This invention relates to elastic fluid turbine powerplants, particularly to a governing system for a large reheat type steam turbine plant especially adapted to permit quick restarting of the plant after a short shutdown. When a very large steam turbine powerplant is shut down, the hot metal parts, particularly those around the inlet ends of the high pressure and intermediate pressure turbines, cool down at a very slow rate, perhaps only about 15° F. per hour. Thus after eight hours of shutdown, the inlet ends of these turbines may still be at a temperature of perhaps 800 to 900° F. If then it is desired to restart the turbine by again firing the boiler which furnishes the motive fluid, the steam entering the still hot turbine might initially be at a comparatively low temperature, perhaps on the order of 600 to 700° F. This would produce a "thermal shock" by reason of the temperature differential of 200 to 300°, which would seriously endanger the structure unless some special starting procedure is employed to make sure the temperature of the hot turbine parts changes at a safe rate. Such a procedure, with conventional turbine governing systems, would require from 1 to 1½ hours to bring the turbines back up to rated speed so the generators could be re-connected with the network to which they deliver power, while another full hour would be required to bring the load on the turbines up to full capacity.

In a power distribution system for a large metropolitan area, where the electrical load fluctuates greatly over a twenty-four hour period, such procedure would make it impractical to shut down a large turbine at night, because the shutting-down process and the restarting process would occupy substantially the entire day period. On the other hand, operating the plant at low load during the night hours is not desirable because of the poor thermal efficiency of the plant in this condition. It therefore becomes desirable to find ways to shorten the restarting cycle, so that a large generating plant can be "put back on the line" in substantially less than 1 hour after an overnight shutdown.

Accordingly, the object of the present invention is to provide an improved governing system for a large reheat type steam turbine powerplant which makes possible the safe re-starting of the plant within a comparatively short time after a temporary shutdown period.

Another object is to provide a high temperature turbine governing system of the type described which is comparatively simple and provided with full safeguards against overspeed conditions.

Other objects and advantages will become apparent from the following description, taken in connection with the accompanying drawing, in which the single figure represents diagrammatically a large high temperature cross-compound turbine powerplant with a governing system for effecting quick restarting in accordance with the invention.

Generally stated, the invention is practiced by providing a steam bypass conduit around the turbine to the condenser whereby the boiler may be fired and brought up to normal pressure and temperature conditions at a rate of flow about one-quarter its normal rated flow, before any steam is admitted to the comparatively hot turbines, with special control valves incorporated in the turbines for admitting high temperature steam at a very restricted rate to both the high pressure and intermediate pressure turbines simultaneously during the restarting procedure.

Referring now more particularly to the drawing, the invention is disclosed as applied to a cross-compound steam turbine powerplant having in series a boiler 1, a superheater 2, a main emergency stop valve 3, a high pressure turbine 4, a reheater 5, an intercept valve 6, an intermediate pressure turbine 7, a low pressure turbine 8, a condenser 9, and conventional condensate and boiler feed pumps 10, 11, for returning the fluid to the boiler. The conduits connecting these components have for convenience been labeled with reference numerals corresponding to the component immediately upstream from the respective conduit sections. The high pressure turbine exhaust conduit 4a is provided with a "non-return" check-valve 4b.

It will be seen from the drawing that the high pressure turbine 4 and intermediate pressure turbine 7 are actually built as an integral unit, having two rotors on a common shaft housed in a common casing. The high pressure steam is admitted to an inlet chamber 12 disposed adjacent the middle of the turbine casing, whence the motive fluid flows to the left through the high pressure turbine rotor and exhausts to conduit 4a at the extreme left-hand end of the turbine casing. Likewise, the reheated motive fluid from intercept valve 6 passes through conduit 6a and enters the intermediate pressure turbine 7 adjacent the midpoint of the casing, flowing to the right through the intermediate pressure turbine rotor and leaving at the extreme right-hand end of the casing through conduit 7a. In low pressure turbine 8, the motive fluid enters adjacent the midpoint of the casing and flows both to the right and to the left through the low pressure turbine rotors, and through the condenser neck 9a to the condenser 9. Cooling water for the condenser is supplied by an inlet conduit 9a and a discharge conduit 9b through which cooling water is circulated by suitable pumps (not shown). A pressure switch indicated diagrammatically at 9c is arranged to signal the failure of cooling water flow.

