June 5, 1945. W. E. CALDWELL 2,377,611

TURBINE

Filed March 1, 1941 2 Sheets-Sheet 1

Fig. 1.

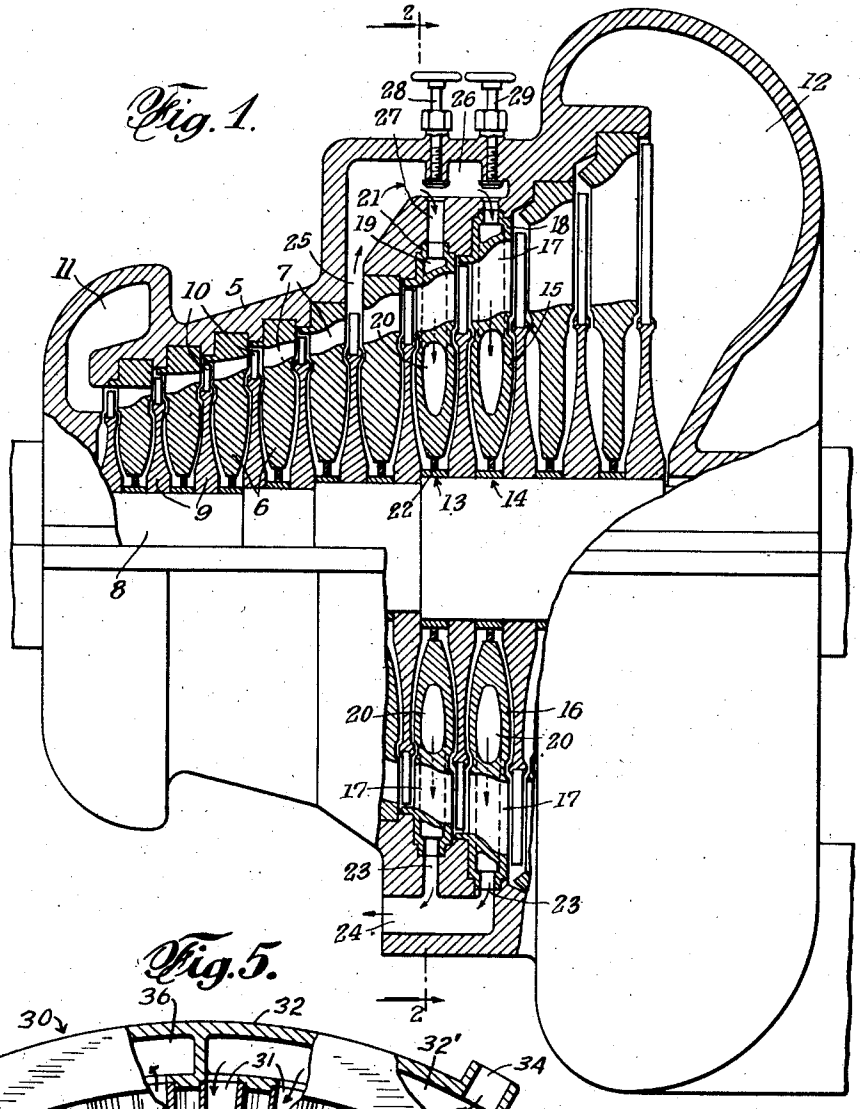
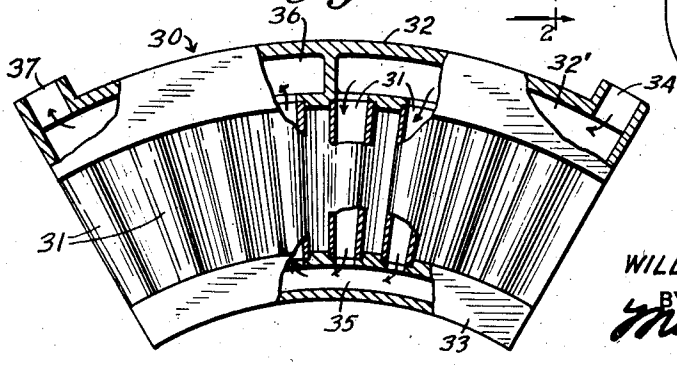


Fig. 5.



