No. 849,543.

PATENTED APR. 9, 1907.

R. HOFFMANN.

HEATING ARRANGEMENT FOR TURBINES.

APPLICATION FILED JULY 9, 1906.

2 SHEETS—SHEET 1.

Fig. 1

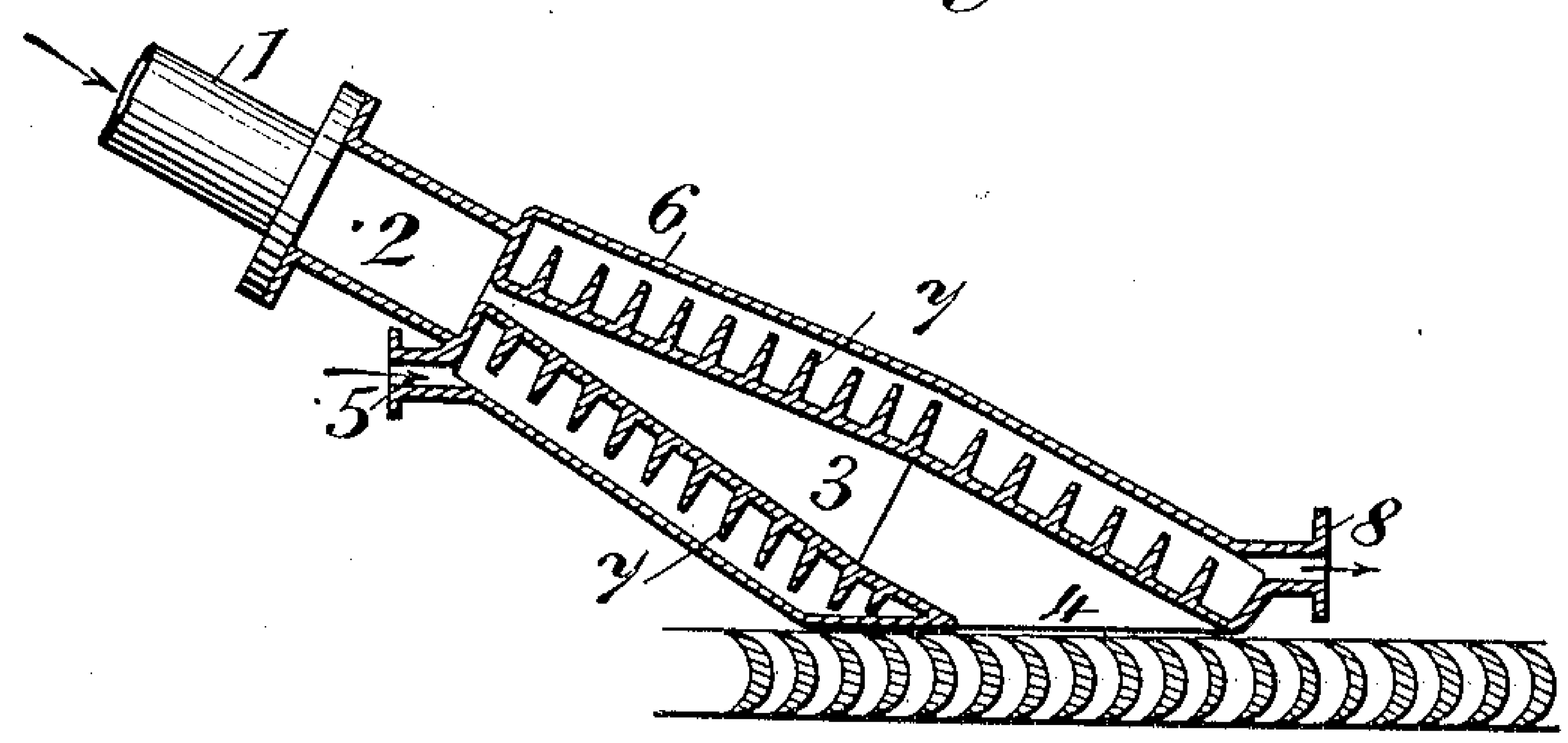

Fig. 2

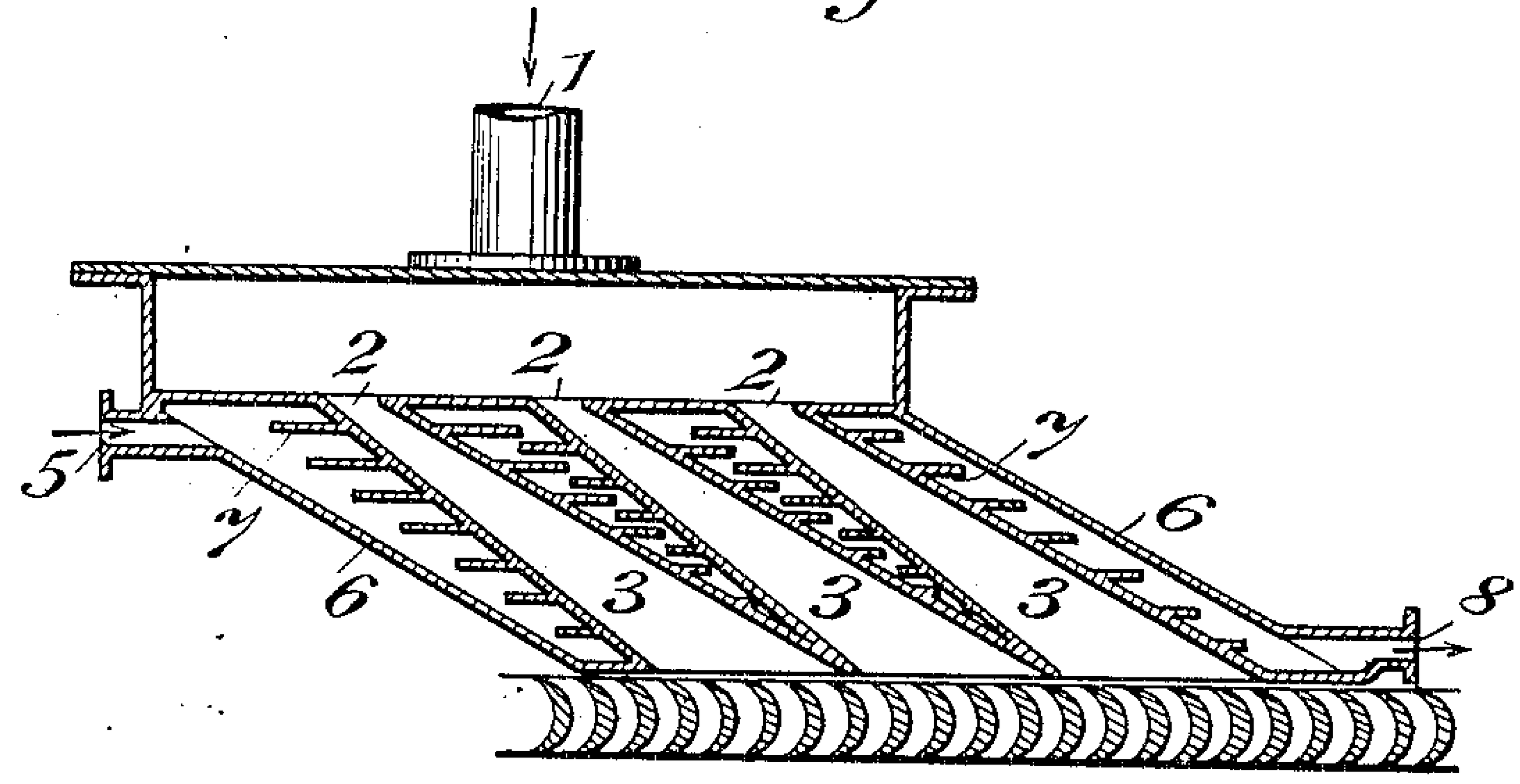

