No. 795,256. PATENTED JULY 18, 1905.

A. R. DODGE.

METHOD OF OPERATING MULTISTAGE TURBINES.

APPLICATION FILED JAN. 23, 1904.

Fig. 1.

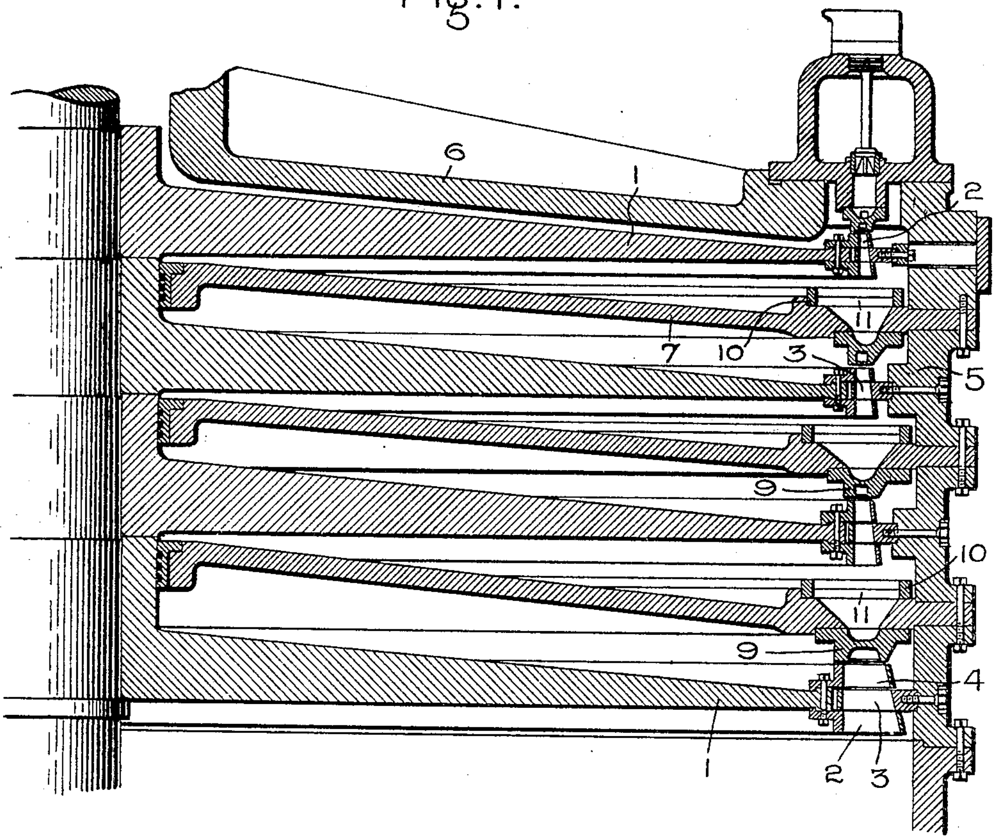
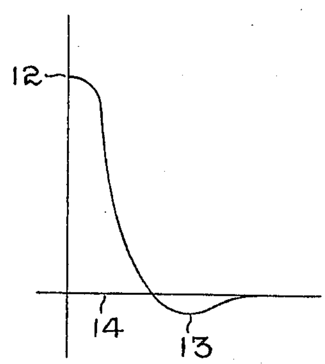


Fig. 2.



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No. 795,256. Patented July 18, 1905.

UNITED STATES PATENT OFFICE.

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METHOD OF OPERATING MULTISTAGE-TURBINES.

SPECIFICATION forming part of Letters Patent No. 795,256, dated July 18, 1905.

Original application filed November 7, 1902, Serial No. 130,371. Divided and this application filed January 23, 1904. Serial No. 190,292.

To all whom it may concern:

Be it known that I, AUSTIN R. DODGE, a citizen of the United States, residing at Schenectady, in the county of Schenectady and State of New York, have invented certain new and useful Improvements in Methods of Operating Multistage Elastic-Fluid Turbines, of which the following is a specification.

The present invention is a division of my prior pending application, Serial No. 130,371, filed November 7, 1902, on elastic-fluid turbines.

Each stage of a multistage elastic-fluid turbine of the jet type is provided with one or more stationary discharging-nozzles, depending principally upon the power to be developed and one or more rows of wheel-buckets inclosed by a shell or casing. Where two or more rows of wheel-buckets are used in a single shell, intermediate buckets are provided which receive the motive fluid from one set of wheel-buckets, reverse its direction, and deliver it at the proper angle to the next. Obviously a clearance has to be provided between the nozzle or nozzles and wheel-buckets and also between the wheel and the intermediate buckets, when the latter are used, for mechanical reasons. This clearance has a direct bearing on the efficiency of the turbine, because it determines the amount of fluid which is non-effective. By a series of actual and exhaustive tests and experiments I have found that a large per cent. of the steam or other elastic fluid which passes through the working passages is lost in leakage at the clearances. It is sometimes as high as twenty-six per cent. in a commercially-operative machine having two rows of wheel-buckets and one row of intermediate buckets. Where the machine is divided into stages, the steam or other motive fluid lost in one stage is renozzled and delivered to the next stage of lower pressure. In this manner the steam due to leakage is not lost, except in the particular stage wherein the leakage takes place, and where two or more wheels are provided in each stage only a portion of the leakage is a total loss, because it passes through some of the bucket-spaces. Other things being equal, the fewer the stages and the greater the number of rows of buckets per stage the greater will be the total loss.

