(No Model.)

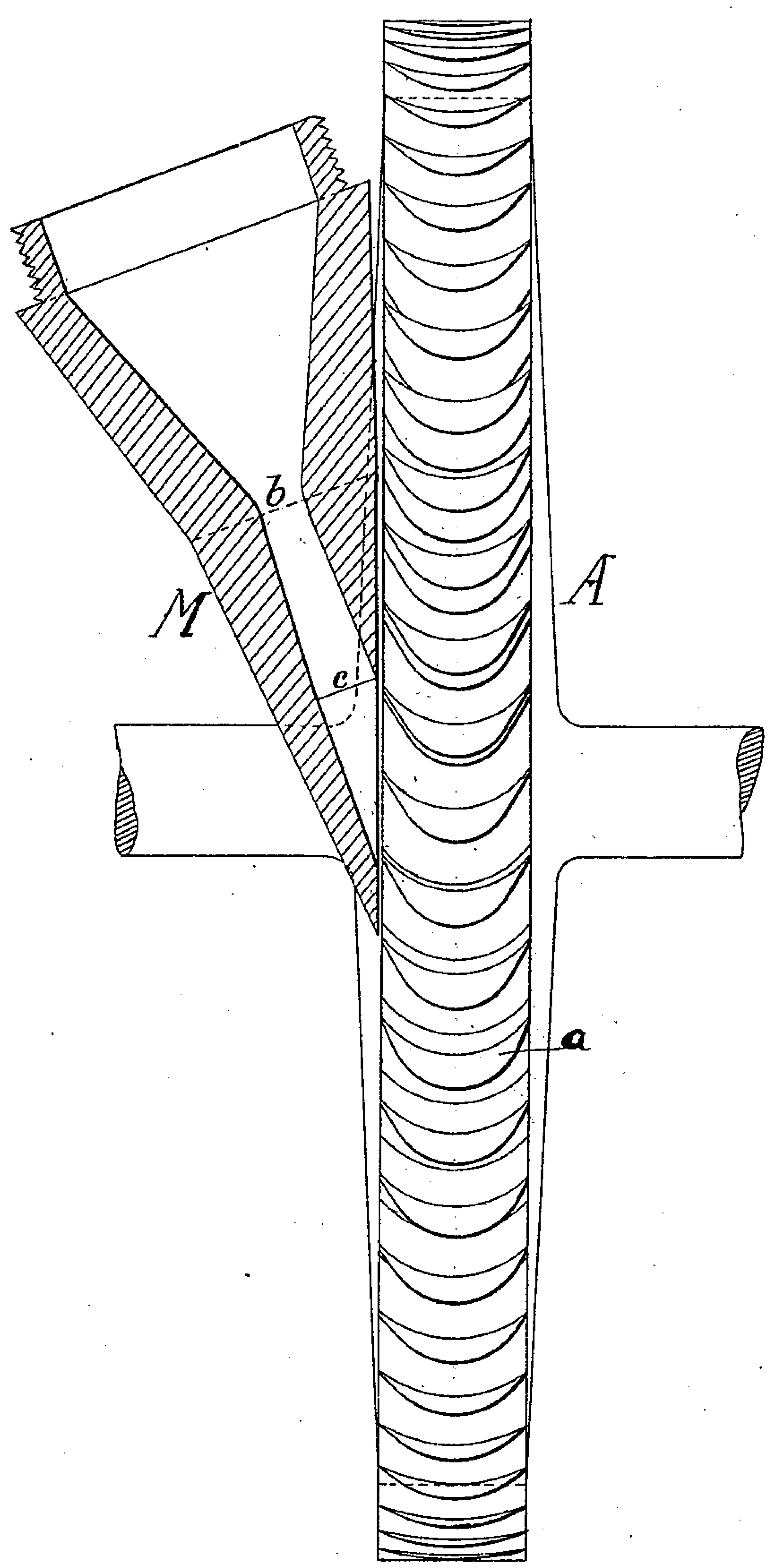
2 Sheets—Sheet 1.

C. G. P. DE LAVAL.

STEAM TURBINE.

No. 522,066. Patented June 26, 1894.

Fig. 1.



Witnesses:

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(No Model.)