The primary means for regulating the rate of flow of motive fluid through the turbines is the high pressure inlet governing valve system indicated diagrammatically at 13 as comprising a main flow control member 13a containing a pilot control member 13b, which forms a "lost motion connection" with the main flow control member 13a so that, as the valve stem 13c rises, the pilot member 13b first opens to admit a limited quantity of steam to the high pressure turbine rotor. After a short delay, the pilot 13b engages the main flow control member 13a so as to position it in the opening direction. The governing valve members 13a, 13b are biased downwardly to closed-position by a spring 13d engaging the upper end of valve stem 13c. The inlet valves are positioned in the opening direction by a rotor 14 engaging the follower roller 15a carried at the extreme left-hand end of an operating lever 15, the mid-portion of which is fulcrumed at 15b on the turbine casing. Cam 14 is positioned by a rack and pinion 16, in a manner which will be obvious from the drawing. It is to be noted that movement of the rack to the right in the drawing causes the cam 14 to position valve stem 13c upwardly in the valve opening direction.

Actually, in such large capacity steam turbines, on the order of 160,000 kw., the admission of motive fluid to

United States Patent Office

Patented May 29, 1956

2,747,373 QUICK-STARTING GOVERNING SYSTEM FOR REHEAT TURBINE

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Application September 24, 1952, Serial No. 311,248

11 Chams. (Cl. 60—75)
the high pressure turbine will ordinarily be controlled by a plurality of valves similar to that shown at 13, each having a main operating lever 13 and a cam keyed to the camshaft 14 but so shaped and oriented that the respective valves open in a preselected sequence. The inlet valve mechanism shown at 13 in the drawing is intended to represent that governing valve which opens first as the rack 16 moves to the right.

The means for actuating these multiple governing valves comprises a hydraulic motor 17 having a piston 17a slidably disposed in a housing 17b and connected by a bell-crank 17c to position the rack and piston 16. Motor 17 is controlled by a hydraulic pilot 18 having a slidable spindle member 18a connected to admit high pressure operating liquid to the upper end of cylinder 17b when the pilot spindle moves downwardly, and to the lower end of cylinder 17b when the pilot moves upwardly. The manner in which this is effected will be obvious from the drawing. It will, of course, be appreciated by those skilled in the art that the hydraulic pressure fluid for actuating the governing system is supplied by a suitable pump (not shown) which may for instance be driven from the turbine rotor.

Pilot 18 is positioned by a floating lever 19, the right-hand end of which is connected by a link 20 to a three-armed lever 21, one arm 21a being connected to link 20 with a second arm 21b connected by another link 22 to piston 17a. Those familiar with the art will appreciate that the main operating piston 17a produces a restoring effect on the pilot 18 by way of the followup linkage 22, 21, 19, 18.

In normal operation, pilot 18 is positioned by an operating governor shown generally at 23 as comprising a conventional centrifugal flyball governor connected to position the pilot 18a connected to the mid-position of lever 25, the right-hand end of which is connected by link 26 to the left-hand end of floating lever 19. The left-hand end of lever 25 is carried by an adjustable fulcrum member in the form of a nut 25a carried on a threaded "synchronizing screw" 27, the position of nut 25a being determined by suitable means or remotely controlled motor means, represented diagrammatically by the hand-wheel 27a. The flyball governor 23 positions pilot 18 to move the piston 17a in order to hold a pre-selected speed or load, the value of which is determined by the position of the synchronizing screw 27.

For shutting down the turbine in the event of an emergency overspeed condition, conventional emergency governors 28 and 28a are associated with the high and low pressure turbine rotors respectively, and are arranged to furnish a signal in the event the speed of either of the rotors reaches a preselected maximum permissible value, which signal trips closed the main emergency stop valve 3 and certain other valves described hereinafter. These emergency governors 28 and 28a may be of any suitable mechanical or electrical type, the precise details of which are not material to an understanding of the present invention. The dot-dash line 28b in the drawing is intended to indicate that the emergency governors 28, 28a are suitably connected to stop valve 3 and other valves so as to close them upon attainment of a preselected overspeed.

In the event of an emergency overspeed condition, it is also necessary in a reheat type turbine powerplant to stop the flow to the intermediate pressure steam remaining in the high pressure turbine 4 and the comparatively long interconnecting conduit 4a, reheater 5, and conduit 5a. The volume of the high pressure steam trapped in these components can be sufficient that it would create a dangerous overspeed in the turbines if permitted to expand through the intermediate and low pressure turbines. To prevent this, the "intercept valve" 6 is provided with a flow control member 6b positioned by a hydraulic motor 6c under the control of a pilot valve 6d. Pilot spindle 6f is connected to be positioned by a lever 6e, the right-hand end of which is connected through suitable linkage to the piston rod so as to effect restoring motion of the pilot 6f. The left-hand end of intercept pilot lever 6e is connected to a link 29 arranged to be positioned by a "pre-emergency governor" shown at 30 as being a second conventional flyball governor similar to governor 23 but set to become effective at a certain speed somewhat higher than the speed at which the machine is shut down. As shown in the drawing, governor 30 positions a lever 31 supported on a fixed fulcrum at its left-hand end and connected at the right-hand end to link 29. It will be seen that an increase in speed will cause governor 30 to pull lever 31 downwardly, causing link 29 to lower pilot 6f so that hydraulic liquid is bled from the motor 6c, whereupon the heavy coil spring 6g causes the flow control member 6b to move downwardly to closed position. This it will be seen that, as the speed rises toward a preselected value, the pre-emergency governor 30 first closes the intercept valve 6 and, at an appreciably higher speed, the emergency governor 28 strips the stop valve 3. In the drawing, pilot 6f is shown below the "aligned" or neutral position which the pilot would occupy in quick starting operation. The reason for this will appear hereinafter.

