July 16, 1963 G. W. CLARK 3,097,487

SYSTEM FOR PREVENTING OVERHEATING OF A STEAM TURBINE

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FIG. 1

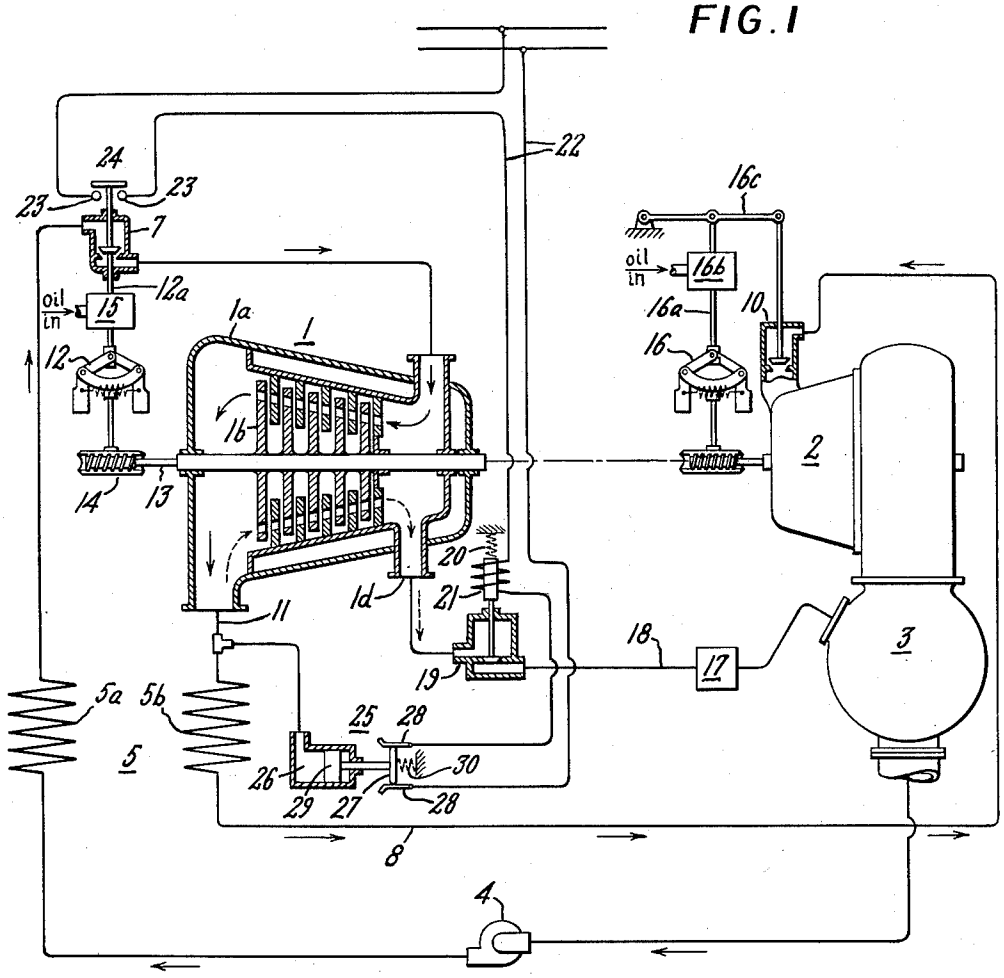
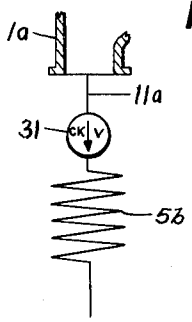


FIG. 2



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SYSTEM FOR PREVENTING OVERHEATING OF A STEAM TURBINE

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This invention relates to elastic fluid turbine powerplants, particularly to a bypass arrangement for a large reheat steam turbine to prevent overheating of the high pressure turbine when steam is trapped therein by sudden closing of the control valves.