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Fig. 2.

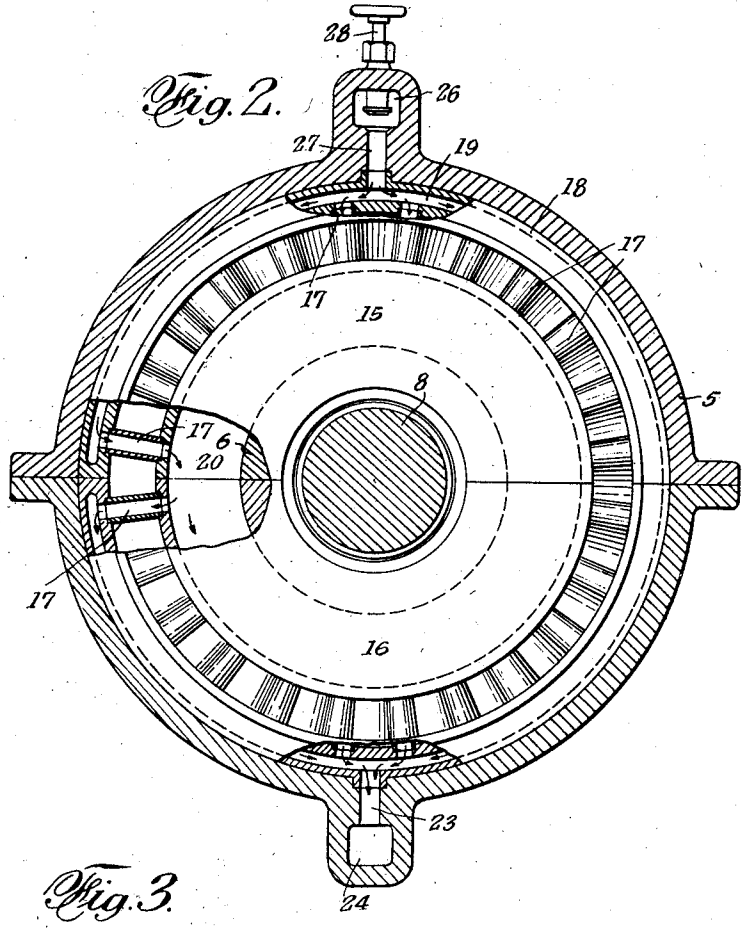


Fig. 3.

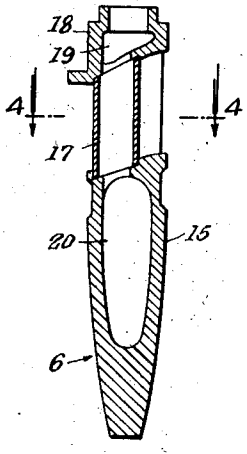
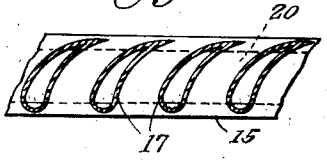


Fig. 4.



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TURBINE

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7 Claims. (Cl. 60—73)

My invention relates to a steam turbine and more particularly to improved means for eliminating or minimizing condensation of steam therein, particularly in the downstream stages of a multi-stage turbine.

It is well known that as the heat energy of the steam is transformed into work in a turbine, the temperature drops and a part of the steam often condenses. The condensed steam, wholly aside from reducing the efficiency of the turbine, erodes and cuts the turbine blades to a very marked extent.

It is the general object of my invention to provide improved means for eliminating or minimizing condensation in a turbine.

