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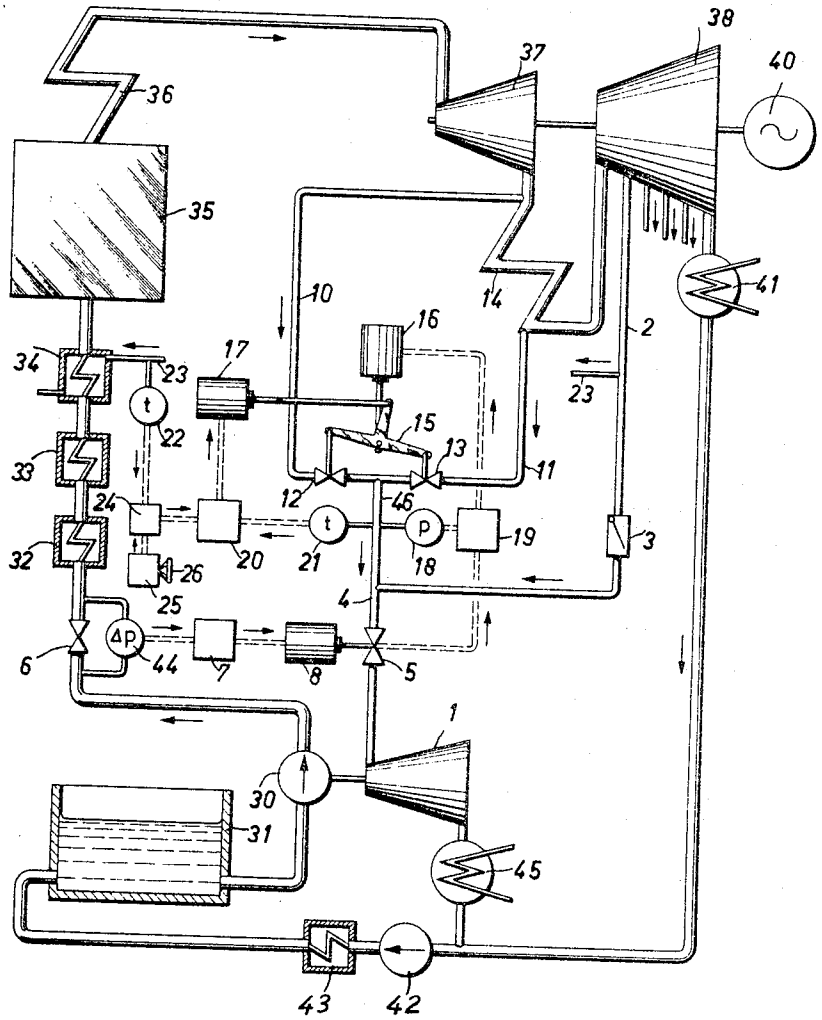

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METHOD AND APPARATUS FOR SUPPLY OF STEAM TO AN AUXILIARY TURBINE IN A STEAM POWER PLANT

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The present invention pertains to a method and apparatus for supply of steam to an auxiliary turbine in a steam power plant in which at least part of the steam is reheated at least once between stages of the main turbine and in which the auxiliary turbine is supplied with steam which, according to the load on the system, is tapped from a stage of the main turbine itself fed with partly expanded and reheated steam, or is withdrawn upstream of such stage.

In steam power plants, feed-water pumps are commonly driven by auxiliary turbines. Thus it is known to supply such an auxiliary turbine, according to the load on the plant, either with steam tapped from a low pressure stage of the main turbine or else with steam drawn from a reheater working at appropriate pressure. The point of withdrawal for the steam from the reheater is so chosen that the temperature of the steam entering the auxiliary turbine does not change sharply on a shift between one and the other of these two sources of supply. In this way, the auxiliary turbine need be designed and exposed only to a limited range of temperatures, and in particular need not be exposed to higher temperatures.