In a conventional reheat steam turbine powerplant comprising a high pressure turbine, reheater, and lower pressure turbine, the flow to the high pressure turbine is controlled by main control valves and the steam flow from the reheater to the lower pressure turbine is controlled by an "intercept valve." The main control and intercept valves are moved to a closed position by a main speed governor and pre-emergency governor respectively when the turbine reaches a pre-determined overspeed condition or by suitable tripping mechanism when there is a failure in the generator electrical system, the steam supply system, or failure of some essential service to the turbine, etc., which will be referred to herein as "system failures." The sudden closing of the main control and intercept valves results in the entrapment of a substantial mass of steam at high temperature and pressure in the high pressure turbine, reheater and interconnecting conduits. This trapped steam, if allowed to remain, is violently agitated by the high speed rotor, and the fluid friction raises the steam temperature well above the normal operating steam temperature. Because the turbine rotor and related parts are designed to operate normally very close to the maximum safe temperature, this increased temperature condition could cause a serious reduction in the strength of the turbine components.

With the tendency to build turbines which operate at higher and higher temperatures and pressures, there is an increased need to evacuate the trapped steam to prevent the highly undesirable temperature rise resulting from these higher operating conditions.

Accordingly, it is an object of this invention to prevent overheating of the high pressure section of a reheat turbine when steam is trapped therein by sudden closing of the main control and intercept valves.

A further object is to provide a system of the type described in which, when the main control and intercept valves are closed, the steam trapped in the high pressure turbine is automatically vented to the condenser in a manner so as to remove the fluid friction heat generated in the high pressure turbine.

A still further object is to provide a bypass system of the type disclosed which is controlled in accordance with the closing movement of the main control valves.

Other objects and advantages will be apparent from the following description taken in connection with the accompanying drawing, in which FIG. 1 represents diagrammatically a large high temperature compound reheat steam turbine embodying my invention; and FIG. 2 illustrates a minor modification of one element of the system.

Generally stated, the invention is practiced by automatically venting the high pressure turbine casing to the condenser in such a manner that the trapped steam flows backwardly through the high pressure turbine when the main control and intercept valves are closed. The venting system is controlled by valve means actuated simultaneously with the closing of the main steam control valves, caused by turbine overspeed or other system failures.

Referring now more particularly to FIG. 1 of the drawing, the invention is illustrated as applied to a steam turbine powerplant having a high pressure turbine section **1**, and at least one lower pressure turbine section **2**. These may be on different shafts, or may be coupled together on a common axis as shown in the drawing. The turbine **2** may exhaust into still lower pressure turbines, or directly into the condenser **3**. The condensate is returned by the boiler feed pump **4** to the steam generator **5**, which is shown as having primary steam generating coils **5***a* and a reheater section **5***b*.

The path of the turbine motive fluid is from the boiler feed pump **4** to the primary steam coils **5***a*, then through the main control valve **7**, to the high pressure turbine **1**, and back to the reheater **5***b*. Steam discharged from the reheater **5***b* passes through the intercept valve **10**, and then to the inlet of the lower pressure turbine **2**. This simple diagrammatic showing, of course, does not include many conventional elements of steam powerplants, such as feedwater heaters, lubricating systems, packing control system, and numerous minor details of the turbine control system, the arrangement of which will be understood by those familiar with steam powerplant design.

The steam controlling system comprises a main speed governor **12** driven by turbine shaft **13** through suitable gearing **14**, which controls the main inlet valve **7** through rod **12***a* and a suitable hydraulic force-multiplying relay **15**. This governor is designed to begin closing valve **7** when turbine **1** exceeds 100% of rated speed, and fully closes the valve at approximately 105% of rated speed.

The reheat steam control mechanism comprises a "pre-emergency governor" **16** driven by turbine shaft **13** to control intercept valve **10** through rod **16***a*, relay **16***b* and lever **16***c*. Intercept valve **10** begins closing at 101% of rated speed and is fully closed at 105% of rated speed.