It is a more specific object to provide improved means for superheating steam or reevaporating condensate within the structure of the turbine itself.

Another object is to provide highly efficient means for reevaporating condensate or superheating steam in a turbine.

It is another object to provide improved structural means within a turbine for superheating steam therein or reevaporating condensate carried by the steam.

It is another object to provide improved structural features in a turbine, and, in general, the object is to provide improved means for increasing the general efficiency of a steam turbine.

Briefly stated, in a preferred form of the invention I provide a plurality of hollow blades, located in that stage or those stages of a turbine where steam condensation normally occurs, and pass a heating fluid through those hollow blades so as to reevaporate condensate in the steam or to superheat the steam, or both to evaporate condensate and superheat the steam.

Generally speaking, it may be stated that a very small percentage of condensate in the steam is not a serious menace, and therefore I prefer to reevaporate condensate after it has been formed rather than to superheat steam to prevent condensation entirely. Reevaporation of condensate may be effected in the turbine much more effectively than the superheating of dry steam. I contemplate in the preferred form passing the heating fluid for reevaporating condensate or superheating the steam, or both, through hollow fixed blades in the turbine. With some complications, the heating fluid could be passed through the movable blades, but the simplicity of the structure involved in passing the heating fluid through fixed blades is such as to recommend that construction. The invention may be embodied in various types of turbines, such as Rateau, Curtis, reaction, etc. While the broader principles of the invention are capable of embodiment in single stage turbines, the invention at the present time is most effectively embodied in a multi-stage turbine.

In the drawings which show, for illustrative purposes only, preferred forms of the invention—

Fig. 1 is a side view in partial section of a more or less typical type of multi-stage turbine;

Fig. 2 is a sectional view, taken substantially in the plane of the line 2—2 of Fig. 1, parts being broken away to illustrate interior construction;

Fig. 3 is an enlarged radial sectional view through a part of the diaphragm and one fixed blade of the turbine shown in Figs. 1 and 2;

Fig. 4 is a fragmentary, sectional view taken substantially in the plane of the line 4—4 of Fig. 3.

Fig. 5 is an enlarged detail view in partial section of a blade packet for a different type of turbine, illustrating a slightly modified form of the invention.

The turbine illustrated is of more or less conventional form and includes a casing 5 carrying a plurality of diaphragm means 6 with stationary blades, nozzles, or partitions 7. The shaft 8 carries the rotatable disks 9 with movable vanes or blades 10, all as is common practice and will be understood. High pressure steam is introduced into the inlet chamber 11 and expands through the various stages of the turbine to the outlet chamber 12 connected to the usual condenser. The steam in expanding through the turbine down to the condenser vacuum of, say, 29 inches would ordinarily condense in part in the lower stages of the turbine and the condensation would increase progressively. It is one important purpose of my invention to reheat the steam within the turbine, preferably at or just below the dew point, and in some instances to slightly superheat the same so as to eliminate condensation or maintain the amount of condensate in the steam below relatively low limits. In some cases it may even be desirable to evaporate the condensate and superheat the steam so that there will be substantially no condensate in the steam in the last stage or stages.

In the preferred form of the invention I employ hollow blades, preferably stationary blades, and pass heating fluid through those blades so as to evaporate condensate or superheat steam, or both. In the form shown, the fixed blades at two adjacent stages 13—14 are hollow. The stage or number of stages having hollow blades and

their disposition will depend upon various circumstances and conditions, it being understood that the purpose of the hollow blades is to permit circulation of heating fluid for the purpose of evaporating moisture or superheating steam, or both.