The method of the present invention provides another solution to this problem and is characterized by the fact that after a shift to supply of the auxiliary turbine with steam withdrawn upstream of the said low pressure stage of the main turbine, one part of the steam for the auxiliary turbine is taken upstream and another part is taken downstream of the reheater (which itself is upstream of that stage), and further by the fact that both fractions are mixed together upstream of the auxiliary turbine. In this way, in contrast to prior proposals, there is achieved the result that this reheater, and especially the downstream (and normally hotter) end thereof, is cooled with a larger volume of steam, because only part of the steam employed in the auxiliary turbine is withdrawn from the main steam channel upstream of this part of the reheater.

The withdrawals of steam upstream and downstream of the reheater may advantageously be so effected that the temperature of the mixed steam resulting from mixture of these withdrawals is adjusted as a function of the steam temperature at the tapping point of said low temperature stage (or as a function of a steam temperature representative of the temperature at that tapping point), when that tapping point steam temperature lies above a limiting value, whereas the temperature of the mixed steam is held constant as soon as the temperature of the steam at that tapping point falls below a limiting value, which may of course be an adjustable one.

In order to permit a convenient preheating of the parts of the plant here in question, it is moreover advantageous to supply to the auxiliary turbine a small amount of steam drawn from the system upstream of the main turbine stage driven by partially expanded steam already referred to, even under load conditions where the supply of the auxiliary turbine is effected by steam tapped from that stage.

The apparatus for practice of the method of the invention is characterized by the fact that upstream and downstream of a reheater, side conduits lead off into the supply line for the auxiliary turbine, at least one of these branch lines including a throttling element.

The apparatus may advantageously be so constructed that each of these two branch lines includes a valve, subjected to adjustment in opposite senses as a function of the temperature of the steam in the inlet to the auxiliary turbine.

Lastly, in order to prevent the temperature of the steam admitted to the auxiliary turbine from falling below a specified limiting value, it is desirable that the reference level signal for the controller which adjusts the temperature of the mixed steam (by adjusting the fractions in the mix) be supplied to a comparator device which receives separate signals representative of the tapping point steam temperature and of an adjustably fixable limiting value, this device transmitting to that controller only the signal representative of the larger of these two temperatures.

The invention will now be described further with reference to the accompanying drawings in which the single figure of drawings is a diagram of a steam power plant according to the invention.

Referring to the annexed drawings, the auxiliary turbine 1 drives the feed pump 30. This pump forces water from a feed-water supply vessel 31 through a feed valve 6, through preheaters 32, 33 and 34 and into the steam generator or evaporator 35. The steam generated in the evaporator 35 is superheated in the superheater 36 before undergoing partial expansion in the high pressure turbine 37. After reheating in the reheater 14, the steam thus partially expanded in the turbine 37 is further expanded in the low pressure turbine 38 before being delivered to a condenser 41 for condensation. The two turbines 37 and 38 are coupled together and to an electric generator 40. The condensate is supplied through a condensate pump 42 and preheater 43 back into the feed-water supply vessel 31.

The preheaters 32, 33, 34 and 43 may be heated either by gaseous products of combustion from the fire which serves the evaporator 35, superheater 36 and reheater 14, or they may be heated with tapped steam, as is illustrated in the case of the preheater 34, for which there is shown a line 23 connecting into the line 2, the latter of which serves for withdrawal of steam from the turbine 38 at an intermediate pressure stage thereof.

On starting up of the plant the pump 30 is either driven by an auxiliary motor (not shown) or the auxiliary turbine 1 is supplied with steam from an auxiliary steam source, again not shown, until the steam necessary for operation of the feed pump may be withdrawn from the power plant itself. Alternatively, for starting up, there may be provided a second feed pump, connected in parallel with the pump 30, and driven from a separate motor.