The foregoing is merely a diagrammatic showing of a conventional arrangement for controlling the main inlet and intercept valves in accordance with the speed of the turbines. It does not include other conventional elements such as the "emergency governor" which instantaneously closes suitable stop valves (not shown) to completely shut down the turbine when it exceeds a predetermined emergency overspeed condition. An embodiment of mechanism of this type is disclosed more particularly in U.S. Patent 2,747,373, issued to M. A. Eggenberger, and assigned to the assignee of the present invention. For the present purpose, it is sufficient to note that the function of relays **15**, **16***b* is to close main valve **7** and intercept valve **10**, respectively, when the oil supply thereto is cut off by an emergency tripping mechanism (not shown) as a result of any one of several types of "system failures" requiring that the turbine unit be shut down.

From the foregoing, it can be seen that when the main control valve **7** and intercept valve **10** close, a substantial volume of steam at a high pressure (perhaps 600 p.s.i.a.) and temperature (perhaps 900° F.) is trapped in the high pressure turbine **1**, conduit **11**, reheater **5***b*, and conduit **8** extending between the reheater **5***b* and intercept valve **10**. This dense steam trapped in turbine casing **1***a* is violently agitated by the action of rotor **1***b* and the resulting fluid friction increases the steam temperature significantly, which could seriously overheat the turbine components. If this friction heating of the steam were permited, it would quickly result in reducing the strength of the rotor and stator members, to an extent making failure quite possible.

In accordance with my invention, I provide a system for venting the trapped steam from conduit **8**, reheater **5***b* and conduit **11** backwardly through the high pressure turbine **1** to the condenser **3** when the control and intercept valves are closed thereby removing the friction heat gener-

ated in turbine 1. As will be more fully discussed hereinafter, the trapped steam is exhausted to the condenser until the temperature and density of the steam remaining is reduced to a preselected level where further agitation will not result in enough friction heating to be harmful to the turbine components.

The special venting system includes a conduit 18 leading from opening 1*d* at the inlet end of turbine 1 to condenser 3. Located in conduit 18 for controlling the flow of steam therethrough is valve 19 which may be actuated by any suitable servo device, such as solenoid 21 in electrical circuit 22. The closing of circuit 22 is effected by downward movement of rod 12*a* which has mounted thereon switch member 24 that engages contacts 23 to close circuit 22 when control valve 7 reaches the fully closed position. Closing circuit 22 energizes solenoid 21 to open valve 19 against the biasing action of spring 20, which is arranged to close valve 19 when the solenoid 21 is de-energized.

In the principal embodiment illustrated, the opening of valve 19 provides a flow path through conduit 18 to the condenser for the steam contained in conduit 8, reheater 5*b*, conduit 11, and high pressure turbine 1. For preventing excessive temperatures in the condenser, which might otherwise damage the heat exchange tubes therein, a "temperature-reducing desuperheater" is provided as shown at 17. The desuperheater is merely a heat exchanger in which water is sprayed to reduce the temperature of the steam.

Although all the steam trapped upstream from the intercept valve 10 may be exhausted through valve 19, it is not desirable to do this, since, after a predetermined amount of steam is exhausted from the reheater, the steam pressure is reduced with a resultant lower steam temperature. If the flow to the condenser is permitted to continue, the steam temperature would rapidly drop to a value where the temperature difference between the still hot turbine components and the cooling steam would be sufficient to result in "thermal shock", which has a most serious effect on the high temperature alloys employed. To prevent excessive cooling and resulting thermal stresses, valve 19 is closed when the steam in the reheater drops to a predetermined pressure, so selected that the density of the steam is reduced to where the temperature rise resulting from further friction heating action of the rotor, taking into account the normal heat loss by radiation etc., will not damage the turbine. To accomplish this, a pressure-operated switch 25 responsive to the pressure located in the conduit 11 is located between high pressure turbine 1 and reheater 5*b*. Switch 25 is biased by spring 30 to move switch member 27 out of engagement with contacts 28 against the steam pressure in conduit 11 communicated to chamber 26. When the pressure in conduit 11 drops below the predetermined value, switch 27 becomes disengaged from contacts 28 to open circuit 22 and de-energize solenoid 21. Valve 19 is then moved by spring 20 to closed position, regardless of the position of switch 24 with respect to contacts 23.