In the form illustrated in Figs. 1 to 4, the diaphragms 6 are made in two parts 15—16 divided on a diametral plane as shown more particularly in Fig. 2. The provision of multi-part diaphragms to render assembly and disassembly easy is now common practice. The blades 17 are preferably cast integrally with or otherwise secured at their inner ends to the diaphragms and may be held at their outer ends in an annular shroud ring 18 which may be considered along with the diaphragm as the diaphragm or diaphragm means in general. The shroud ring 18 is provided with an annular passage means or conduit 19 in open communication with the outer ends of the hollow blades 17. Each part of the two-part diaphragm preferably has an annular passage or cored out section 20 communicating with the inner ends of the hollow blades. The shroud rings 18 are preferably set into annular recesses or are otherwise arranged in fluid-tight engagement with the casing, for example as indicated at 21, and the inner bores through the diaphragms may be provided with seal means 22, as is now common practice. Heating fluid is introduced into one of the passages and passes through the hollow blades into the other passage from which it is discharged either through other hollow blades or to a condensate discharge, as will be described.

In the form shown heating fluid is admitted to the annular passage 19 in the shroud ring and from such passage 19 the heating fluid passes through the hollow blades and into the annular passageway 20 in the inner diaphragm sections. The heating fluid passes from the inner diaphragm passage 20 through the hollow blades 17 in the lower diaphragm section and thence through a passage 23 to a condensate discharge connection 24. The heating fluid for the hollow blades may come from any suitable or convenient source and may be in the form of a gas, vapor, or liquid. In the preferred form I employ steam as the heating fluid and the steam for heating may be bled from the turbine at an upstream stage, where its temperature is quite high, so that there will be a substantial differential in temperature between the heating fluid within the blades and the lower pressure steam and condensate passing outside of the blades. As illustrated, there is a bleed connection 25 from an upstream stage of the turbine, which bleed passage communicates with a chamber 26. The casing has a passage 27 connecting the chamber 26 with the annular shroud passage 19. If desired, a valve means may be employed for controlling the flow of heating fluid, and in the form shown a valve 28 is employed to control the inlet passage 27 rather than the bleed passage 25, although the passage to be controlled and the means for controlling it are largely a matter of choice or design. In the form shown, wherein I have two adjacent stages with hollow blades, I employ a duplicate or similar construction, and a second valve 29 may be employed for controlling the passage of fluid through the hollow blades of the second hollow blade stage.

The hollow blades are preferably of relatively thin section, considering, of course, the pressures which such blades might be called upon to withstand. However, in the lower or downstream stages of the turbine (usually or often subatmospheric), the pressures are relatively small. The hollow blades are preferably made of high strength, relatively thin, high conducting material. The hollow blades, as stated, may be secured to the diaphragms and shroud rings by any suitable means, such as being cast integrally with those parts, or the hollow blades may be welded, brazed, or otherwise secured to the diaphragm means, as will be understood.

It will be noted that, due to the extremely high velocity of the steam passing the hollow blades and thus conducting the heat therefrom, relatively enormous amounts of heat may be tarnsmitted through the metal of the blades and the condenaste will be effectively evaporated completely or to the desired degree, depending upon such factors of design as steam velocities, temperature differences, character of metal of the hollow blades, and some other factors. It will be understood that the areas of the blades in the downstream stages increase progressively at a very rapid rate and it is in those downstream stages that condensation usually becomes a menace. Therefore, there is ample area in the blades for conducting the amount of heat necessary to control condensation in those stages when condensation is greatest. As stated, I prefer to employ the hollow blades at that stage which is substantially at or just below the dew point of the steam passing through the turbine. Relatively small quantities of moisture, say, up to 3% or 4% are not of great moment and it is relatively much easier to evaporate water in the steam than it is to superheat dry steam. However, as has been indicated, the number of stages having hollow blades and the disposition of those stages relative to each other and relative to the turbine as a whole, will be in accordance with the results desired or economically attainable.