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Fig. 3

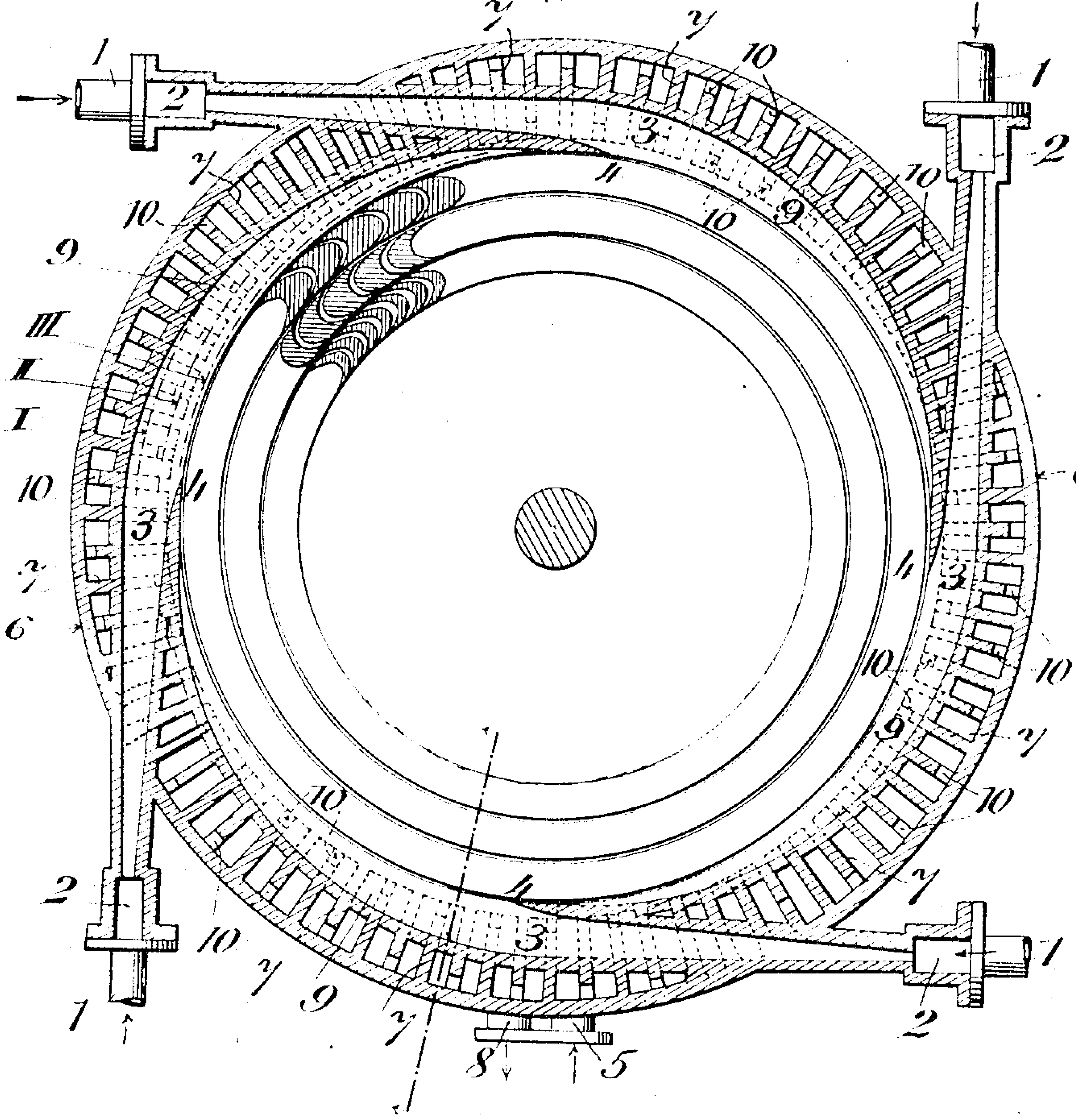
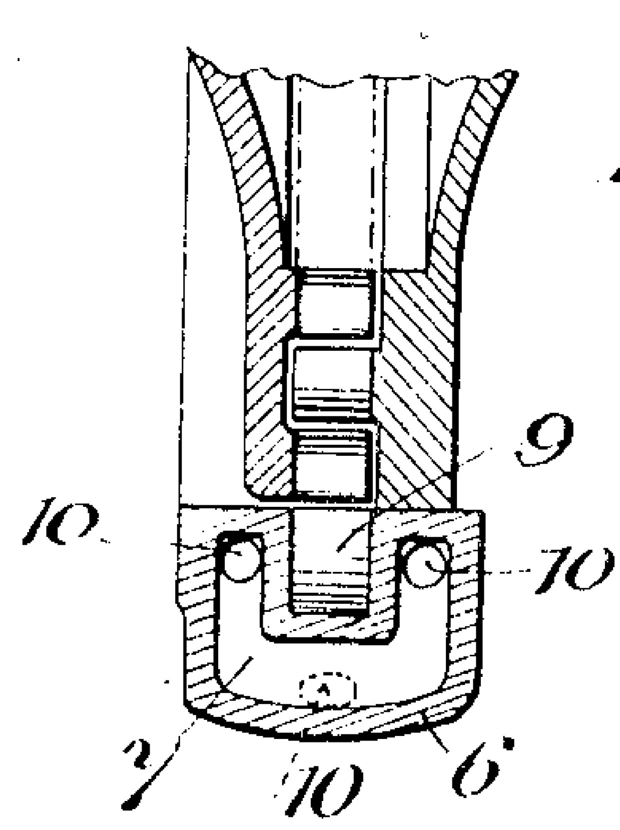