Certain types of jet-turbine with which I am familiar depend for their operation upon the conversion in the nozzle of substantially all of the pressure of the fluid into vis viva or velocity and the abstraction of the energy from the fluid-stream by the buckets in successive operations. In these cases the terminal pressure of the nozzle is several pounds above the shell-pressure, and as the motive fluid flows through the spaces between the wheel and intermediate buckets (which spaces will hereinafter be referred to as the "working passage") its pressure is gradually decreased until it coincides with that of the shell. The object in having the terminal pressure of the nozzle above that of the shell is to overcome frictional retardation and to assist in forcing the fluid through the working passage. Manifestly when the pressure of a fluid-stream flowing through a passage having one or more openings or clearances extending perpendicular to the direction of flow is greater than that of the surrounding medium a certain amount of the fluid will escape at said opening or openings or clearances and be lost in so far as the particular wheel is concerned.

I have found that with given clearances the amount of leakage in a jet-turbine is dependent upon the difference in pressure between the discharge or terminal end of the nozzle and that of the wheel shell or casing, and the greater this difference in pressure the greater will be the leakage. I have discovered that by maintaining the shell-pressure approximately the same as or even a little above the nozzle-terminal pressure the leakage through the clearances can be eliminated or reduced to such a small amount that it can be disregarded, thereby increasing the efficiency of the turbine.

In carrying out my invention I employ as many stages or shells as are necessary, and each stage or shell has one or more rows of wheel-buckets.

While my invention is useful in connection with multistage-turbines having a single wheel per stage, it has its greatest utility where two or more rows of wheel-buckets are provided for each stage. Each stage is provided with an expanding-nozzle of suitable character which is capable of expanding the motive fluid down to a predetermined pressure, and I have found that the high velocity of the fluid can be relied upon to force it through the working passage. An expanding-nozzle will within certain limits function according to the divergence of its walls—that is to say, it will receive steam or other elastic fluid at one pressure and discharge it at a predetermined lower pressure into a shell or receptacle regardless of whether the pressure of the shell or receptacle is the same or different. I make use of this peculiarity of the nozzles and so form them that the pressures at their discharge or terminal ends are substantially the same as or even slightly below those of the shells or casings for the bucket-wheels. Between one shell and the next are one or more fluid-carrying conduits or passages, which may or may not be controllable, as conditions demand, and which are of such cross-sectional area that it or they retain or hold back enough fluid in the preceding shell to create a back pressure that is equal to or slightly greater than the terminal-end pressure of the preceding nozzle. The amount that the shell-pressure exceeds the terminal-end pressure of the nozzle varies somewhat in different machines, depending upon the number of stages and the number of rows of buckets in each stage. The first-stage nozzle or nozzles can be arranged to expand the steam from boiler to any desired pressure. The pressure within the first-stage shell may be maintained a pound or two above the terminal pressure of the nozzle by placing some sort of a restriction between the first stage and the next. In a multistage-machine each stage is correspondingly treated. The said restriction may take the form of a valve or valves or nozzles for the following stage, or both, or it may be a relatively restricted exhaust-opening which maintains a certain back pressure. Assuming that the nozzle delivers steam to a working passage or passages in a given stage at a predetermined pressure and that the shell-pressure is maintained slightly above it—for example, one pound—the pressure of steam within said working passage in flowing therethrough will gradually rise to that of the shell. Under this condition the pressure in the shell opposes the tendency of the steam to escape at the clearances. If, on the other hand, the shell-pressure exceeds that of the nozzle-end pressure by any considerable amount, the fluid in the shell tends to flow inward through the clearances and mingle with that in the working passage.

In the accompanying drawings, which illustrate a turbine for practicing my invention, Figure 1 is a partial axial section of a turbine, taken in a plane passing through a nozzle; and Fig. 2 is a diagram showing the pressures in the nozzle and wheel-casing.