2 Sheets—Sheet 2.

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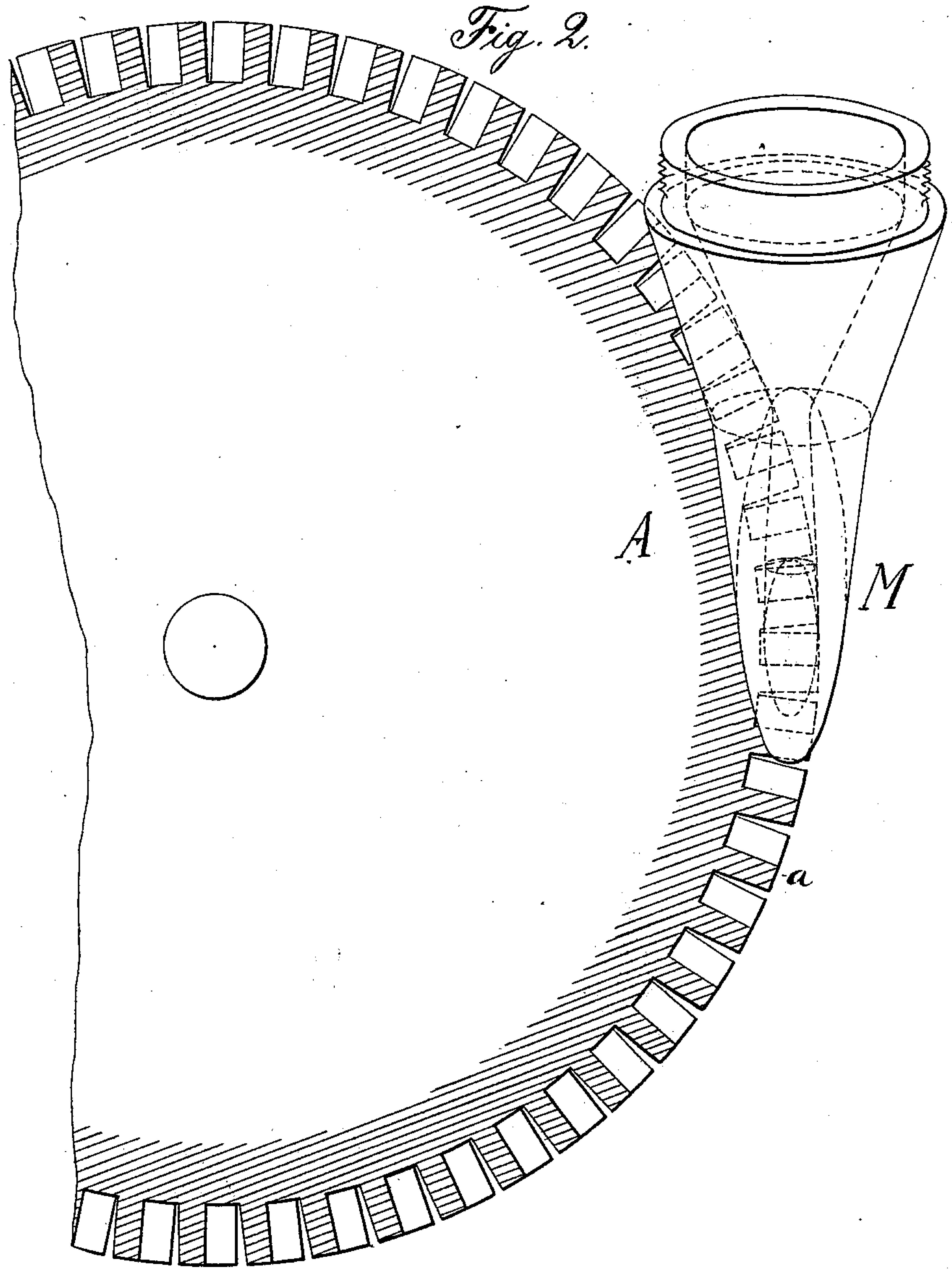
STEAM TURBINE.

No. 522,066. Patented June 26, 1894.

Fig. 2.



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UNITED STATES PATENT OFFICE.

CARL GUSTAF PATRIK DE LAVAL, OF STOCKHOLM, SWEDEN.

STEAM-TURBINE.

SPECIFICATION forming part of Letters Patent No. 522,066, dated June 26, 1894.

Application filed May 1, 1889. Serial No. 309,209. (No model.) Patented in Belgium September 29, 1888, No. 83,196, and in England April 29, 1889, No. 7,143.

