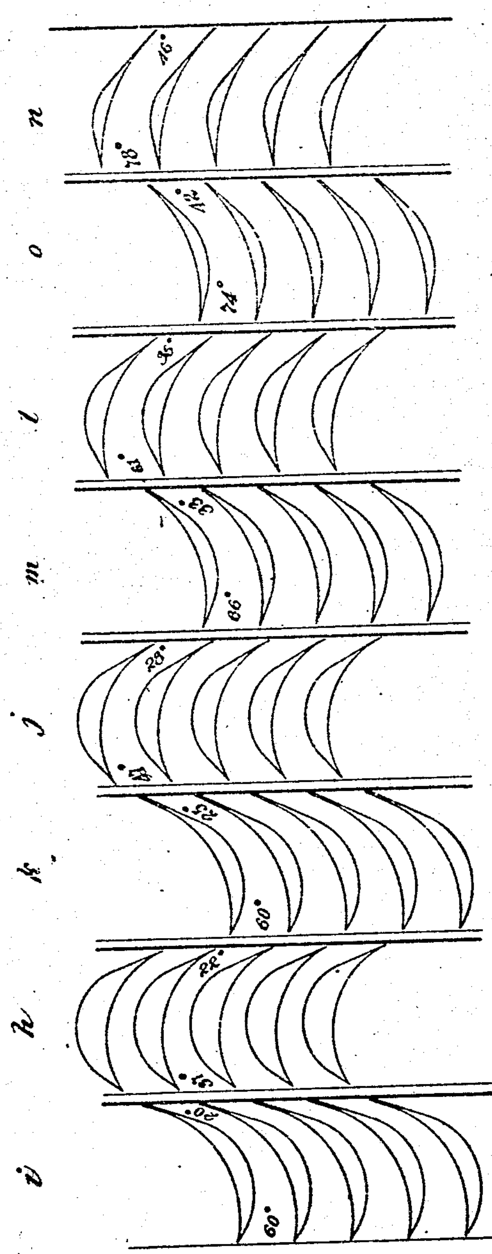
Fig. 5



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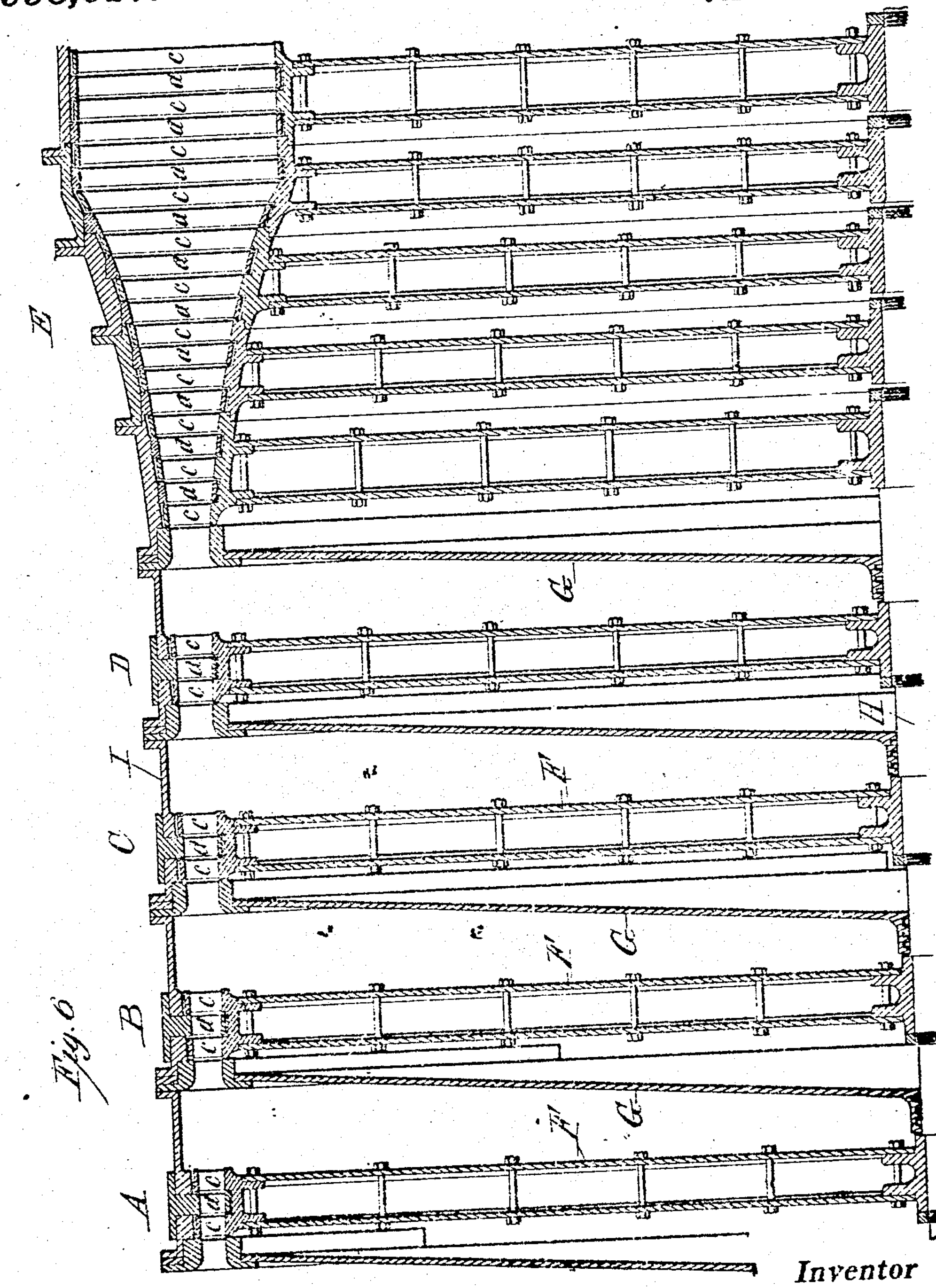
5 SHEETS—SHEET 5.