Fig. 4



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UNITED STATES PATENT OFFICE.

RUDOLF HOFFMANN, OF MÜLHAUSEN, GERMANY.

HEATING ARRANGEMENT FOR TURBINES.

No. 849,543. **Specification of Letters Patent.** **Patented April 9, 1907.**

Application filed July 9, 1906. Serial No. 325,408.

To all whom it may concern:

Be it known that I, RUDOLF HOFFMANN, a citizen of the Republic of Switzerland, residing at Mülhausen i/E., Germany, have invented certain new and useful Improvements in Heating Arrangements for Turbines; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same, reference being had to the accompanying drawings, and to letters or figures of reference marked thereon, which form a part of this specification.

On turbines for steam or other elastic fluids the smallest possible number of blades is required with a given speed when steam is expanded right down in one stage only. This keeps true whether there be employed only one or several speed stages for the one-pressure stage, according to circumferential speed. If with a given circumferential speed the given range of pressure is dealt with by several pressure stages instead of one, the number of wheel-disks increases as the square root of the number of pressure stages.

The frictional work of steam in the channels and vanes or buckets is proportionate to the square of the steam velocity and proportionate to the length of the channels in which it has to pass. This length is made up of the several wheel-buckets and guide-blades and has to be proportionate to the speed of steam. Out of both factors the frictional work is thus proportionate to the third power of speed. Besides this the frictional work is inversely proportionate to the density of the flowing steam. Now it will be found by a simple arithmetical operation that the total frictional work of steam flowing through the blades and vanes of a turbine will be less when only one pressure stage is used for a given total range of pressure than when two or more pressure stages are employed. In spite of these advantages obtained in heat economy and constructive design most of the turbine builders have abandoned the idea of using the whole steam-pressure in one pressure stage only. One reason for this is given by the water which is deposited or formed naturally when steam is expanded to any higher degree. Even highly superheated steam when expanding down from boiler-pressure will soon reach the state of saturation and, when further expanding down to condenser-pressure deposit a certain percentage of water. Now this water has not only a destructive action on the blades of the turbine, but it also gives increased friction on account of the high density of the water, and the heat produced by this friction can only partly be gained back in form of mechanical or energetic work. Moreover, at each change of direction of the flowing steam in the buckets of the wheels the steam is densified by centrifugal action, so that by the heat produced some water is evaporated which goes back into the state of water when centrifugal action at straight direction of flow ceases and the pressure again diminishes. At each passage of the steam in one of the curved buckets or vanes the above change in the moisture of the steam repeats itself and brings some new losses.