Under conditions of full load the auxiliary turbine is supplied with steam through the tapping line 2, which contains a check valve 3 and which leads into the inlet line 4 to the auxiliary turbine, in a fashion known in and of itself. A steam valve 5 is provided in the line 4. This valve is adjusted in setting by means of servomotor 8 in accordance with the pressure differential existing across feed valve 6, as measured at a pressure difference measuring device 44 whose signal is delivered to a controller 7 for operation of the servomotor 8. The steam which leaves the auxiliary turbine is condensed in a condenser 45 from which it is returned by the condensate pump 42 into the feed-water supply vessel 31.

In accordance with the invention the input line 4 leads, via a section 46, through branch lines 10 and 11 to points in the main steam channel which are respectively upstream and downstream of, i.e. at the inlet and outlet of, the reheater 14, branch lines 10 and 11 con-

taining respectively valves **12** and **13**. These valves are adjusted by means of the servomotors **16** and **17**, operating on the valves through the three-armed lever **15**. Servomotor **16**, which is the faster operating one of the two, constitutes the parameter adjusting element of a pressure control loop including the pressure measuring device **18** and the controller **19**. The pressure controller **19** receives a signal from the valve **5**, representative of the setting of the latter, and this signal, for openings of the valve above a specified value, serves to raise the reference value to which the pressure *p* at **18** is controlled by the loop including elements **18**, **19** and **16**. The loop including elements **18**, **19** and **16** thus adjusts the openings of valves **12** and **13** in the same sense to hold the pressure in line **46** at a value dependent on the opening of valve **5**, which in turn depends on the setting of the main feed-water control valve **6**.

The more slowly operating parameter adjusting servomotor **17** responds to the output of a controller **20**. By the differential action of servomotor **17** on valves **12** and **13**, controller **20** operates to maintain the temperature of the steam mixture in line **46**, as measured at **21**, at a value defined by a signal delivered to controller **20** from the comparison device **24**. This device receives a signal representative of actual temperature from the temperature measuring device **22** in line **23** and a signal from the limiting value signal generator **25**. By means of a handwheel **26** the signal from the generator **25** can be set at any desired value. This value sets the lower limit to the temperature, as measured at **21**, of the mixture of steam to be admitted through lines **46** and **4** into the auxiliary turbine. The comparison device **24** serves to choose the signal representative of the higher of the two temperatures supplied to it and to supply this higher temperature as a reference value to the controller **20**. In this way upon shift, with declining load, from feed of the auxiliary turbine with steam tapped at line **2** from the low pressure stages of turbine **38** to steam drawn at lines **10** and **11** upstream of this turbine, the temperature of the steam mixture in the line **46** will remain substantially equal to the temperature which prevails with declining load at the tapping point of line **2** (and which is measured at **23** even after such shift), until the limiting temperature setup at generator **25** is reached. If the load on the plant declines further so that the tapped steam temperature measured at **23** falls below this limiting value, the device **24** will supply to the controller **20** as a reference the limiting temperature signal from generator **25**. This apparatus has accordingly the function of preventing sudden changes in the temperature of the steam supplied to the auxiliary turbine.

Under conditions of full load the valve **5** will be less than completely open. It therefore imposes a slight throttling on the steam flow to the auxiliary turbine. The pressure reference value signal which is transmitted from the valve **5** to the controller **19** is consequently lower than the actual pressure measured at **18**. The valves **12** and **13** are therefore held both nearly closed by servomotor **16**. A small flow of steam is however maintained through the lines **10**, **11** and **46** and through the valves **12** and **13**, even when the auxiliary turbine is being fed with steam tapped from turbine **38** at line **2**, in order that these elements **10**, **11**, **46**, etc. of the system may remain at approximately their correct operating temperatures.