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UNITED STATES PATENT OFFICE.

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ELASTIC-FLUID TURBINE.

996,317. Specification of Letters Patent. Patented June 27, 1911.

Application filed August 24, 1905. Serial No. 275,623.

To all whom it may concern:

Be it known that I, Charles G. Curtis, a citizen of the United States, and a 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 description.

The object I have in view is the production of a turbine, which will be of high efficiency and of small bulk, and which will be particularly applicable for marine purposes, although it may be used for other purposes.

The turbine is preferably of the drum variety, although such form is not essential, and it may be of the annular or forced flow variety, although it may be modified by combining it in the higher stages with a turbine or turbines of jet form, in which only a proportion of the periphery of each wheel is acted upon at one time by the elastic fluid.

In order to secure the maximum of efficiency I provide a turbine with buckets all upon the same angle, and working with equal velocities, and developing equal energy in each wheel and in which the buckets increase in depth toward the exhaust in such a relation as to develop equal velocities and equal energies in each row of buckets, and provide a passageway for the increased bulk of the steam as it expands toward the exhaust. This increased depth is gradual and in order to secure the maximum efficiency should be made upon the line of a curve which may be determined by calculation. Such a form of turbine will produce the greatest efficiency, but it may be open to the objection of having too great a depth of buckets for the last few stages, and also in having too slight a depth of buckets for the first stages. The practical trouble with the exhaust end of the turbine may be overcome by increasing the angle of entrance and discharge of the wheel and intermediate buckets so as to compensate for the decrease in height, which will be necessary in order to have the depth of the buckets conform to the volume curve. The last few buckets toward the exhaust can be of uniform depth, the angle of entrance and discharge being in such proportion as to provide for the increased bulk of fluid. If desired the depth of the buckets of the last few stages may be gradually increased, not so much, however, as will be necessary in order to secure the proper increase of space to accommodate the increased bulk of steam, but in order to permit of a greater angle of entrance and discharge in the buckets, as would be the case if all of the last few rows of buckets were of the same height. The objection to having the first few rows of buckets of the proper theoretical depth in order to provide for the bulk of steam passing through is that if the depth of the buckets for the intermediate portion of the turbine be properly proportioned for correct theoretical conditions the depth for the first few rows will be exceedingly small, and in fact may not exceed the actual clearance between the fixed and movable surfaces. This objection may be overcome by forming the first rows of buckets to operate upon the jet type and using only a portion of the periphery of each wheel at a given time, and so constructed that the wheels may be arranged in separate casings, or if desired, in groups of a small number of wheels, each group within a casing, the several casings to be connected together by passages properly proportioned to accommodate the increased bulk of steam, and to properly direct it over an increasingly larger portion of the periphery of the wheels as it travels in the direction of the exhaust.

