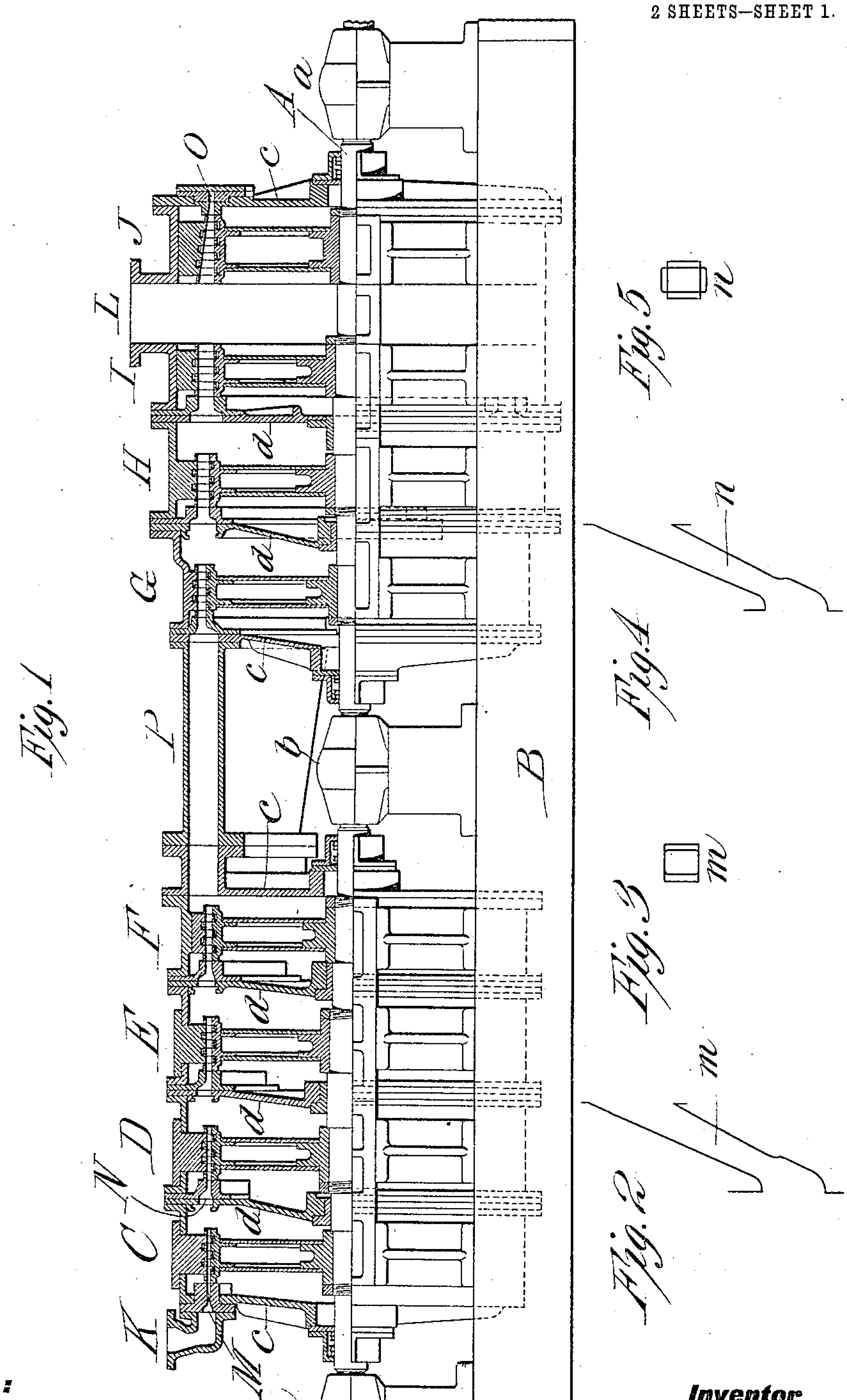
No. 831,540. PATENTED SEPT. 25, 1906.

C. G. CURTIS.

ELASTIC FLUID TURBINE.

APPLICATION FILED DEC. 11, 1903.