For providing direct manual control of the turbine governing valves 13, as in starting the turbines, a manual starting member represented by hand-wheel 32 is provided. This manual control is represented diagrammatically as comprising a threaded screw 32a carried in a stationary nut and having a lever end adapted to engage lever 19, so that by turning the hand-wheel 32 pilot 18a can be forced downwardly to admit operating liquid to the upper end of cylinder 17 so as to move piston 17a downwardly in the valve-closing direction. In normal operation, the manually positioned screw 32a is backed off by a lever 19 so that the pilot 18a is under the sole control of speed governor 23. In preparation for starting the turbine, the hand-wheel is turned to cause screw 32a to force pilot spindle 18a to its lowest position, so that motor 17 will close the governing valves 13. Then, when it is desired to admit steam through valves 13, the screw 32a is gradually backed off, permitting pilot 18 to rise and cause motor 17 to open the control valves.

To permit quick-starting the plant with high temperature steam at temperatures on the same order of magnitude as that of the still hot turbine inlet parts, a bypass arrangement is provided permitting operation of a steam generating equipment at part load, without passing any steam through the turbines, until the pressure and temperature of the motive fluid rise to values which the turbine can safely handle. Generally this means that the motive fluid must be within about 100°F of the temperature of the turbine parts.

This bypass arrangement comprises a turbine bypass conduit 5b for taking steam from the discharge side of reheater 5 and passing it directly to the condenser 9. For preventing excessive pressures and temperatures in the condenser, which might otherwise damage the heat exchange tubes therein, a "pressure-reducing orifice heater" is provided as shown at 33. This comprises a plurality of pressure reducing orifices in series, shown as 33a, 33b, 33c, with a plurality of water spray nozzles 33d, 33e interposed between the respective orifices. The function of the orifices is to reduce the steam pressure in progressive steps, while the water spray reduces the temperature of the steam admitted to the condenser. The supply and control of this desuperheating water will be noted hereinafter.

If the steam delivered by the boiler were taken directly from the superheater 2, when bypassed to the condenser as described above, the heat exchange tubes in the reheater 5 would be burned out. Therefore it is necessary to provide a second "high pressure bypass" conduit 2b, which takes steam from the outlet side of superheater 2 and supplies it to the inlet side of re-
heater 5. Thus the bypassed steam maintains at normal safe operating temperatures the heat exchange tubes in the boiler 1, superheater 2, and reheater 5. To control the pressure and temperature conditions in the superheater and reheater during this process, several regulating devices are associated with the high pressure bypass conduit 25. These include a high pressure bypass pressure regulating valve shown diagrammatically at 34 as having flow control means adapted to hold at a preselected value the pressure of the steam in the superheater 2, in accordance with a pressure signal derived from a suitable detector 35, responsive to the superheater discharge pressure. Pressure detector 35 transmits an appropriate signal to the regulating valve 34 as indicated by the dot-dash line 35a.

The temperature of the reheater 5 is prevented from rising to a dangerous level by temperature control means comprising a "desuperheater" in the form of a water injection spray 36, the water supply to which is controlled by a valve 37 in accordance with a signal received from a temperature detector 38 responsive to the temperature at the discharge side of reheater 5, as indicated by the dot-dash line 38a. The temperature detector 38 is arranged to increase the flow of desuperheater water when the temperature rises, so as to hold a preselected reheater outlet temperature. In normal operation, when the discharge temperature of reheater 5 is maintained at its rated value by the normal flow of steam therethrough, detector 38 automatically discontinues the supply of water.

The precise nature and mechanical details of the control devices 34, 35 and 36, 37 are not material to an understanding of the present invention, since they may obviously take the form of any of numerous pneumatic, hydraulic, or electrical temperature and pressure controlling devices known to the art.

