

**1,063,511.**

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# UNITED STATES PATENT OFFICE.

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## STEAM-TURBINE AND GOVERNING MECHANISM THEREFOR.

1,063,511.

Specification of Letters Patent.

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*To all whom it may concern:*

Be it known that we, LUDWIG CUBELIC, a subject of the King of Prussia, residing at Charlottenburg, Germany, and GEORG FORNER, a subject of the King of Prussia, residing at Berlin, Germany, have invented certain new and useful Improvements in Steam-Turbines and Governing Mechanism Therefor, of which the following is a specification.

The present invention relates to turbines connected to an exhaust steam system and to which live steam can be supplied, and to the governing mechanism for such turbines.

The object of the invention is to improve their construction and operation.

Our invention is described and illustrated as carried out in a multi-stage turbine having a high pressure inlet and an exhaust conduit of suitable construction. In addition to this inlet, conduits for low pressure steam are provided which communicate with stages of the turbine operating at different pressures and having different discharge or flow areas for steam. As an example of this feature, two such conduits are shown. In the turbine, the cross-sectional area of the working passage increases from the first to the last stage to accommodate the increased volume of steam as the pressure decreases. To state the matter in other words, the nozzle and bucket areas increase from the inlet toward the exhaust. Under normal or low pressure operating conditions, steam is admitted by a conduit to a pressure stage having a working passage whose cross-sectional area is designed to receive and pass the necessary amount of steam to drive the maximum rated load. When the volume of low pressure steam supply materially decreases, it follows that said cross-sectional area will be too great for said volume and hence the steam will not be utilized to its best advantage. To obviate this, the supply of low pressure steam to the particular stage above specified is cut off and said steam is admitted by another conduit to another pressure stage nearer the high pressure inlet and having a working passage of smaller cross-sectional area which corresponds more closely to the theoretical area for the given volume of steam. If under these conditions the supply is inadequate to drive the load, and in many cases it would be, steam at a higher pressure, for example at boiler pres-

sure, is admitted to the inlet or high pressure stage of the turbine and the latter will then operate under mixed pressure conditions. Care should be exercised in selecting the stage to which low pressure steam is admitted under mixed pressure conditions to see that the pressure of the fluid therein is low enough so that such steam as is received therein from the high pressure source will not tend to flow into the conduit supplying steam from the low pressure source.

The various conduits referred to above are provided with suitable valves under the control of a governing mechanism that is adapted to open and close them at the proper times, as will appear later.

From the foregoing, a characteristic feature of our invention will be seen to reside in the fact that, when operating under mixed pressure conditions, the low pressure or exhaust steam is supplied to a stage of the turbine having a smaller section of working passage than when the turbine is operating solely under low pressure conditions.

In the accompanying drawing, illustrating one embodiment of the invention, Figure 1 is a diagrammatic view of a mixed pressure turbine and the governing mechanism therefor, and Fig. 2 is a detail view of a part of one of the regulators.

1 indicates a multi-stage turbine of any suitable construction and comprising a high pressure and a low pressure portion. The high pressure portion is idle except when the turbine is operating on the mixed pressure plan. The turbine is provided with a casing 2 and diaphragms 3 for dividing it into stages. In each stage is a bucket wheel 4, and in line with each row of buckets and supported by a diaphragm is a nozzle 5. The initial or high pressure stage is provided with a nozzle 6, usually slightly divergent, to which high pressure steam is admitted by the conduit 7. The first stage wheel is made larger in diameter than the others because the steam velocity is higher and hence requires a higher bucket speed if the best results are to be obtained. The exhaust from the turbine passes by conduit 8 to a suitable condenser. Low pressure steam, such as the exhaust from an engine, turbine or other apparatus enters the turbine at some suitable stage, as for example the third in an eight stage machine, by the conduit 9. This is the normal operating condition or rela-

tion of parts. Such steam also enters the turbine under different conditions by the conduit 10 communicating with the first stage on the exhaust side of its wheel. This is the condition when the turbine is operating on the mixed pressure plan, the conduit 9 then being closed.