2 SHEETS—SHEET 1.



Witnesses:

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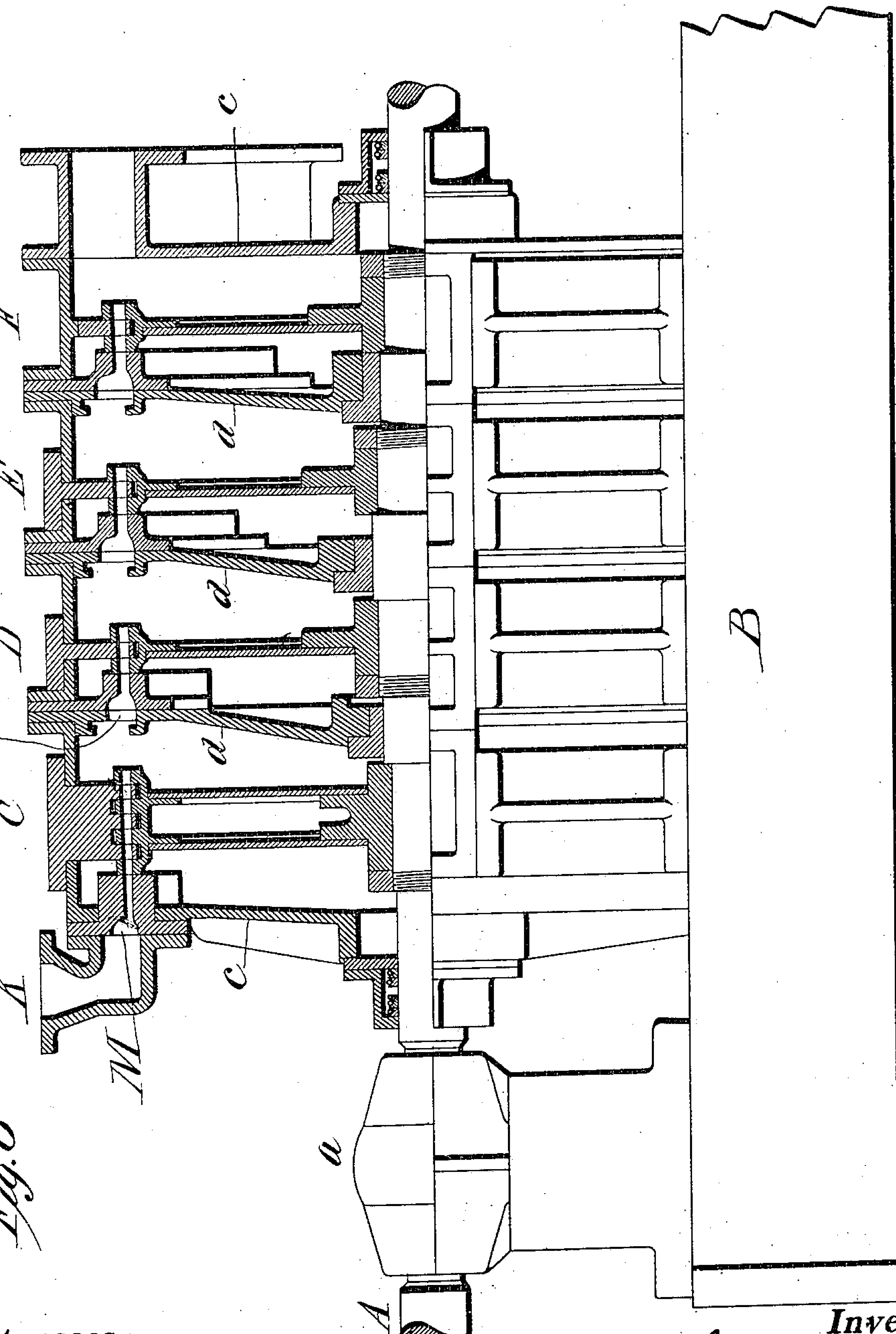

Fig. 6

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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. 831,540. Specification of Letters Patent. Patented Sept. 25, 1906.

Application filed December 11, 1903. Serial No. 184,746.

To all whom it may concern:

Be it known that I, CHARLES G. CURTIS, a citizen of the United States, residing in the borough of Manhattan, city of New York, 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 to construct an elastic-fluid turbine in which the movable vanes have the same or approximately the same speed, specially adapted for the development of large powers at low speeds of revolution and for the utilization of high boiler-pressures, which will have the advantages arising from the employment of a large number of stages of expansion and will still have a practically low pressure in the shell of the first stage. This I accomplish by developing and utilizing in the first stage of the turbine a larger amount of energy than is developed and utilized in any one of the subsequent stages, so as to thereby reduce the pressure in the first shell to the desired low pressure, the remaining energy of the elastic fluid being extracted by two or more subsequent stages, preferably in equal amounts. To secure this result, the nozzle of the first stage is made of the expansion type and has such a ratio of expansion as will produce the desired low pressure in the first shell, while the nozzles of the subsequent stages will have a less ratio of expansion or be of the non-expansion type, the latter preferred. The pressure produced in the first shell may in this way be made any pressure desired. It is desirable that this should not be over sixty or seventy pounds gage-pressure, which may be readily secured with an initial pressure as high as two hundred and fifty pounds gage, whereas if equal amounts of energy were developed and utilized in the several stages of a turbine having, for illustration, eight stages the pressure in the first shell would be undesirably high. Such a high pressure is undesirable on account of the bursting and distorting stress which the pressure will produce on the large shell area, also because of the friction loss due to rotation of the wheel in an atmosphere of high density, and, further, because of the increased leakage through the packing around the shaft between the first shell and the next succeeding shell of the turbine. These difficulties are overcome by my present construction.