To all whom it may concern:

Be it known that I, CARL GUSTAF PATRIK DE LAVAL, a subject of the King of Sweden and Norway, and a resident of Stockholm, in the Kingdom of Sweden, have invented certain new and useful Improvements in Steam-Turbines, (which invention has been patented to me in foreign countries, to wit: Belgium, September 29, 1888, No. 83,196, and for which I have also obtained British Letters Patent No. 7,143, dated April 29, 1889,) of which the following is a specification.

My invention relates to an improvement in that class of engines in which a turbine or bucket wheel is rotated by a jet of steam or other elastic fluid.

The object of my invention is to render such turbines more economical in use than heretofore and to that end my engine is so contrived that the greatest possible amount of the energy contained in the steam is converted into velocity before the steam reaches the turbine wheel and the *vis viva* of the steam is utilized in rotating the wheel instead of its pressure.

Heretofore in steam turbines, as well as in other steam engines, the energy contained in the steam has been utilized in the form of pressure and the steam has performed its mechanical work during its expansion. According to my invention the steam is expanded in a nozzle or conduit of peculiar construction before it acts upon the turbine or bucket wheel. During this expansion of the steam in the nozzle or conduit the pressure of the steam is converted into velocity and the energy contained in the steam is made use of after it leaves the nozzle or conduit in the form of its *vis viva*. The steam reaches the wheel in this expanded condition and rotates the wheel by its *vis viva* while heretofore the steam was expanded within or against the turbine wheel or other movable part, which was so actuated by the pressure of the expanding steam.

In the accompanying drawings:—Figure 1 is a front view of my improved steam engine, partly in section. Fig. 2 is a fragmentary side view of the same, also partly in section.

Like letters of reference refer to like parts in both figures.

A represents a turbine wheel provided at its face with buckets *a*.

M represents the steam nozzle which is fitted with its discharge end against one side of the wheel, so as to direct the current of steam against the buckets thereof. This nozzle has its receiving end connected with a steam pipe or other steam supply which furnishes steam to the nozzle under a suitable pressure. The nozzle may be contracted from its receiving end to its narrowest portion *b*, which has the proper area to deliver the volume of steam which is required for performing the work for which the engine is designed. The nozzle is diverging or gradually enlarged in cross section from this narrowest point to its discharge opening *c* by which the steam is delivered against the buckets of the wheel. The axis of the nozzle is arranged at an acute angle to the plane of the wheel and the end of the nozzle is arranged parallel with the side of the wheel, so as to fit as closely as possible against the same. This renders the diverging portion of the nozzle shortest at the point where the revolving buckets first reach the nozzle, and longest at the point where the buckets leave the nozzle.

The buckets of the wheel are concavo-convex and arranged with the convex side forwardly, so that the side portion of each bucket which is adjacent to the steam nozzle, stands about in line with the axis of the nozzle in passing by the latter, while the opposite side portion of the bucket stands about at right angles to the axis of the nozzle. This permits the steam current to enter between the buckets on the receiving side of the wheel with very little resistance.

Scientific researches made by other investigators, as well as my own, have shown that when steam issues from a cylindrical or converging nozzle, the maximum of expansion which it is possible to attain by either of these forms of nozzles corresponds to 57.7 per cent. of the initial pressure. A certain amount of velocity and of *vis viva* is imparted to the steam by such nozzles but a large amount of the pressure, more than one half, is not converted into velocity and the efficiency of such nozzles is therefore very low. I have ascertained that it is possible to expand the steam to or below the atmospheric pressure by a diverging or flaring nozzle and to convert all the energy contained in the steam into *vis viva*.

In my improved nozzle, as shown in the drawings, the converging portion of the nozzle serves principally to reduce the cross section of the outlet to that area which will emit the necessary quantity of steam. In engines of ordinary size, this area of the narrowest portion of the nozzle is so small that the steam supply pipe has to be much larger in diameter in order to render its connection with other fittings convenient and to avoid excessive friction in the pipe, but while the converging portion of the nozzle is therefore desirable, it is not indispensable.

The steam current, when leaving the narrowest part of the discharge nozzle, has reached the maximum of expansion which is possible in a straight or contracted nozzle, and the pressure under this degree of expansion is equal to 57.7 per cent. of the initial pressure. In the diverging nozzle, the pressure is still further reduced by expansion and the speed of the current is correspondingly increased so that, at the discharge end of the diverging nozzle, the pressure has nearly dropped to that of the atmosphere or to that of the fluid or medium into which the nozzle discharges and practically all the pressure of the steam has been converted into velocity. In other words, the 57.7 per cent. of the initial pressure, which existed in the steam current at the throat or narrowest point of the nozzle, is converted into velocity by expansion in the diverging nozzle.