It remains to note that the high pressure bypass conduit 20 contains a manual high pressure bypass shut-off valve 39, a high pressure bypass emergency stop valve 40, actuated by the emergency governor 28 by the signal transmitted as indicated by line 28b, and a pressure reducing orifice 41 disposed between the regulating valve 34 and the desuperheater 36. The function of orifice 41 is to reduce the pressure of the bypassed steam to a value of the same order of magnitude as that occurring in the reheater in normal operation. The reheater outlet pressure and the temperature of the steam bypassed to the condenser through conduit 50 are controlled in the following manner. A manual turbine bypass stop valve 42 is opened to place the bypass 50 under control of an automatic valve shown at 43. This is actually a multiple valve having a steam flow control component 43a and a second desuperheating water flow control valve 43b, the latter regulating the supply of water to the pressure-reducing desuperheater 33 through the water supply conduit 44. It will be apparent from the drawing that conduit 44 is connected to the discharge conduit 11c of the boiler feed pump and supplies desuperheater water to the respective sprays 33a, 33c. The valves 43a, 43b are positively linked together and controlled by a signal from a pressure detector 45 responsive to reheater outlet pressure, as indicated by the dot-dash line 45a. It may be noted that valve 43 and pressure detector 45 are arranged so that the valve 43 opens at about 435 p. s. i. and maintains reheater discharge pressure constant about 450 p. s. i. closing whenever the pressure at the reheater discharge tends to fall below 450 p. s. i.

As noted above, the turbine governing valve 13 represents that one of the multiple inlet valves which opens first when operation of the high pressure turbine 4 is initiated. In restarting the turbine after a short shutdown with the turbine from previous operation, it is desired that steam be admitted simultaneously to both the high pressure turbine 4 and intermediate pressure turbine 7 at temperatures which do not vary by more than a preselected differential from the temperature of the inlet parts of the respective turbines. To this end, the "intercept valve bypass conduit" 5c takes steam from the reheater outlet by way of conduit 5a and supplies it to an "intercept bypass control valve" 46. It will be seen that valve 46 has a flow control member 46a biased to closed position by a spring 46b and arranged to move in the opening direction by a lever 46c connected by a link 46d to the point 15c on the main operating lever 15. By proper selection of the sizing of the pilot valve 13b and the intercept bypass flow control member 46a, and by proper design of the actuating levers 15, 46c, the relative sizes of the flow control openings admitting steam to the high pressure turbine 4 and intermediate pressure turbine 7 can be determined. The arrangement is so selected that the rate of steam flow through the turbines 4, 7 will just bring them to normal speed and other operating conditions when operating at "no load." It is also to be noted that the positive mechanical interconnection between the main governing pilot valve 13b and the intercept bypass control valve 46c insures that they will open simultaneously. On the other hand, the main intercept valve 6 is not opened by the governor until valves 13b, 46a have been opened wide so as to bring the machine up to speed and apply a small load. More load can then be applied to the turbine by opening additional inlet valves 13 and the intercept valve. This constitutes the reason for the displacement of pilot 6f below the aligned condition. The amount of this displacement is identified at 6h, and is so selected that valves 13b, 46a get wide open before the intercept valve 6 begins to open. The intercept valve bypass conduit 5c is provided with an intercept bypass emergency stop valve 47, which is also connected to be closed by the emergency governor 28 through interconnection with the dot-dash over-boost signal line 28b.

It remains to note that the turbine governing system is provided with special means for over-powering the emergency governor 30 in such a manner as to close the intercept valve 6 during the quick-starting cycle. This means comprises a manual control member shown as a hand-wheel 48 arranged to position a nut 48a by rotation of a lead-screw 48b. Pivoted to the nut 48a is a lever 49; the other end of which is connected by a link 50 to a bell-crank 51, the other arm of which is pivoted to the intercept valve control link 29. The intermediate portion of lever 49 is provided with a pivot 49a disposed in an elongated slot 51a in a link 51b, the other end of which is pivoted to the third arm 21c of the bell-crank.

The "normal operating position" of the nut 48a and lever 49 are shown in dotted lines in the drawing. In such condition, the pivot pin 49a "floats" freely in the elongated slot 51a, so as to have no effect on the governing mechanism.

The operation of the entire system is as follows.

First, it is to be noted that the governing system as shown in the drawing represents the "quick-starting condition" with the boiler just about to be fired. As indicated by the legend on the drawing, solid arrows indicate fluid flow as it occurs in normal operation, dotted arrows represent the fluid during the quick-starting cycle, and the dot-dash lines represent the paths of the various condition-sensing signals. Now, let it be assumed that the entire plant, including the steam-generating apparatus 1, 2, 5 is shut down. The manual hand-wheel 33 will be turned by a spring 19 and the main operating piston 17a will be at the bottom of its stroke so that both valves 13b and 46a will be closed, as shown. Since the preemergency governor 30 is not running, lever 31 will tend to assume its uppermost position, so that pilot 6f is raised to effect communication of operating liquid to actuator 6c. (In the drawing, pilot 6f is shown lowered, for a reason to be seen shortly.)
If now it is desired to start the plant, supply of cooling water to the condenser by way of conduits 9a, 9b will be initiated. Other turbine auxiliaries such as a separately driven pump for supplying lubricating oil to the bearings and hydraulic actuating liquid to the governor will be put into operation. These are conventional components and are therefore not shown in the figure.