The operation of my novel venting system can be seen from the following.

When the main control valve 7 and intercept valve 10 are closed due to an emergency overspeed condition or a system failure, high density steam is trapped in turbine 1, conduit 11, reheater 5*b*, and conduit 8. When control valve 7 reaches the fully closed position, switch 24 engages contacts 23 to close circuit 22 and energize solenoid 21 and open valve 19 against the action of spring 20. The steam trapped between control valve 7 and intercept valve 10 now flows backwardly as indicated by the dotted arrows in the drawing through high pressure turbine 1, valve 19 and conduit 18 to the condenser 3 due to the large differential in pressure between turbine 1 and condenser 3. Thus, the steam in turbine 1 is exhausted to the condenser before it can be reheated by friction, due to churning action of rotor 1*b*, to a higher than normal operating temperature. The steam is appropriately cooled by the water spray in desuperheater 17 before the steam enters condenser 3 so that the condenser tubes will not be damaged. When the steam begins to evacuate from reheater 5*b*, the pressure and temperature of the trapped steam begins to drop and at a predetermined steam pressure, spring 30 biases piston 29 to disengage switch 27 from contacts 28 and open circuit 22. The opening of circuit 22 de-energizes solenoid 21 and valve 19 is moved to the closed position by spring 20. This action thus prevents the complete evacuation of all the steam trapped between the high pressure turbine 1 and intercept valve 10 to prevent the drop in temperature of the steam to a point where too rapid cooling of the high pressure turbine could cause thermal shock.

In some cases it may be preferred to prevent the evacuation of steam from the reheater 5*b* and conduit 8 through bypass conduit 18. To this end, the previously disclosed arrangement can be modified, as shown in FIG. 2 on the drawing. In place of the pressure switch 25 and conduit 11, a non-return valve 31 can be located in conduit 11*a* extending between turbine 1 and reheater 5*b*. The check valve 31 prevents the evacuation of steam from reheater 5*b* back through the turbine 1 when the bypass valve 19 is open. Thus the reheater will remain at normal operating temperature and pressure while only the dense steam in turbine 1 is vented to the condenser.

Thus it is seen that the invention provides a novel venting system which exhausts to the condenser the steam trapped in the high temperature turbine to prevent friction heating of the steam and turbine components by the rotor when the control and intercept valves are suddenly closed.

While only two embodiments have been disclosed herein, and those in quite diagrammatic fashion, it will be apparent that many changes and substitutions of equivalents may be made without departing from the invention. For example, although the venting system is shown applied to a reheat steam turbine powerplant, it would obviously apply to a multiple turbine arrangement in which the steam was not reheated. In addition, the control valve 7 might be an "intercept valve" controlling the flow of steam from a reheater after expansion through a preceding supercritical pressure turbine stage. Also, the bypass valve 19 and the control therefor can obviously take the form of any of numerous pneumatic, hydraulic, or electric control devices. In addition, valve 19 could be operated mechanically by a special speed governor connected directly to the turbine shaft, or other mechanisms which would be apparent to one skilled in the art. If valve 19 was not electrically operated, switching mechanism 25 could, of course, be suitably modified to close valve 19 when the pressure in conduit 11 drops to a certain value.

It is, of course, intended to cover by the appended claims all such modifications as fall within the true spirit and scope of the invention.

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

1. In a reheat turbine powerplant having conduits connecting in series steam generating means, high pressure turbine, reheater, lower pressure turbine and condenser, first valve means controlling the flow of motive fluid to the high pressure turbine, second valve means controlling the flow between the reheater and lower pressure turbine, and governing means controlling the operation of said first and second valve means and adapted to close them upon occurrence of a predetermined operating condition, the combination of bypass conduit means with bypass valve means communicating between the high pressure turbine and condenser, electrical means including first switching means operated by the governing means for moving the bypass valve to the open position when the first and second valves are closed to exhaust the entrapped fluid to the condenser, pressure responsive switching means in series with said first switching means and exposed to the pressure in the conduit communicating between the high pres-

sure turbine and reheater, said pressure responsive switching means being constructed and arranged to actuate the electrical means to move the bypass valve to the closed position after a predetermined amount of motive fluid has been exhausted to the condenser.