The diverging nozzle is so proportioned that the speed of the steam increases as it passes through the nozzle. In order to attain this result the divergency of the nozzle should be such that the areas of succeeding cross sections of the nozzle increase in a lesser degree than the volume of the steam from cross section to cross section. The speed of the steam at each given cross section of the nozzle depends upon the proportion between the passing volume of the steam and the area of the cross section, and under the proportion stated the volume of the steam in passing through the diverging nozzle increases in greater proportion than the areas of the cross sections of the nozzles, whereby the velocity of the steam is correspondingly increased.

As an illustration it may be stated that a nozzle in which the diverging portion has a diameter of one-eighth of an inch at its narrowest point, a diameter of three-eighths of an inch at its discharge end and a length of three inches will expand steam of one hundred and sixty-five pounds pressure per square inch down to three pounds and will produce a steam current of corresponding velocity.

With a properly proportioned diverging nozzle, the steam issues from the nozzle in a compact jet, which has no tendency to further expand or change its pressure or specific gravity, hence there is no tendency for the steam to leak at the sides of the wheel but the entire jet is bodily thrown against the wheel and made effective in actuating the same.

The steam current issuing from the nozzle with little or no pressure, but great velocity, strikes the buckets of the wheel and revolves the latter at an exceedingly high rate of speed, in many cases higher than fifteen thousand revolutions per minute. The practically complete conversion of the pressure of the steam into velocity and the utilization of the *vis viva* of the swiftly moving current of steam renders this engine very economical in the consumption of steam while its construction is exceedingly simple.

From what has been said, it is evident that all necessity of tightening against steam pressure ceases at the end of the nozzle. In this consists one of the advantages of my steam turbine above all other constructions where steam is admitted to the turbine under pressure, and consequently leaks out at all sides instead of passing through the turbine wheel. The live steam does not come in contact with any of the working parts of the turbine, and the machine therefore works equally well with superheated as with saturated steam. Here is also an opportunity for economizing heat, which is impossible in ordinary steam engines on account of the sensitiveness of the packing boxes to heat.

The economy of this turbine has been established by numerous trials. For instance with a fifty horse power turbine dynamo an effect of 63.7 horse power was obtained with a consumption of 19.73 pounds of steam and 2.67 pounds of coal per hour and horse power.

I am aware that in Williams on *Heat in its Relations to Water and Steam*, pages 235 to 244, a theory is set forth which apparently does not agree with that set forth in the foregoing description, but whether this disagreement be real or only apparent, the fact is that the statements contained herein are correct and based upon many carefully conducted trials of steam turbines provided with the various nozzles referred to, which trials have extended over a considerable period of time and were made under widely different pressures.

I claim as my invention—

1. The combination with a bucket or turbine wheel, of a stationary nozzle opening adjacent to the wheel and having its bore diverging or increasing in area of cross section toward its discharge end, whereby the elastic fluid under pressure is expanded in passing through the diverging nozzle and its pressure is converted into velocity before the jet is delivered against the wheel, substantially as set forth.

2. The combination with a bucket or turbine wheel, of a stationary nozzle opening adjacent to the wheel and provided with a contracted receiving portion and with a discharge

portion having its bore diverging or increasing in area or cross section toward its discharge end, substantially as set forth.

3. The combination with a turbine wheel provided with concavo-convex buckets, of a stationary nozzle arranged at an acute angle adjacent to the side of the wheel and provided with a discharge portion having its bore diverging or increasing in area of cross section toward its discharge end, substantially as set forth.

4. The combination with a bucket or turbine wheel, of a stationary nozzle arranged to deliver a jet of expansive fluid against the wheel and having its cross sections increasing in area toward its discharge end in a lesser degree than the increase of the volumes of the fluid passing through the respective cross sections, whereby velocity is imparted to the fluid during its expansion in the nozzle, substantially as set forth.

In testimony that I claim the foregoing as my invention I have signed my name in presence of two witnesses, this 19th day of March, 1889.

CARL GUSTAF PATRIK DE LAVAL.

Witnesses:
TYKO ROBSAHM,
EMIL HAASE.