To condition the governing mechanism for the quick-starting cycle, the hand-wheel 48 is rotated so that nut 48a travels to the left on lead-screw 48b, whereupon pivot 49a engages the left-hand end of slot 51a and pulls link 50a to the right so as to cause bell-crank 51 to rotate counterclockwise and thereby move link 29 downwardly, overpowering the pre-emergency speed governor 30. This causes pilot 6f to drain the operating liquid from motor 6c, and the intercept valve member 6b descends to closed position, as shown. Next it is necessary to open the manual high pressure bypass shutoff valve 42 and the manual turbine bypass shutoff valve 43.

Now with the condensate pump 10 and boiler feed pump 11 operating, the boiler 1 may be fired, and the temperature and pressure of the steam in the superheater discharge conduit 2a begins to rise. When the superheater discharge pressure reaches a value slightly higher than rated pressure, the pressure detector 35 causes the pressure regulating valve 34 to open, and thereafter holds the superheater discharge pressure constant at that value. The pressure of the steam flowing from the superheater to the reheater is reduced at the pressure-reducing orifice 41 to the reheater pressure which may be around 400 to 500 p. s. i. Specifically, when the reheater discharge pressure rises to a preselected value, the pressure detector 45 causes steam bypass valve 43a to open, and steam begins to flow from the reheater 5 to the condenser 9 by way of conduit 5b and the pressure-reducing desuperheater 33. Simultaneously, the water supply valve 43b is opened and the water sprays 33d, 33e, effect an appropriate reduction of temperature of the steam entering the condenser so that the condenser tubes will not be damaged.

Increasing the firing rate of the boiler will now cause the discharge temperature of the superheater and reheater to progressively rise and the rate of flow through the turbine bypass conduit 5b to increase, with pressure regulating valve 43c maintaining a constant pressure in the discharge conduits 5a, 5b of reheater 5. The boiler firing rate is gradually brought up to a value which will produce conditions of 900°F and 900 p. s. i. in the superheater discharge conduit 2a. Control of the firing rate determines the superheater discharge temperature, and the pressure detector 35 controlling the high pressure bypass valve 34 holds the superheater discharge pressure at the desired value. The orifice 41 reduces this pressure, and the temperature detector 38 controlling the desuperheater water valve 37 maintains the temperature at the discharge side of the reheater at a value of perhaps about 900°F, which value is carefully selected to be no more than a safe differential from the temperature of the still-hot turbine parts during the quick-starting cycle.

As noted above, the turbine bypass regulating valve 43a maintains the reheater discharge pressure in conduits 5a, 5b at a preselected value between 400 and 500 p. s. i. The capacity of the high pressure bypass 2b and the turbine bypass conduit 5b is adequate to permit the steam generator 1, 2, 5 to operate at about one-quarter of its maximum firing rate. This is sufficient to permit the boiler to be brought up to the desired discharge conditions, which rate is of course a function of the boiler operating characteristics. It is necessary here to note only that the capacity of the bypass conduits must be sufficient to permit the steam generator to develop the desired operating pressure with its entire output going through the bypass to the condenser, none passing through the turbines.

It will be seen that now there is available steam at appropriate pressures and temperatures for operating both the high pressure turbine 4 and the intermediate pressure turbine 7. Therefore, the turbines may be started by rotating the hand-wheel 32 so pilot 18a is permitted to move upwardly and operating liquid is supplied to the lower end of hydraulic cylinder 17b to move piston 17a up and begin to operate the governing valve position in the intercept bypass valve 46a. Thus steam at substantially the temperature of the hot inlet parts of the turbine is caused to flow simultaneously through both high pressure turbine 4 and intermediate pressure turbine 7. Since the intercept valve 46a is open, steam from the high pressure turbine 4 through conduit 4a goes to the reheater 5 and, if the flow through valve 13b is larger than that through valve 46a, a part of the steam passing the high pressure turbine will flow through the bypass conduit 5b directly to the condenser.

When valves 13b and 46a are about 3/4 open, the rate of flow is sufficient to drive the turbine rotors at normal operating speeds. This of course means that the main operating governor 23 and the pre-emergency governor 39 are rotating at normal speed. The main starting hand-wheel 32 can now be backed away from lever 19 so governor 23 controls the speed of the turbine; but nut 48a of the quick-starting hand-wheel 48 is still in the full-line position so it overpowers the pre-emergency governor 30 and holds the intercept valve 6 closed.