In the drawings Figure 1 shows the curve of volumes in a turbine having 25 rows of moving buckets and 24 intermediates, the buckets being all of the same angle and working with equal velocities, and arranged to develop equal energy in each stage. Fig. 2 shows a diagrammatical view of buckets and intermediates of the same number, showing the increased depth of the buckets toward the exhaust to accommodate the increased bulk of steam due to expansion. Fig. 3 shows in diagrammatical form a turbine having 19 rows of buckets, the wheels of the first eight rows being arranged in pairs to form jet turbines, and the wheels of the remaining eleven rows being arranged in the form of a single annular turbine, most of the buckets being of increasing depth toward the exhaust, the last three rows of buckets being of equal depth, but with increasing angles of entrance and delivery. Fig. 4 illustrates a development of the turbine similar to that illustrated in Fig. 3, with the addition of nozzles for each stage in the jet turbines and a nozzle for the annular turbine. Fig. 5 is a development of the turbine illustrated in Fig. 4, showing the increased angles of entrance and discharge of both wheels and intermediates and Fig. 6 is a longitudinal sectional view of an embodiment of the invention showing a turbine similar to that developed in Fig. 5.

In all the views like parts are designated by the same reference characters.

In Fig. 1 the line *a*—*b* represents the energy of foot pounds developed per pound of steam. *c* represents the moving vanes and *d* the fixed parts or nozzles. The line *e*—*f* represents the curve of volumes in cubic feet. For clearness of illustration the energy of foot pounds per pound is presumed to be 10,000 foot pounds for each row of buckets. Working on an expansion of from 175 pounds to 1.10 pounds absolute and based on a reëvaporation of 50 per cent. of condensed increment for each expansion the pressure within the steam passages at the different stages would be as shown in Fig. 1. The volumes would increase from about three cubic feet per pound in the first stage to about 300 for the 25th, and the curve of volume would be a steadily rising one.

In the turbine illustrated in Fig. 2 the depths of wheel buckets and nozzle buckets are regulated in accordance with the curve illustrated in Fig. 1. Instead of having the buckets secured to a drum of cylindrical form such as would be the case if they were made directly in accordance with the chart illustrated in Fig. 1, the drum is formed upon a curve calculated to be the same as that of the upper, outer or free edges of the buckets, so that a line drawn through the center of each bucket will be straight and parallel to the shaft of the drum. By this means the size of the turbine will be reduced and will be smaller than if a cylindrical drum were used. In a turbine constructed as shown in Figs. 1 and 2 the last few rows of buckets would be undesirably deep. In Fig. 3 a means is shown for avoiding this, in which the last three rows of buckets are of equal depth. In order to provide for the increased volume of steam due to expansion, the angles of entrance and discharge of these buckets are increased. As already described in connection with Figs. 1 and 2, the buckets in the first few rows of the turbine will be undesirably low, and in a full sized machine their depth may not exceed the actual clearance between the fixed and moving parts. In order to avoid this objection the first rows of buckets may be made of greater depth, and the nozzles may be so arranged as to discharge upon but a portion of the periphery of each wheel at the same time. The depth of the buckets and areas of nozzles discharging upon them will be properly calculated so as to provide the proper area through which the steam would pass.

In Figs. 3 and 4 the first eight rows of buckets are arranged in the form of a jet turbine, two rows of wheels being arranged in each set. In Fig. 4 the development of the turbine illustrated in Fig. 3 is illustrated. Here the first eight rows of wheels are arranged in sets of two, the nozzles and wheel buckets having the same angles of entrance and delivery. The nozzles and intermediate nozzles are arranged in segments of a circle, the segments increasing in depth in successive sets toward the exhaust. The fourth set discharges in the annular flow turbine, in which the entire periphery is utilized. The first row of buckets of the annular flow turbine will under these conditions have a reasonable depth so as to be efficient. This depth will increase gradually and in accordance with the curve illustrated in Fig. 1 until its depth becomes the maximum practicable, when the buckets may be of uniform depth and the angles of entrance and discharge increased.