In that form of the invention shown in Figs. 1 to 4, there are diaphragms which extend inwardly to the rotor shaft. However, in some types of turbines, such diaphragms are not employed, and the fixed blades are held in sections or so-called blade packets interposed between adjacent rows of movable blades. The operation of such turbines in general is the same or similar, but the structures are slightly different. For example, as shown in Fig. 5, there is a blade packet 30, including a plurality of hollow blades 31 spaced apart from each other, as will be understood, and more or less as shown in Fig. 4. The blades 31 may be secured between innner and outer shroud rings 32—33. One of the shroud rings (in this case the outer ring 32) is provided with an annular passage 32' having a heating fluid inlet connection 34, corresponding in general to the inlet connection to the annular heating fluid chamber 19 in the shroud ring of the previously described form. The inlet passage 32' may extend substantially half-way around the blade packet and such passage communicates with the outer ends of about half of the hollow blades in the blade packet. The inner shroud ring 33 has an annular passage 35 which may communicate with the inner ends of all of the blades in the packet. Heating fluid entering through the inlet passage 34 is distributed by the annular passage 32' to all of the blades communicating with that passage, and the heating fluid passes from the outer ends of the blades through those hollow blades and into the passage 35, from which it passes through the blades in the left-

hand end of the packet to the outer ends thereof and into a discharge passage **36** in the shroud ring **32**. From the passage **36** the heating fluid may be discharged through a discharge passage **37** to a receiver for the heating fluid or condensate from the heating fluid. Blade packets such as are shown in Fig. 5, are secured in the turbine casing and the inlet connections such as **34** would communicate as through an annular passage in the casing or through piping with the heating fluid inlet connection, and the outlet passages as **37** would communicate as through an annular passage or piping in the casing to the main condensate discharge passage, as will be understood.

In connection with the illustrated embodiments of my invention, it is to be understood that the condensate from the hollow blades (when condensible heating vapor is used as a heating fluid) will be drawn off from the blades and discharge passages preferably by gravity, but the heating fluid flowing through the hollow blades will have a scavenging effect so as to carry the condensed heating fluid through the hollow blades and discharge passages. In certain instances, the hollow blades, passages, etc., may be pitched to facilitate the disposal of the condensate, and in other cases the scavenging effect of the flowing heating fluid may be employed in addition to or in lieu of such other expedients as pitching of the blades and passages.

There are other ways of arranging blades, buckets, and nozzles in steam turbines, and it is to be understood that my invention is not limited to such embodiments as have been herein shown, since the invention, unless otherwise indicated, is not limited to the structural features shown but is directed more particularly to the provision of hollow blades, buckets, nozzles, or partitions, with means for passing heating fluid therethrough for the purpose of evaporating condensate or superheating steam, or both. When the term "blade" is referred to herein, I mean to include what are generally considered as blades, that is to say, actual blades, buckets, nozzles, or dividing partitions forming operative parts of a steam turbine.

I have referred herein throughout to a steam turbine, but it is understood that by the term "steam" I mean to include vapor turbines in general, for example, mercury turbines or the like, where the problem of condensate may be encountered.

With certain boiler water or boiler conditions, solids are carried by the steam and form deposits on the turbine blades after a considerable period of operation. These deposits cause a reduction in capacity and may also reduce the amount of heat transferred through the blades in the reevaporative portion of the machine. In a conventional turbine, the solids deposited on the blades may usually be taken care of by shutting down the unit and passing wet steam at much reduced speed until the solids are dissolved and washed off of the blades. In a turbine embodying my invention as herein described, the solids may be quite readily dissolved and washed from the blades in and below the reevaporative portion thereof by simply cutting off the supply of heating fluid to the blades and permitting operating steam to condense so as to dissolve and wash off deposits. The same result could be accomplished by shutting off the condensate discharge from the hollow blades so as to permit the latter to fill with condensate which would cool off and therefore not function for reevaporation of condensate in the operating steam.

When conventional turbines are shut down, much moisture usually remains in the turbine and serious corrosion of the blades, and, in fact, all interior portions of the turbine often results. It is a feature of my invention that, when a turbine is shut down, heating fluid may be passed through the hollow blades so as to maintain the entire interior of the turbine hot and thus drive out all moisture, whereby interior corrosion is eliminated or reduced to a minimum.