The turbines are now operating at normal rated speed. The electric driver generated by the turbines may now be interconnected with the power distributing network (not shown). With load thus applied to the turbines, the operating governor 23 causes hydraulic motor 17 to begin to open the main governing valve 15a. Continued upward movement of piston 17a causes the three-arm lever 21 to rotate counterclockwise so that link 51 moves to the left relative to pivot 48a. Thus, the "governor mechanism" releases link 29 of the pre-emergency governor, gradually causing pilot 6f to lift and open the intercept valve in proportion to further control valve movement.

Meanwhile the turbine bypass valve 43a and the high pressure bypass valve 34 have progressively closed, in the following manner. As noted above, valves 34 and 43 are arranged to maintain a preselected superheater and reheater discharge pressure respectively. When the turbine governing valves are opened and steam is admitted to the turbines, the superheater and reheater pressure tend to drop, thus permitting the controlling valves progressively to close in attempting to keep the respective pressures constant.

In this way the automatic pressure regulating valves 34 and 43a automatically reduce progressively, and then stop entirely, the flow through the high pressure bypass 2b and the turbine bypass 5b when motive fluid is admitted to the turbine.

The invention provides a comparatively simple addition to the governing systems known to the prior art, by which the boiler can be operated at a reduced rate, with no flow through the turbines until the proper steam conditions are obtained. This is effected by a bypass system which maintains all portions of the steam generating equipment at safe temperatures and pressures and discharges the bypassed steam safely into the condenser. The specially arranged turbine inlet valves 13b, 46b effect supply of motive fluid to the high pressure and intermediate turbines at an rpm sufficient to keep the turbines at an adequate temperature and drive the rotors at normal operating speed at "no load." The main intercept valve 6 remains closed until the electrical generators are synchronized, after which the intercept valve gradually opens so that a high reheater pressure is maintained in connection with its control valve in the unit. This is necessary to allow the boiler to keep the temperature of the reheat steam at 900°F or above, which is necessary to start the hot turbine safely. As the load is increased
to rated load, the intercept valve will be opened wide and normal operating conditions are resumed. Once in normal operation, the quick-starting hand-wheel 48 may be rotated so nut 48a assumes the dotted line position shown in the drawing, in which condition pivot 49a merely floats freely in the slot 51a so as to have no effect on the governing mechanism.

With this arrangement, it is possible to start safely a high temperature reheate type turbine in a period of 15 or 20 minutes, as compared with several hours required without the invention. Thus it becomes feasible to shut down a large reheat turbine plant promptly when the load falls at night, shutting down the associated boiler entirely and refiring the boiler and restarting the turbine in the morning when the load on the power system begins to increase.

The special emergency stop valves 40, 47, in addition to the conventional main stop valve 3, are under the control of the emergency governor 28 to provide full emergency over-speed protection both during the quick-starting cycle and during normal operation.

An additional advantage of the system is that if, during normal operation, the load is suddenly removed from the turbines, so the governing valves 13 suddenly close, the pressure in conduit 2a will rise and pressure detector 35 will cause valve 34 to open and motive fluid to be diverted through bypass 2b, whereupon the bypass valve 43 opens up the reheat turbine and has discharged condenser, until the boiler controls can react to reduce the firing rate to the "no-load" condition. This provides an additional safety feature and operation convenience.

While only one specific embodiment has been described herein, and that in quite diagrammatic fashion, it will be apparent that many changes and substitutions of equivalents may be made without departing from the invention. 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 we claim as new and desire to secure by Letters Patent of the United States is:

1. In a reheat turbine powerplant having in series a boiler, superheater, high pressure turbine, reheater, main intercept valve, intermediate pressure turbine, and condenser, the combination of a first steam conduit communicating between the superheater and the reheater outlet, automatic pressure-regulating valve means for maintaining the pressure of the steam discharged from the superheater at a first preselected high value, means for maintaining the pressure at the outlet of the reheater at a value below said first pressure, means for reducing the pressure and temperature of steam entering the condenser through said fourth conduit, and means for opening both the first governing valve means and the intercept bypass valve while the main intercept valve remains closed, whereby comparatively cool steam may be bypassed around the turbines directly to the condenser in starting and warming up the boiler.