In the accompanying drawings, Figure 1 is a side elevation and partial section of a turbine embodying the present invention, the section following the line of the fluid-passageway. Fig. 2 is an outline view of the front and rear walls of one section of the first-stage nozzle, showing approximately its proportions. Fig. 3 is a view showing in outline the relative shape and proportions of the throat and end of the nozzle-section of Fig. 2. Fig. 4 is a view similar to Fig. 2 of one section of the nozzles of the subsequent stages. Fig. 5 is a view similar to Fig. 3 of the nozzle-section of Fig. 4, and Fig. 6 is a sectional view of the first four stages of a modified form of turbine embodying the invention.

The turbine illustrated in the drawings is one having seven direct stages and one reverse stage. The wheels of all the stages are mounted upon a shaft A, having outside bearings *a* and preferably an intermediate bearing *b*, supported from a base B, from which the shells are also supported.

The seven direct stages are indicated by the letters C D E F G H I, while the reverse stage is represented by the letter J. The shells have outside heads *c*, provided with stuffing-boxes, through which the shaft passes, the different stages within each shell being separated from each other by diaphragms *d*, provided with sleeves, which hug the shaft closely.

K is the steam-inlet, and L is the exhaust. The last stage I of the turbine and the reverse stage J are in the same shell and deliver the steam in opposite directions into the exhaust L, as described in my application, Serial No. 159,748, filed June 2, 1903. The nozzle M of the first stage is a nozzle of the expansion type, while the nozzle N of the second and each subsequent stage has a lesser degree of expansion and is preferably of the non-expansion type. The nozzle O of the reverse stage is of the expansion type and is designed, with the expansion secured in the movable and stationary vanes coöperating with it, to utilize the entire boiler-pressure at one stage of expansion. A conduit P connects the shell of the stage F with the nozzle of the stage G where the turbine is separated to admit the center-bearing *b*. Each direct stage of the turbine is illustrated as provided with four sets of movable vanes and three sets of intermediate stationary vanes, although if enough stages were employed and a suitable speed of the vanes permitted two sets, or even a single set, of movable vanes could be used in each stage or the first stage could have a plurality of sets of movable vanes and the subsequent stages a smaller number or even one set each. Such form of turbine is illustrated in Fig. 6, in which the first stage is provided with four sets of movable vanes and the second and succeeding stages with a single set each. The wheels carrying the movable vanes are all made of the same or approximately the same diameter, and hence the vanes have the same or approximately the same speed.

In Fig. 2 is illustrated on a larger scale one of the sections *m* of the first stage of the nozzle M in outline. For a turbine working, for illustration, with an initial or boiler pressure of two hundred and sixty-five pounds absolute an expansion of twelve per cent. between the throat and the nozzle end will give a pressure of about ninety-six pounds absolute at the nozzle end and with the proper set of coöperating vanes a pressure in the shell of the first stage of seventy-nine pounds absolute. This pressure will be a practical one and will avoid the difficulties already referred to. This is the expansion intended to be represented in Figs. 2 and 3.

In Fig. 3 the outer rectangle represents the size of the opening at the end of each nozzle-section, while the inner rectangle represents the size of the opening at the throat, the expansion being secured by the divergence of the front and rear walls of the nozzle-sections.

In Fig. 4 is shown in outline a section *n* of the nozzle N of the second or of any subsequent stage. The proper thinning of the side walls at the outer ends of the nozzle-sections is secured by diverging the side walls; but this is compensated for so as to give the same cross-sectional area at the throat as at the nozzle end by making the throat oblong in shape and longer in its greater dimensions than the length of either side of the rectangle which is formed by the nozzle end. This is illustrated in Fig. 5, in which the square figure represents the shape of the end of the nozzle-section and the oblong shape of the throat. With an expansion-nozzle for the second stage, such as that illustrated in Figs. 4 and 5, and using the illustration already referred to, the nozzle would receive the steam at seventy-nine pounds pressure absolute and would deliver it at about forty-five pounds absolute, producing a pressure in the shell of the second stage of about forty-two pounds absolute. The energy thus developed and utilized in the second stage will be about one-half that developed and utilized in the first stage, and similarly the energy developed and utilized in each subsequent stage will be about one-half of that developed and utilized in the first stage. The turbine with the seven direct stages is thus equivalent to a turbine of eight direct stages in which the energy is divided equally between all the stages, except that in the present instance the first stage instead of utilizing one-eighth of the total energy utilizes one-quarter of that energy, while the subsequent stages each utilize one-eighth of the total energy.