The object of the present invention consists in gradually heating the expanding steam in such a way that this steam, although getting gradually cooler with the progressing diminution of pressure, still will keep or remain hot enough that the state of saturation never will be entirely reached nor any water formed in consequence of the expansion of the steam. Of course this object can be obtained the much easier if the steam arrives from the boiler in an already highly-superheated state. Yet, as I have said above, this superheat of boiler-steam when within practical limits would not be enough to bring the steam dry onto the turbine-wheels when it has in one pressure stage been expanded down to condenser-pressure. I therefore propose to heat the walls of the conical expansion-nozzles and of their continuations by means of a steam-jacket. This steam-jacket is heated by saturated steam at full boiler-pressure, and a water-pipe with automatic blow-off has to be provided at the bottom of the jacket to lead off the condensed steam. To get enough heating-surface, the outside of the walls of the expansion-nozzles may be provided with ribs, which thus project into the space of the steam-jacket and are directly exposed to the steam. These ribs can take up as much heat and lead it to the smooth inside surface of the expansion-nozzles as there may be heat carried off by the steam which is flowing on this inside with very high velocity.

In order that a sufficient quantity of heat may be given up to the inside flowing steam, the walls of the nozzles may further be of a certain thickness, so as to form a heat-radiating body, radiating to the inside of course. It may be reminded that a little, more or less, thickness of the walls of the nozzles has little influence on the resistance to the passage of heat, the greatest resistance being given by the skin of metal on both sides.

Referring to the drawings, in which like parts are similarly designated, Figure 1 is a section showing a single expansion-nozzle having radiator-ribs and surrounded by a steam-jacket. Fig. 2 is a similar section showing several nozzles included in a single steam-jacket. Fig. 3 is a section of a turbine, showing the nozzles conforming in curvature to the wheel they supply; and Fig. 4 is a transverse section through one of the nozzles, its steam-jacket, and a part of the turbine-wheel.

In all of the figures, 1 indicates the steam-pipe supplying live steam to the nozzle. 3 indicates the end of the expanding portion of the nozzle, and 4 is the end of the nozzle, beveled or otherwise cut to admit steam to the wheel. The steam-jacket 6 is provided with a steam-inlet pipe 5, heat-radiator ribs 7, and an outlet 8 for the primed steam and condensation-water. The working steam goes from the pipe 1 to the entrance 2 of the expansion-nozzle, from thence to the end 3 of the conical part of the expansion-nozzle in expanding down gradually, and then it goes farther through a prismatic continuation of the nozzle into the outlet 4, which is, as usual, cut on an angle to suit the inclined position of the nozzle with regard to the wheel-surface. Several nozzles may be united in one steam-jacket, as is shown in Fig. 2. It will be found of advantage to make not too many nozzles, but to reduce their number and to increase their dimensions accordingly in order to find sufficient space for the heating-ribs.

In radial turbines, with steam coming from the outside, the conical expansion-nozzles may be curved around the wheel, and the usual prismatic continuation of the nozzle, with its end cut on a bevel or incline, may take the form of a spiral-shaped channel around the wheel. By these means the heavy water drops, if there are any of them, will be carried radially outward in the channel and will remain the much longer in contact with the heated wall. Such an arrangement is shown in Figs. 3 and 4 of the drawings. In the front view, Fig. 3, the parts 2 2 are the beginnings of the expansion-nozzles, 3 3 are their ends, 4 4 are the extreme points of the prismatic continuations of the nozzles with the ends cut on a bevel. These beveled ends are reaching from the points 3 3 on to the extreme points 4 4, so that the prismatic channels will become some spiral-shaped ones. The point 3 of any one nozzle will about fall together with the point 4 of the foregoing nozzle and with the end of its spiral-shaped steam-channel. The conical nozzles and their spiral-shaped continuating channels are steam-jacketed, and the walls are provided with heating-ribs. These ribs 7 7 are carried on out to the outer wall of the jacket in order that the heat from these outer walls may also be led on to the inside walls. The ribs 7 7 are provided with holes on convenient places, so as to allow the heating steam to circulate. The condensation of the heating steam will cause a certain circulation from the inlet 5 on to the outlet 8 of the condense water. The centrifugal force will push the flowing steam in the end of the conical nozzle and in the spiral-shaped channel outward. At the point 3 the density of steam will therefore be somewhat higher than on the inside periphery of the spiral channel between points 3 and 4. Thus the steam in going forward in the spiral channel will still further expand and increase in speed in such a manner that all points of same distance from the wheel center have the same density and velocity of steam. All points on the arch-line I of Fig. 3 have higher density of steam and smaller velocity than the points on arch-line II, and the points on arch-line II have again higher density and smaller speed than all points on arch-line III.