2. In a reheat turbine powerplant having in series a boiler, superheater, high pressure turbine, reheater, main intercept valve, intermediate pressure turbine and condenser, the combination of a first steam conduit communicating between the superheater and the high pressure turbine inlet and having first governing valve means, a second steam conduit in parallel with the intercept valve and communicating between the reheater discharge and the intermediate pressure turbine inlet, an intercept bypass valve in said second conduit, a high pressure bypass conduit connecting between the superheater and the reheater inlet, automatic pressure-regulating valve means for maintaining the pressure of the steam discharged from the superheater at a first preselected high value, automatic desuperheater means for injecting water into the bypassed steam entering the reheater through said third conduit for maintaining the temperature of the steam entering the condenser through said fourth conduit, automatic desuperheater means for injecting water into the bypassed steam entering the reheater through said fourth conduit, whereby the boiler may be operated at a limited rate to establish normal operating conditions therebetween with the steam flowing through said fourth bypass conduit direct to the condenser while said governing valve, main intercept valve, and intercept bypass valve remain closed, and means for opening said governing valve and intercept bypass valve substantially simultaneously while the main intercept valve remains closed, whereby steam may be admitted to the high pressure and intermediate pressure turbines for bringing the rotors thereof up to normal speed while excess steam is bypassed to the condenser.

3. In a reheat turbine powerplant having in series a boiler, superheater, high pressure turbine, reheater, main intercept valve, intermediate pressure turbine, and condenser, the combination of a first steam conduit communicating between the superheater and the high pressure turbine inlet and having first governing valve means, a second steam conduit in parallel with the intercept valve and communicating between the reheater discharge and the intermediate pressure turbine inlet, automatic pressure-regulating valve means for maintaining the pressure of the steam discharged from the superheater at a first preselected high value, automatic desuperheater means for injecting water into the bypassed steam entering the reheater through said third conduit for maintaining the temperature of the steam entering the condenser through said fourth conduit, automatic desuperheater means for injecting water into the bypassed steam entering the reheater through said fourth conduit, whereby the boiler may be operated at a limited rate to establish normal operating conditions therebetween with the steam flowing through said fourth bypass conduit direct to the condenser while said governing valve, main intercept valve, and intercept bypass valve remain closed, and means for opening said governing valve and intercept bypass valve substantially simultaneously while the main intercept valve remains closed, whereby steam may be admitted to the high pressure and intermediate pressure turbines for bringing the rotors thereof up to normal speed while excess steam is bypassed to the condenser.

4. In a reheat turbine powerplant having in series a boiler, superheater, high pressure turbine, reheater, main intercept valve, intermediate pressure turbine and condenser, the combination of a first steam conduit communicating between the superheater and the high pressure turbine inlet and having first governing valve means, a second steam conduit in parallel with the intercept valve and communicating between the reheater discharge and the intermediate pressure turbine inlet, automatic pressure-regulating valve means for maintaining the pressure of the steam discharged from the superheater at a first preselected high value, automatic desuperheater means for injecting water into the bypassed steam entering the reheater through said third conduit for maintaining the temperature of the steam entering the condenser through said fourth conduit, whereby the boiler may be operated at a limited rate to establish normal operating conditions therebetween with the steam flowing through said fourth bypass conduit direct to the condenser while said governing valve, main intercept valve, and intercept bypass valve remain closed, and means for opening said governing valve and intercept bypass valve substantially simultaneously while the main intercept valve remains closed, whereby steam may be admitted to the high pressure and intermediate pressure turbines for bringing the rotors thereof up to normal speed while excess steam is bypassed to the condenser.
means for maintaining the pressure of the steam discharged from the superheater at a first preselected high value, automatic desuperheater means for maintaining the temperature of the steam discharged from the reheater at a preselected value, a fourth conduit communicating between the reheater and the condenser, orifice means for reducing the pressure of steam admitted through said fourth conduit to the condenser, second automatic desuperheater means for injecting water for limiting the temperature of the steam entering the condenser, whereby the boiler may be brought up to normal operating conditions with all the steam generated therein flowing directly to the condenser, and means for opening said first and second valves to admit steam to the high pressure and intermediate pressure turbines and bring the rotors thereof up to normal speed while excess steam is bypassed from the reheater through said fourth conduit to the condenser.

5. In governing mechanism for a reheat turbine powerplant having conduits connecting in series a boiler, superheater, high pressure turbine, reheater, main intercept valve, intermediate pressure turbine, and condenser, the combination of first governing valve means controlling the admission of steam to the intermediate pressure steam turbine, second intercept valve means controlling the admission of steam to the intermediate pressure steam turbine through said bypass conduit means, first motor means controlled by a main operating governor for opening said first and second valves simultaneously, second motor means actuating the main intercept valve, pre-emergency speed governor means connected to said second motor means and adapted to open the main intercept valve only after said first and second valve means have opened a preselected amount, and means for disabling the second motor means whereby the first and second valve means may be opened to admit motive fluid simultaneously to the high pressure and intermediate pressure turbines while the main intercept valve remains closed.