In Fig. 5 *h* represents a row of wheel buckets and *i* a row of nozzles of an embodiment of the invention which is intended only to be an illustrative example. These have the same angles of exit and entrance as of the preceding rows of buckets in the turbine. The entrance of the wheels as shown is 37 degrees and the angle of exit is 22 degrees. The angle of entrance of the nozzles is 60 degrees and the angle of exit is 20 degrees. This is calculated for a turbine having a peripheral speed of 350 feet per second, and 1400 feet per second steam velocity, with a nozzle with an efficiency of 92.5 per cent. In the three succeeding stages it is shown that the angles of entrance and exit of the wheels and nozzles increase. *j* is the 17th wheel and *k* the nozzle preceding it. *l* is the 18th wheel and *m* the nozzle preceding it, *n* the 19th wheel and *o* the nozzle preceding it. As shown the angles of entrance and discharge of these passages are as follows: In the 17th wheel the angle of entrance is 47 degrees and the angle of discharge 28 degrees; for the nozzle preceding this, the angle of entrance is 60 degrees and the angle of discharge is 25 degrees. In the 18th wheel the angle of entrance is 61 degrees and the angle of discharge is 36 degrees; for the nozzle preceding it the angle of entrance is 66 degrees and the angle of discharge is 33 degrees. In the 19th wheel the angle of entrance is 78 degrees and the angle of discharge 46 degrees; for the nozzle preceding it the angle of entrance is 74 degrees and the angle of discharge 42 degrees.

In the example illustrated all the angles of discharge of the nozzles preceding wheel *n* are 20 degrees and their entrance angles are 60 degrees, and the entrance angle of the buckets of each wheel preceding nozzle i is 37 degrees and its discharge is 22 degrees.

A structural form of turbine is shown in Fig. 6. This turbine is a practical form of that developed in Fig. 5. Four jet stages A, B, C, D, and one annular stage E at the low pressure end of the turbine are shown, all having movable buckets c and fixed intermediate nozzles d, there being two sets of the former and one set of the latter in each of the high pressure stages. The annular stage has eleven sets of moving buckets c and ten sets of fixed intermediate nozzles d, the depths of the first eight sets of moving buckets being gradually increased upon the curve shown in Figs. 1 and 2, and the remaining three sets of moving buckets being all of the same depth, but becoming gradually flatter, as described in connection with Fig. 5. Any form of wheels or casing can be used, a convenient form being illustrated and being quite similar to that disclosed in my co-pending application for patent Serial No. 114,357, filed July 5, 1902. Wheels F and diaphragms G similar to those disclosed in that application are illustrated in Fig. 6. A shaft H supports the wheels and a casing I incloses the wheels and diaphragms and supports the intermediate nozzles.

Having now described my invention what I claim as new and desire to secure by Letters Patent is:

1. In an elastic fluid turbine, the combination of wheel buckets and fixed nozzles, a portion of the wheel buckets and nozzles being all on the same angle and increasing in depth toward the exhaust, in such a relation as to develop equal velocities and energies in each row of buckets, and a portion of the wheel buckets and nozzles not increasing in depth in such relation, but having the angles of entrance and exit increased, so as to provide a passageway of the proper size for the increased bulk of the elastic fluid as it expands toward the exhaust.

2. An elastic fluid turbine, having wheel buckets and fixed nozzles, a portion of the wheel buckets and nozzles being all on the same angle and increasing in depth toward the exhaust, in such a relation as to develop equal velocities and energies in each row of buckets, and a portion of the wheel buckets and nozzles not increasing in depth in such relation, but having the angles of entrance and exit increased so as to provide a passageway of the proper size for the increased bulk of the elastic fluid as it expands toward the exhaust, in combination with high pressure jet stages.

3. In an elastic fluid turbine, the combination of wheel buckets and fixed nozzles, a portion of the wheel buckets and nozzles being all on the same angle and providing for progressive increase of dimensions of the expanding fluid solely by increase of depth toward the exhaust, and a portion of the wheel buckets and nozzles not increasing in depth in such relation but providing, wholly or in part, for the increased bulk of fluid by having the angles of entrance and exit increased so as to provide a passageway of proper size.

4. In an elastic fluid turbine, the combination of wheel buckets and fixed nozzles, a portion of the wheel buckets and nozzles being all on the same angle and providing for progressive increase of dimensions of the expanding fluid solely by increase of depth toward the exhaust, and a portion of the wheel buckets and nozzles not increasing in depth in such relation but providing, wholly or in part, for the increased bulk of fluid by having the angles of entrance and exit increased so as to provide a passageway of proper size, in combination with high pressure jet stages.

This specification signed and witnessed this 18th day of August, 1905.

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Witnesses:
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