1 represents a wheel having one or more rows of peripheral buckets; but the particular arrangement of the buckets on the wheel can be varied as desired. Between the buckets are formed spaces or working passages 2 of suitable cross-sectional area for conveying fluid. When two or more rows of wheel-buckets are provided, intermediate buckets 3 are arranged between them which serve to properly reverse and direct the fluid from one row to the next. These intermediate buckets are supported by the casing and have suitable spaces or passages between them and, taken in connection with the wheel-buckets, form the working passage. Between the rows of buckets and between the nozzle and buckets are clearances 4, which are made as small as possible consistent with good operation. Surrounding the wheels is a casing or shell 5, preferably containing as many parts or sections as there are wheels. Situated above the first wheel or on the high-pressure side thereof and supported by the casing is a cover 6, and a diaphragm 7 is located below the wheel or on the low-pressure side. The diaphragm 7 is provided with a passage or opening which has such a cross-sectional area as will permit the motive fluid to flow freely from one wheel-compartment to the next and at the same time create a back pressure which is substantially the same as or slightly above the terminal-end pressure of the preceding nozzle. Bolted to each diaphragm or otherwise secured in place is an expanding sectionalized nozzle 9, which in the lower pressure stages registers with the working passage of the preceding stage. This nozzle is provided with diverging side walls which convert the pressure of the motive fluid into velocity or vis viva and discharge it with a pressure substantially the same as the shell-pressure against the wheel-buckets at the proper angle. By increasing the divergence of the side walls to such an extent that the terminal-end pressure of the nozzle is below that of the shell the speed of the stream is slightly increased, which means theoretically that the bucket speed should be slightly higher relative to that of the stream to obtain the maximum efficiency; but this slight increase in the speed of the stream over the normal, assuming that the bucket speed be kept the same, is more than compensated for by the decrease in the leakage. A diaphragm may be situ-

ated adjacent to the exhaust side of the last wheel, through which the exhaust escapes to the condenser or atmosphere, as the case may be, if it be desired to regulate the pressure in the last stage. The cross-sectional area of the passage or passages in each of the diaphragms is such that it can handle the volume of steam delivered by the nozzle 9; but at the same time it creates a slight back pressure in the shell that is the same as or slightly greater than the terminal-end pressure of the nozzle. The energy of the fluid-stream is fractionally abstracted by the rows of buckets, and while the velocity of the fluid is decreased by each succeeding bucket there is enough residual velocity left in the fluid to cause it to discharge freely from the wheel. In case the nozzles do not maintain the proper shell-pressure due to changes in load or otherwise I may provide valves 11, which vary the opening or openings between succeeding stages. These valves may be operated by hand where the variations in pressure are infrequent, or they may be moved automatically under the control of the governor where the pressures are continually changing between wide limits. The admission of motive fluid to the first stage or shell can be controlled by separately-actuated valves, which preferably have an open and a closed position, but no intermediate, so as to prevent throttling. Each nozzle is divided into a plurality of closely-associated sections which discharge the motive fluid as a solid stream against the bucket-wheel. This arrangement of nozzle sections or passages is highly desirable, because a greater economy can be obtained than where they are spaced a considerable distance apart; but in so far as the broad idea of the invention is concerned this is immaterial.

In Fig. 2 is illustrated diagrammatically the fall in pressure from the source of supply to the exhaust of a given stage. For example, assume that 12 represents the pressure at the inlet end of a nozzle or nozzle-section. The divergence of the side walls causes the pressure to fall rapidly down to point 13, which is below the pressure in the stage as indicated by the horizontal line 14. As the fluid passes through the working passage its pressure gradually rises until it corresponds to that of the shell, and the point in the working passage at which the two coincide would vary in different machines. Preferably it would occur midway between the ends.

It is evident from the foregoing that the efficiency of the turbine is increased by decreasing the amount of steam lost due to leakage.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. The method of operating an elastic-fluid turbine, which consists in imparting velocity to the fluid-stream by means of a nozzle or nozzles, abstracting velocity from the stream by means of buckets located within a shell or casing, and maintaining a shell-pressure which is substantially the same as that of the terminal-end pressure of the nozzle.

2. The method of operating a multistage elastic-fluid turbine, which consists in passing the motive fluid through one or more expanding-nozzles to impart velocity thereto, abstracting the velocity of the fluid-stream by means of relatively movable buckets located within a shell, and maintaining a pressure within the shell which is substantially the same as the terminal-end pressure of the nozzle or nozzles.

3. The method of operating an elastic-fluid turbine, which consists in dividing it into stages, passing the fluid from one stage to the next through a nozzle or nozzles which impart velocity thereto, abstracting the velocity in each stage due to the preceding nozzle or nozzles, and maintaining in each stage a pressure which is substantially equal to the terminal-end pressure of the nozzle or nozzles discharging into it.

4. The method of operating an elastic-fluid turbine, which consists in dividing it into stages, passing the fluid from one stage to the next through a nozzle or nozzles which impart velocity thereto, transforming the velocity of the fluid into useful work by means of two or more rows of buckets in each stage, and maintaining pressures within the stages which are the same or substantially the same as the terminal-end pressures of the nozzle or nozzles.

5. The method of operating a turbine, which consists in dividing it into stages, discharging motive fluid into each stage or shell under considerable velocity and at a pressure substantially the same as that of the shell, and permitting the same to rise until it is the same as that of the shell, and converting the energy of the motive fluid into useful work by means of relatively movable buckets.

In witness whereof I have hereunto set my hand this 20th day of January, 1904.

AUSTIN R. DODGE.

Witnesses:
BENJAMIN B. HULL,
HELEN ORFORD.