Steam is admitted to the turbine by three valves, which for convenience may be designated a main low pressure valve 11, a secondary low pressure valve 12 and a high pressure valve 13. The main low pressure valve 11 is actuated by the main hydraulic motor comprising a piston 14 and a cylinder 15. Said motor is controlled in its action by a regulator 16 comprising a casing and a piston valve 17. This regulator may for convenience be termed a "secondary regulator" because it is subject to the control of another regulator to be described later. It may also be designated by the term "pressure regulator" because it is moved by a fluid, such as oil, under pressure, as distinguished from being moved positively by mechanical means. The secondary low pressure valve is actuated by the secondary motor 18 comprising a cylinder 19 and two movable pistons 20 and 21. To the cylinder space between the pistons, fluid under pressure is admitted by the pipe 22. This pressure varies with the variations in pressure of the low pressure source and may be transmitted directly or indirectly. Above the piston 20 is a spring 23 that tends to raise it, and under the piston 21 is a spring 24 that tends to raise it. The piston rod 25 of the main motor is connected to the piston rod 26 of the secondary motor by the lever 27. The movements of the secondary motor are controlled by the secondary or pressure regulator 16. Therefore, it will be seen that said regulator serves a double purpose, *i. e.*, regulating the action of both the low pressure valves 11 and 12. The high pressure valve 13 is actuated by a motor 28 comprising a cylinder 29 and a piston 30. Its piston rod 31 is connected by a lever 32 to the piston valve of the primary regulator, to be described later, said lever being also connected by a pivot 33 to the lever 27 which unites the piston rods of the low pressure valve motors. The high pressure valve motor is regulated in its movements by the primary regulator 34 comprising a ported casing 35 and the piston valve 36 which is connected by a rod 37 and pivot to the horizontal lever 32. The piston valve is provided with specially formed piston heads 38, best shown in Fig. 2, which have serrations or notches 39 at their opposite ends to permit fluid under pressure, such as oil, to flow to the motor 28 under the control of the speed governor, as will appear later. The primary regulator also controls the passage of fluid under

pressure, such as oil, to the secondary regulator 16.

40 indicates a speed governor which is driven by the shaft 41. The latter may indicate the main shaft of the turbine or a shaft driven thereby. The essential condition is to have the governor responsive to changes in speed of the turbine. To the sliding collar of the governor is pivotally attached a governor lever 42, the other end of said lever being pivotally attached to the rod 37, or what is the same thing, to the horizontal lever 32. Attached to the governor lever is a balanced pilot valve 43 contained in a ported casing 44. Fluid under pressure, such as oil, is admitted to the casing by the conduit 45. Fluid is exhausted from the valve casing in the usual way.

For convenience, different positions of the parts have been illustrated by different kinds of lines to show different operating conditions. In full lines is shown the relation of parts for exhaust or low pressure operation; in dotted lines is shown the relation of parts for mixed pressure operation, and in broken and dotted lines is shown the relation of parts for high pressure operation. Owing to the small size of the drawing, no attempt has been made to show the exact position of the parts but only the characteristic or general relation.

Considering first the low pressure operation:—if the available amount of steam decreases, the load remaining the same, there will be a decrease in the speed of the turbine and the governor will move the pilot valve 43 downward. Since the special piston 38 of the regulator 34 is provided at its upper and lower ends with serrations or notches 39, Fig. 2, oil under pressure will flow from the pilot valve through the pipe 46 and notches 39 and pipe 47 into the cylinder 29 below its piston and start the high pressure valve 13 in operation. The upward movement of the piston 30 raises the left hand end of the lever 32 about its pivot 33 as a fulcrum. This movement of the lever moves the piston valve 36 of the primary regulator 34 upward so that oil under pressure can freely enter the cylinder 29 below the piston and move the same upward until the governor connections return the pilot valve to its neutral position, the one shown. Simultaneously with the movement of the piston 38, the small pistons 48 are raised so that oil under pressure is admitted to the under side of the piston 49 of the regulator 16 and said piston is moved upward against the stress of the compression spring 50, located at the upper end. The result of this is to permit oil to exhaust from the under side of the piston 14 of the low pressure valve motor and to admit oil under pressure to the upper side of said piston 14, causing the main low pressure valve 11 to

close to a greater or less degree. The amount that it closes should roughly approximate the decrease in said supply so as to hold the pressure substantially constant. Assuming that the low pressure supply of steam further decreases, the load remaining the same on the turbine, the secondary regulator valve 17 will continue its upward movement until the pipe 51 is placed in communication with the exhaust port 52 in the casing of said secondary regulator 16. This relieves the pressure above the piston 20 of the secondary low pressure valve motor and said valve 12 opens to a greater or less degree under the action of the spring 24. At or about the time the valve 12 is opening, valve 11 is closed by the action of its motor.