If the load now declines, the pressure of the steam in line **2** will decline. In consequence, by operation of the control loop comprising elements **18**, **19** and **16**, the opening of valves **12** and **13** will be increased. This effect is reinforced by the fact that with declining steam pressure in the line **2**, the valve **5** will open beyond the limiting or critical value therefor, inasmuch as the output of the auxliary turbine will not have declined correspondingly. This raises the reference value signal for pressure delivered from valve **5** to controller **19**, which in turn produces a rapid response of the control elements **16**, **18** and **19**, opening valves **12** and **13** as above indicated. The control loop comprising elements **17**, **20** and **21** will now trim the settings of the valves **12** and **13** differentially, i.e. in opposite senses, so that the temperature of the steam mixture in line **4**, derived from steam drawn both upstream and downstream of the reheater **14**, will be equal to the instantaneous temperature of steam tapped at line **2**, measured at **22**. The transfer of the control over the mixed steam temperature at controller **20** to a fixed limiting temperature which occurs in the event of a further decline in load has already been described.

Since the temperature and pressures of the boiler appropriate to various steam plant loads are at least approximately known, the control functions which have been described can also be accomplished by deriving in a load-representative signal generating device suitable control signals for the setting of valves **12** and **13** (as by servomotor **16**) or, alternatively, only for the trimming thereof (as by servomotor **17**).

The invention is not restricted to the system shown and described having a single reheater. Rather, it can be applied to plants having plural reheating stages. In such applications it is possible to extend the shift in auxiliary turbine supply, as a function of pressure changes, to include shift in supply from a reheater operating at one pressure range to another reheater operating at a higher pressure range. Optionally, this may be carried out with the provision of an intervening range of pressures over which the steam for the auxiliary turbine is drawn as tapped steam from a turbine disposed between the two reheaters. In such systems the supply of steam from the reheaters may include withdrawal of steam both upstream and downstream of each reheater as it is employed in turn, in accordance with the invention.

In certain of the appended claims reference is made to the high and low pressure stages of a main turbine. This is equivalent terminology of the high and low pressure turbines which are separately recited in certain other claims and which have been hereinabove identified respectively with elements **37** and **38** in the drawing. In addition, use is made in certain of the appended claims of the concept of a steam channel in which a high pressure turbine, a reheater and a low pressure turbine are connected in series. With reference to the drawing this main steam channel extends in part from the evaporator **35** through the superheater **36**, high pressure turbine **37**, reheater surface **14**, low pressure turbine **38** and condenser **41**. In that channel the elements **37**, **14** and **38** are clearly seen to be connected in series for steam flow.

The operation of the control loop **19**, **16** and **18** may be further understood from a recognition of the fact that at high plant load the valve **5** will be nearly wide open and specifically will be in the range of openings where the pressure reference signal delivered from valve **5** to controller **19** varies directly with that opening. Under these load conditions however the pressure in the tapping line **2** is also high so that the pressure measured at **18** will be higher than that defined by the signal received by controller **19** from valve **5**. With this inequality of input signals to the controller, the controller will hold valves **12** and **13** closed except for such minimum opening thereof as may be desired in order to maintain the conduits **10** and **11** at operating temperature. Upon a decline in load, the pressure at the tapping line **2** and hence at **18** also will decline, thus reversing the inequality of input signals to controller **19**. In consequence the loop **18**, **19** and **16** will open the valves **12** and **13**, substituting in the supply of turbine **1** a mixture of steam drawn through branch conduits **10** and **11** for steam tapped from the turbine **38** at **2**. The check valve **3** will prevent back-flow of steam from line **46** through line **2** and into turbine **38**.

I claim:

1. The method of supplying steam to an auxiliary turbine in a steam power plant having a steam reheating surface between high and low pressure stages of a main turbine which comprises tapping steam for said auxiliary turbine from one of said low pressure stages at high plant load and, at lower plant load, withdrawing steam both upstream and downstream of said surface and mixing the steam so withdrawn before supplying it to the auxiliary turbine.