The length of the nozzle and of the spiral channel and the sections at points 2 and 3 have to be determined with a view of the above centrifugal action on the steam. The increase of volume of steam as a result of the heating has also to be considered. Even with superheated steam the heating of the expansion-nozzles and of their spiral-shaped continuations will be a necessary and an effective means for getting dry steam on to the turbine-wheel. It will thus be possible to work with one pressure stage only, giving the smallest amount of steam-friction and allowing of the most simple design of the turbine without deterioration of the turbine blades or buckets by the action of water. The gaining on the mechanical work done by the steam will also be somewhat higher than the expenditure in heating steam.

Of course my system will also give advantage with turbines with two or more pressure stages and with several wheels.

I am quite aware that the heating of the steam in turbines has been proposed before. The proposed means, however, were different from mine and could not give the same advantages. Thus it has been proposed to mix hot gases with the arriving steam or with the exhaust-steam of a first-pressure stage before it had to go to the following pressure stage or following wheel. This mixture of gases with saturated steam, however, gives a loss of energetic work. In other instances it has been proposed to heat from the outside by steam or otherwise the exhaust-steam of a first-pressure-stage turbine before it had to go to a second turbine or second-pressure stage. In this case the action is different from mine, because during heating the steam does not alter pressure or other conditions and the heating is going on by steps, as it were, while in my system the heating is done gradually and continuously during expansion. With the system of heating by steps the constructive advantages and simplicity of design of my system cannot be obtained.

Having now particularly described and ascertained the nature of the said invention and in what manner the same is to be performed, I declare that what I claim is—

1. In a turbine, a nozzle, and passages supplied therefrom in combination with a steam-jacket to heat said nozzle and passages, said steam-jacket surrounding the nozzle.

2. In a steam-turbine, an expansion-nozzle, a steam-jacket surrounding the nozzle and heat-conducting ribs between the jacket and nozzle arranged to form a continuous steam-passage therethrough, whereby the nozzle and passages supplied with steam therefrom are heated by conduction to heat the working steam.

3. In a steam-turbine, the combination with turbine-wheel of a nozzle extending in a spiral partly around the periphery thereof, a steam-jacket for said nozzle, radiator-ribs between the jacket and nozzle forming a continuous tortuous passage through the jacket, and a steam inlet and outlet for the jacket.

4. In a turbine, an expansion-nozzle terminating in spiral form and a steam-jacket surrounding the nozzle.

5. In a steam-turbine, an expansion-nozzle terminating in a spiral non-expanding end having a discharge-opening therein, a steam-jacket surrounding the nozzle, ribs between the nozzle and jacket-walls and steam-passages through the ribs, said passages out of alinement.

6. In a single-stage turbine, the combination with a plurality of expanding-nozzles, of a steam-jacket common to all the nozzles, radiator-ribs on the nozzles projecting into the jacket and an independent inlet and outlet to said jacket for heating medium.

In testimony that I claim the foregoing as my invention I have signed my name in presence of two subscribing witnesses.

RUDOLF HOFFMANN.

Witnesses:
GEO. GIFFORD,
ANDREW HEER.