Some of the advantages of my invention have been herein set forth. Other advantages and embodiments will occur to and be understood by those skilled in the art. The invention has been shown as embodied in a more or less conventional type of turbine, and it wil lbe understood that modifications in new designs would permit a better and perhaps more advantageous embodiment and utilization of the invention.

While the invention has been described in considerable detail and preferred forms illustrated, it is to be understood that various changes and modifications may be made within the scope of the invention as defined in the appended claims.

I claim:

1. In a multi-stage steam turbine including fixed diaphragm means carrying fixed blades, a plurality of said fixed blades in a downstream stage of said turbine being hollow, said diaphragm means carrying said hollow blades having an interior passage communicating with the inner ends of all of said hollow blades, said diaphragm means having inlet conduit means communicating with the outer ends of some only of said hollow blades, means for introducing heating fluid into said last mention conduit means, and a second conduit means defining an outlet and communicating with the outer ends of the remainder of said hollow blades, for the purpose described.

2. In a steam turbine, diaphragm means carrying fixed blades, a plurality of said blades being hollow, said diaphragm means having an outer peripheral conduit communicating with the outer ends of some only of said hollow blades, said diaphragm means having conduit means communicating with the radially interior ends of all of said hollow blades, whereby heating fluid introduced into said first conduit means will pass therefrom through said some only of said hollow blades and into said second mentioned conduit means, said diaphragm means having outlet conduit means communicating with the outer peripheral ends of the remainder of said hollow blades, to receive heating fluid or condensate issuing from said last mentioned blades.

3. A diaphragm means for a steam turbine formed in a plurality of parts, hollow blades carried by each of said parts, each of said parts having conduit means therein communicating respectively with only the blades in said parts and at the outer radial ends thereof, said diaphragm means having further conduit means communicating with the inner radial ends of all of said hollow blades, and means for introducing heating fluid to one of said first mentioned conduit means, and means for removing condensate from the other of said first mentioned conduit means.

4. In a steam turbine, a plurality of fixed hollow blades, inlet conduit means communicating with one radial end of a plurality only of said hollow blades, a discharge conduit means communicating with one radial end of another plurality of said blades, and a third conduit means

communicating with the other radial ends of all of said aforementioned hollow blades, whereby heating fluid admitted through said inlet conduit means will pass through said first plurality only of said hollow blades and into said third conduit means and then through said another plurality of said blades and then into said discharge conduit means.

5. A steam turbine including a plurality of hollow blades, conduit means communicating with the outer radial ends of one plurality only of said hollow blades, a separate outlet conduit means communicating with the outer radial ends of a second plurality of said hollow blades, common conduit means communicating with the inner radial ends of both of said plurality of blades, whereby heating fluid introduced into said first conduit means will pass inwardly through said one plurality only of said hollow blades and into said common conduit means and then outwardly through said second plurality of blades and into said outlet conduit means.

6. In a turbine, a blade packet including a plurality of hollow blades, inlet conduit means communicating with one end of some only of said hollow blades, outlet conduit means communicating with the corresponding end of the remainder of said hollow blades, and a third conduit means communicating with the opposite ends of all of said hollow blades, whereby heating fluid admitted through said inlet conduit means will pass through said some only of said hollow blades and into said third conduit means and then through the remainder of said hollow blades and then into said outlet conduit means.

7. In a turbine, a blade packet including a plurality of hollow blades, inlet conduit means communicating with the outer ends of some only of said hollow blades, outlet conduit means communicating with the outer ends of the remainder of said hollow blades, and a third conduit means communicating with the inner ends of all of said hollow blades, whereby heating fluid admitted through said inlet conduit means will pass through said some only of said hollow blades and into said third conduit means and then through the remainder of said hollow blades and then into said outlet conduit means.

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