To illustrate the actual working conditions of a turbine of this character, I give in the following table the pertinent data for such a machine intended to develop about twelve-hundred-horse power:

Stage.	Inlet pressure lbs. per sq.in. abs.	Shell pressure lbs. per sq.in. abs.	Throat pressure lbs. per sq. in. abs.	Sq. ins. of throat required.	Nozzle end pressure abs.	Sq. ins. of nozzle end required.
1	265	79	152.9	1.339	95.7	1.5048
2	79	41.7	45.58	4.24	45.58	4.24
3	41.7	21.2	24.00	7.8	24.0	7.8
4	21.2	10.4	12.23	14.84	12.23	14.84
5	10.4	4.9	6.00	29.25	6.00	29.25
6	4.9	2.2	2.83	60.66	2.83	60.66
7	2.2	1.0	1.27	135.0	1.27	135.0

It will be understood that if a turbine operating with a boiler-pressure of two hundred and sixty-five pounds absolute and an exhaust-pressure of one pound absolute, as with the turbine illustrated in the above table, were provided with eight stages, each developing and utilizing one-eighth of the energy, the pressure in the first shell would be approximately one hundred and fifty pounds absolute, which would be an undesirably high pressure and would involve the difficulties already referred to.

What I claim is—

1. In an elastic-fluid turbine, the combination of several stages of expansion with movable vanes having approximately the same speed, such stages being constructed so as to develop and utilize a larger amount of energy in the first stage than in any one of the two or more subsequent stages, substantially as set forth.

2. In an elastic-fluid turbine, the combination of several stages of expansion with movable vanes having approximately the same speed, such stages being constructed so as to develop and utilize a larger amount of energy in the first stage than in the one immediately following, substantially as set forth.

3. In an elastic-fluid turbine, separate compartments, means to admit motor fluid successively thereto, and rotatable buckets in each compartment, said buckets being arranged to coöperate with said means and abstract a greater percentage of velocity from the motor fluid in an initial compartment than in other succeeding compartments.

4. In an elastic-fluid turbine, the combination of several wheel-chambers connected in succession, movable vanes in each wheel-chamber having approximately the same speed, and nozzles for the several wheel-chambers, the nozzles for the first chamber having a greater ratio of expansion than the nozzle for any of the two or more subsequent chambers, substantially as and for the purpose set forth.

5. In an elastic-fluid turbine, the combination of several wheel-chambers connected in succession, movable vanes in each wheel-chamber having approximately the same speed, and nozzles for the several wheel-chambers, the nozzle of the first chamber being of the expansion type and those of the two or more subsequent chambers being of the non-expansion type, substantially as and for the purpose set forth.

6. In an elastic-fluid turbine, the combination of several wheel-chambers connected in succession, two or more sets of movable vanes having approximately the same speed, and one or more sets of stationary intermediate vanes in each wheel-chamber, and nozzles for the several wheel-chambers, the nozzle for the first chamber having a greater ratio of expansion than the nozzle for any of the two or more subsequent chambers, substantially as and for the purpose set forth.

7. In an elastic-fluid turbine, the combination of several wheel-chambers connected in succession, two or more sets of movable vanes having approximately the same speed, and one or more sets of stationary intermediate vanes in each wheel-chamber, and nozzles for the several wheel-chambers, the nozzle of the first chamber being of the expansion type and those of the two or more subsequent chambers being of the non-expansion type, substantially as and for the purpose set forth.

8. In an elastic-fluid turbine, the combination of several stages of expansion, movable vanes in each stage, an expansion-nozzle for the first stage, a non-expansion nozzle for each of the subsequent stages, two shells each divided by diaphragms into two or more chambers containing the movable vanes, outside bearings for the shaft of the turbine, and an intermediate shaft-bearing between the two shells, substantially as set forth.

9. In an elastic-fluid turbine, the combination of a casing, rows of wheel-buckets, a shaft for the wheels, and means for dividing the casing into compartments so that the high-pressure stage or stages will contain more rows of wheel-buckets than the low-pressure stage or stages.

10. In a multistage impact-turbine, stage-compartments with supply and discharge passages, and buckets coöperating with said passages, the buckets arranged in a greater number of rows in the first than in succeeding stages.

This specification signed and witnessed this 4th day of December, 1903.

CHARLES G. CURTIS.

Witnesses:
JNO. ROBT. TAYLOR,
JOHN L. LOTSCH.