6. Governing mechanism in accordance with claim 5 in which the mechanism for disabling the second motor means comprises an overriding lever member for positively maintaining the intercept valve closed, adjustable fulcrum means adapted to move one end of said lever from a starting position to a normal operating position, first linkage means connecting the opposite end of said lever to position the intercept valve in the closing direction, and second linkage means including a member positioned in accordance with the motion of the first and second valves and having a lost-motion connection with an intermediate portion of said lever, said lost-motion connection constituting an operating fulcrum for said lever when the first and second valves are closed, whereby the main intercept valve may be closed by moving said adjustable fulcrum to the starting position, said lost motion connection permitting free motion of said lever without effect on the main intercept valve after movement of said fulcrum to normal operating position.

7. Governing mechanism in accordance with claim 5 in which the mechanism for disabling the second motor means comprises an overriding lever member for maintaining the main intercept valve closed during a preselected initial movement of the first motor means in the direction to open the first and second valves and for positioning the main intercept valve proportional to further movement of said first motor means, adjustable fulcrum means for moving one end of the lever from a starting position to a normal operating position, first linkage means connecting the opposite end of said lever to the second motor means, and second linkage means including a member positioned in accordance with motion of the first motor means and having a lost motion connection with an intermediate portion of said overriding lever member, whereby the main intercept valve is subject to the control of the pre-emergency governor when said adjustable fulcrum is in normal operating position, said second linkage means serving to override the pre-emergency governor and maintain the main intercept valve closed while the first and second valve means move said preselected initial portion of their travel.

8. In governing mechanism for a reheat turbine powerplant having conduits connecting in series a boiler, superheater, high pressure turbine, reheater, main intercept valve, intermediate pressure turbine, and condenser, the combination of first governing valve means regulating the admission of steam to the high pressure turbine, other conduit means for opening said bypass valve means and communicating between the reheater and the intermediate pressure turbine, first motor means for opening said first and second valves simultaneously and including a motor controlled by a main operating governor, second motor means for opening the main intercept valve and including a motor controlled by a pre-emergency speed governor, means for disabling said second motor means whereby the main intercept valve remains closed while the first motor means moves the first and second valve means in the opening direction up to a preselected limit, and means for disabling the main intercept valve proportional to movement of the first and second valve means above said limit whereby a higher than normal reheater pressure is maintained during part load operation of the turbine.

9. In a reheat turbine powerplant having steam generating means for supplying motive fluid at a first preselected high pressure to a high pressure turbine, steam reheating means, main intercept valve means for controlling the flow of motive fluid from the reheater to an intermediate pressure turbine, and a condenser, the combination of first governing valve means for controlling the flow of motive fluid from the steam generator to the high pressure turbine, means defining a bypass passage with first bypass valve means for admitting motive fluid to the intermediate pressure turbine independently of said main intercept valve means, second bypass conduit means with pressure reducing means for supplying motive fluid from the steam generator to the reheater inlet at a pressure substantially below said first pressure, and third bypass conduit means communicating between the reheater outlet and the condenser and having valve means for determining the flow therethrough, means for reducing the pressure and temperature of steam entering the condenser through said third bypass conduit, and means for opening the first and second and the first bypass valve means while the main intercept valve remains closed, whereby steam may be bypassed from said generating means to the condenser during the starting cycle of the powerplant.

10. In a reheat turbine powerplant having in series steam generating means, a high pressure turbine, steam reheating means, main intercept valve means, an intermediate pressure turbine, and a condenser, the combination of first governing valve means for admitting a limited flow of steam to the high pressure turbine adequate to establish normal operating conditions therein at no load, first bypass conduit means in parallel with said main intercept valve and communicating between the reheater and the intermediate pressure turbine, second valve means for admitting steam through said first bypass conduit at a limited rate to the intermediate pressure turbine adequate to establish normal operating conditions therein at no load, second high pressure bypass conduit means communicating between the steam generator outlet and the reheater inlet, means for maintaining the pressure of the steam at the outlet of the steam generator at a first preselected high value, means for maintaining the temperature of the steam discharged from the reheater at a preselected value, third bypass conduit means communicating between the reheater outlet and the condenser, means for limiting to preselected safe values the pressure and tem-
perature of the steam entering the condenser through said third bypass conduit, whereby the steam generating means may be operated to establish normal steam operating conditions with all the steam from the generator flowing to the condenser without passing through the turbines, and means for opening said first and second valve means to admit steam simultaneously to the high pressure and intermediate pressure turbines and establish normal operating conditions therein while said main intercept valve means remains closed and any excess steam produced by the generator is bypassed from the reheater through said third conduit to the condenser.

11. In governing mechanism for a reheat turbine powerplant having conduits connecting in series a steam generator, high pressure turbine, reheater, main intercept valve, intermediate pressure turbine, and condenser, the combination of first governing valve means regulating the admission of steam to the high pressure turbine, bypass conduit means with second bypass valve means communicat

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