2. In a reheat turbine powerplant having conduits connecting in series steam generating means, a high pressure turbine, a reheater, a lower pressure turbine, and condenser, first valve means controlling the flow of motive fluid to the high pressure turbine, second valve means controlling the flow of motive fluid from the reheater to the lower pressure turbine, and governing means controlling the operation of the first and second valve means and adapted to close them upon occurrence of a predetermined operating condition, the combination of bypass conduit means with bypass valve means communicating between the high pressure turbine and condenser, means controlled by said governing means for opening the bypass valve when the first and second valves are closed, and check valve means in the conduit between the high pressure turbine and reheater, whereby the fluid trapped between the first valve means and the check valve means is vented to the condenser to prevent overheating of the turbine components by friction heating of the trapped fluid.

3. In governing mechanism for a reheat turbine powerplant having conduits connecting in series steam generating means, a high pressure turbine, a reheater, a lower pressure turbine, and condenser, a main valve controlling the flow of motive fluid to the high pressure turbine, an intercept valve controlling the flow of fluid between the reheater and lower pressure turbine, and governing means for closing the main control and intercept valves when the turbine exceeds a predetermined speed, the combination of conduit means including a bypass valve communicating between the high pressure turbine and condenser, means actuated by said governing means to open the bypass valve when the main control and intercept valves are closed, pressure responsive means exposed to the pressure in the conduit communicating between the high pressure turbine and reheater and being constructed and arranged to move the bypass valve to the closed position after the pressure has dropped to a predetermined level as the motive fluid is exhausted to the condenser, and desuperheater means in the bypass conduit for cooling the bypassed steam to prevent damage to the condenser.

4. In a reheat turbine powerplant having conduits connecting in series steam generating means, a high pressure turbine, a reheater, a lower pressure turbine, and condenser, first valve means controlling the flow of motive fluid to the high pressure turbine, second valve means controlling the flow of motive fluid from the reheater to the lower pressure turbine, and governing means controlling the operation of the first and second valve means and adapted to close them upon occurrence of a predetermined operating condition, the combination of separate bypass conduit means with bypass valve means communicating between the high pressure turbine and condenser, means controlled by said governing means for opening the bypass valve when the first and second valves are closed, and means to hold the pressure in the reheater to a predetemined level after said bypass valve is opened, whereby the high pressure steam trapped in the high pressure turbine is caused to flow through the high pressure turbine to the condenser to prevent the turbine components from overheating by friction heating of the trapped steam.

5. Elastic fluid turbine plant in accordance with claim 4 where said means to hold the pressure in the reheater to a predetermined level comprises means responsive to motive fluid pressure in the first turbine outlet end portion for re-closing the bypass valve when the fluid pressure level in said outlet end portion falls to a preselected value to prevent excessive cooling of said turbine.

6. Elastic fluid turbine plant in accordance with claim 4 where said means to hold the pressure in the reheater to a predetermined level comprises non-return valve means in the conduit connecting the first turbine outlet end portion to the reheater for preventing reverse flow from the reheater into the first turbine when the vent valve opens.

7. In a high pressure elastic fluid turbine powerplant, the combination of inlet valve means admitting high pressure motive fluid to first and second turbine sections connected in series with intercept valve means controlling the admission of fluid to the second turbine, a vent conduit communicating with the inlet end portion of the first turbine, normally closed vent valve means in said vent conduit, and speed responsive means for opening said vent valve means and simultaneously closing the inlet and intercept valves, whereby high pressure motive fluid trapped in the first turbine flows to the inlet end of the first turbine and escapes through the vent conduit to prevent friction heating of the trapped fluid by the churning action of the first turbine rotor, and means to hold the pressure between the intercept valve and the outlet end portion of the first turbine to a predetermined level after said vent valve means is opened.

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