Referring now to the levers connected to the motor pistons and their action:—as the main low pressure valve 11 moves toward its seat, a small movement only is imparted to the piston rod 37 of the primary regulator 34, because as the piston rod 25 moves downward the piston rod 26 of the secondary low pressure valve motor has moved upward, and hence the pivot 33 uniting the levers 27 and 32 has only changed its position slightly. From this it will be seen that the under side of the piston 49 of the secondary regulator 16 is subjected to pressure from the regulator 34 during the mixed pressure operation and also during the high pressure operation. This relation is illustrated in broken and dotted lines. If the pressure or amount of the low pressure supply is increased, the speed of the turbine is increased, assuming the load to be constant for simplicity of description. The governor 40 then moves the pilot valve 43 upward and oil under pressure flows through the pipe 53, primary regulator 34 and pipe 54 to the upper side of the piston 30 of the high pressure valve motor, causing the valve 13 to move toward its closed position. By the downward movement of the valve 13, the rod 37 of the valve of the primary regulator is also moved down to its neutral position. This cuts off the piston 49 of the secondary regulator from the supply of oil under pressure and connects it to the exhaust through port 55. The spring 50 then moves the piston valve of the secondary regulator downward. This action permits oil under pressure to flow from the inlet port 56 to the upper side of the piston 20 and cause the latter to move the secondary low pressure valve 12 toward its seat. As the rod 26 of the low pressure valve motor moves downward, it carries with it the right hand end of the lever 32 due to the connecting pivot 33. This movement of the lever 32 moves the valve rod 37 of the primary regulator downward slightly and with it the pilot valve 43. This also places the lower side of piston 14 of the main low pres-

sure valve 14 in communication with the pressure pipe 57 and its upper side with the exhaust through pipe 58, primary regulator 34 and pipe 53 and the valve opens. It will thus be seen that just as soon as the exhaust or low pressure steam has the necessary pressure or quantity to drive the load, a reconnection of the exhaust supply conduit 9 automatically takes place. If, with pure exhaust operation, the load on the turbine is reduced, the speed increases and the governor permits oil under pressure to flow through the pipe 53, notches 39 in piston 38 (Fig. 2), pipe 58 to the upper side of piston 14, thereby closing the main low pressure valve 11 by the proper amount. This condition or relation of parts is indicated by the levers shown in full lines.

To recapitulate, the regulating mechanism is so devised that so long as the supply of low pressure steam is sufficient, the valves 12 and 13 remain closed while the valve 11 regulates the admission of steam under the control of the speed governor. If, however, the speed falls below a certain predetermined limit and the valve 11 cannot supply the necessary amount of low pressure steam, then the regulating mechanism causes a change from low pressure to mixed pressure operation, closing valve 11 and opening valves 12 and 13. As a result of this, such low pressure steam as is available flows by the conduit 10 to the first stage and is discharged by the nozzles or other devices to the second wheel. Since the discharge area of the working passage in this stage is smaller than that of any of the subsequent stages, it follows that a more favorable utilization of the steam will be obtained than would be the case if the exhaust steam always entered the turbine at the same place.

We have shown two low pressure conduits leading to different pressure stages in the turbine, and under ordinary conditions this is sufficient, but it is evident that a greater number of connections can be made if desired. The governing mechanism can also be applied to other types of turbines than the particular one illustrated and described herein.

In accordance with the provisions of the patent statutes, we have described the principle of operation of our invention, together with the apparatus which we now consider to represent the best embodiment thereof; but we desire to have it understood that the apparatus shown is only illustrative, and that the invention can be carried out by other means.

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

1. A turbine having a high pressure inlet and an exhaust outlet between which a drop in pressure takes place, low pressure con-

- duits connected to the turbine at points intermediate the inlet and outlet where different pressures exist, and means responsive to an operating condition of the turbine for controlling the flow of low pressure fluid between the turbine and one or another of said conduits.
2. A turbine comprising relatively movable parts for extracting energy from an elastic fluid, and an exhaust outlet, in combination with conduits for supplying low pressure fluid to parts thereof which have different cross-sectional areas of discharge, and means responsive to an operating condition of the turbine to change the admission from one of the conduits to another.
3. A turbine comprising high and low pressure portions, an inlet for the high pressure portion, an inlet for the low pressure portion, an exhaust, and a conduit which admits low pressure fluid to the high pressure portion under certain conditions.
4. A mixed pressure turbine, in combination with a conduit for supplying steam to a given stage for low pressure operation, a conduit for supplying low pressure steam to a stage of the turbine having a smaller cross-sectional area of working passage than the one first named for mixed pressure operation, a conduit for admitting high pressure steam to a stage having a still smaller cross-sectional area for mixed pressure operation, and means for controlling the conduits.
5. A mixed pressure turbine having a high pressure inlet and an exhaust outlet, in combination with low pressure conduits connected to regions of different pressure therein, high and low pressure valves, and governing means organized and arranged to cause one of the low pressure valves to close and another to open when the supply of fluid from the low pressure source changes.
6. A mixed pressure turbine having a high pressure inlet and an exhaust outlet, in combination with low pressure conduits connected to regions of different pressure therein, high and low pressure valves, means for actuating the valves, and governing means organized and arranged to cause one of the means to close a low pressure valve and open another as the supply of low pressure fluid changes.
7. A turbine having an inlet and an exhaust outlet, in combination with a high pressure valve, low pressure conduits connected to regions of different pressure in the turbine, valves for the conduits, a speed governor, a primary regulator controlled by the governor that directly controls the high pressure valve, and a secondary regulator for the low pressure valves that is controlled by the primary regulator.
8. A turbine having an inlet and an exhaust outlet, in combination with a high pressure valve, low pressure conduits connected to regions of different pressure in the turbine, valves for the conduits, motors for actuating the valves, a speed governor, a primary regulator controlled by the governor which directly controls the action of one of the valve motors, and a secondary regulator that controls another valve motor and is itself controlled by the primary regulator.
9. A turbine having conduits admitting low pressure fluid thereto and an exhaust outlet, valves for the conduits, and a governing mechanism organized and arranged to shut off the flow of fluid through one of the conduits and admit it by another when the pressure of the low pressure source of supply decreases.
10. A turbine having conduits admitting low pressure fluid thereto and an exhaust outlet, valves for the conduits, a speed governor, connections between the valves and the governor for modifying the action thereof, and a regulating means that is controlled by the governor and is also connected to said valves.
11. A mixed pressure turbine having a high pressure inlet and an exhaust outlet, with a working passage between, conduits that receive low pressure fluid from the same source and discharge it into regions in the turbine having different cross-sectional areas of working passage, valves for the inlet and the low pressure conduits, and governing mechanism arranged to open the valve in the low pressure conduit leading to the region having the smaller area of working passage when the high pressure valve is opened.
12. A multi-stage turbine that is provided with high and low pressure inlets and an exhaust outlet, and normally operates as a low pressure turbine, valve means for shifting the point of admission of the low pressure fluid from a low pressure stage to one of higher pressure as the fluid from the low pressure source decreases in amount, a valve for admitting live steam to the inlet to supplement the low pressure supply, a speed governor, and actuating means for the several valves that are controlled by the governor.
13. In combination, a steam turbine divided into a plurality of stages, a conduit admitting high pressure motive fluid to the turbine, conduits admitting low pressure motive fluid to stages of the turbine of different pressures, and valve mechanism for controlling the passage of fluid through said conduits.
14. In a multi-stage turbine operating on the mixed pressure plan, a conduit admitting high pressure fluid, conduits admitting low pressure fluid to stages of different pressures, and valve means for opening the high pressure conduit, closing one of the low pres-

sure conduits and opening another for mixed pressure operation.

15 In combination, a multi-stage turbine operating on the mixed pressure plan and comprising a stage that utilizes high pressure fluid only, one or more stages that normally utilize low pressure but which utilize high pressure fluid only when the turbine is operating on the mixed pressure plan, and 10 stages that normally utilize low pressure fluid but which utilize both low and high pressure fluid when the turbine is operating on the mixed pressure plan.

15 16. In combination, a multi-stage turbine operating on the mixed pressure plan and comprising a stage that utilizes high pressure fluid only, one or more stages that normally utilize low pressure but which utilize high pressure fluid only when the turbine is 20 operating on the mixed pressure plan, stages that normally utilize low pressure fluid but which utilize both low and high pressure fluid when the turbine is operating on the

mixed pressure plan, and valve means for connecting and disconnecting said stages 25 with the sources of low and high pressure fluid.

17. In a multi-stage turbine operating on the mixed pressure plan, a conduit admitting high pressure fluid, conduits admitting low 30 pressure fluid to stages of different pressures, valves controlling the passage of fluid through the high and low pressure conduits and means for simultaneously opening the high pressure conduit and closing one of 35 the low pressure conduits and opening another for operating the turbine on the mixed pressure plan, and a governor for said valves.

In witness whereof, we have hereunto set 40 our hands this 4th day of May, 1912.

LUDWIG CUBELIC.  
GEORG FORNER.

Witnesses:

OTTO SCHMIDT,  
FRIEDRICH GANZERT.

Copies of this patent may be obtained for five cents each, by addressing the "Commissioner of Patents, Washington, D. C."