2. The method of supplying steam to an auxiliary turbine in a steam power plant having a steam reheating surface between high and low pressure stages of a main turbine which comprises withdrawing steam both upstream and downstream of said surface, mixing the steam so withdrawn before supplying it to the auxiliary turbine, and adjusting the ratio of steam withdrawn upstream of said surface to steam withdrawn downstream of said surface in accordance with differences between the temperature of said mixed steam and the temperature of steam tapped at said low pressure stage for values of said tapped steam temperature above a lower limit.

3. The method of supplying steam to an auxiliary turbine in a steam power plant having a steam reheating surface between high and low pressure stages of a main turbine which comprises withdrawing steam both upstream and downstream of said surface, mixing the steam so withdrawn before supplying it to the auxiliary turbine, adjusting the ratio of steam withdrawn upstream of said surface to steam withdrawn downstream of said surface in accordance with differences between the temperature of said mixed steam and the temperature of steam tapped at said low pressure stage for values of said tapped steam temperature above a lower limit, and adjusting said ratio in accordance with differences between the temperature of said mixed steam and a fixed temperature for temperatures of steam tapped at said low pressure stage below said lower limit.

4. The method of supplying steam to an auxiliary turbine in a steam power plant having a steam reheating surface between high and low pressure stages of a main turbine which comprises tapping steam from one of said low pressure stages, withdrawing steam both upstream and downstream of said surface, mixing the steam so withdrawn, supplying said auxiliary turbine under conditions of high plant load preponderantly with steam so tapped, and supplying said auxiliary turbine under conditions of low plant load preponderantly with steam so withdrawn.

5. In a steam power plant having a high pressure main turbine, a steam reheating surface, and a low pressure main turbine connected in series for steam flow, apparatus for the supply of steam to an auxiliary turbine comprising means to withdraw steam from a stage of said low pressure turbine, separate means to withdraw steam both upstream and downstream of said surface, and valve means included in at least one of said separate withdrawal means.

6. In a steam power plant having a high pressure main turbine, a steam reheating surface, and a low pressure main turbine connected in series for steam flow, apparatus for the supply of steam to an auxiliary turbine comprising means to withdraw steam from a stage of said low pressure turbine, separate means to withdraw steam both upstream and downstream of said surface, a separate valve in each of said last-named separate withdrawal means, and means to shift the settings of said valves differentially as a function of the temperature of steam flowing into said auxiliary turbine.

7. In a steam power plant having a high pressure main turbine, a steam reheating surface, and a low pressure main turbine connected in series for steam flow, apparatus for the supply of steam to an auxiliary turbine comprising means to withdraw steam from a stage of said low pressure turbine, separate means to withdraw steam both upstream and downstream of said surface, a separate valve in each of said last-named separate withdrawal means, and means to shift the settings of said valves differentially as a function of the temperature of steam flowing into said auxiliary turbine for values of said temperature above a lower limit.

8. In a steam power plant having a steam channel including a high pressure turbine, a steam reheating surface and a low pressure turbine all connected in series in said channel, apparatus for the supply of steam to an auxiliary turbine, said apparatus comprising means to withdraw steam from said low pressure turbine, separate means to withdraw steam from said channel upstream and downstream of said surface, a separate flow control means in each of said last-named separate withdrawal means, a delivery conduit leading into said auxiliary turbine, said delivery conduit connecting with said withdrawal means, a valve in said delivery conduit, means responsive to the opening of said valve to generate a pressure reference signal, means to develop a signal representative of the pressure in said delivery conduit, servo-mechanism responsive to differences between said pressure representative and pressure reference signals to adjust both of said flow control means in the same sense, separate means to develop signals representative of the temperature of said delivery conduit and of said first-named withdrawal means, and servo-mechanism responsive to differences between said last-named two signals to adjust said flow control means in opposite senses.

9. In a steam power plant having a steam channel including a high pressure turbine, a steam reheating surface and a low pressure turbine all connected in series in said channel, apparatus for the supply of steam to an auxiliary turbine, said apparatus comprising means to tap steam from a stage of said low pressure turbine, separate branch conduits for withdrawal of steam from said channel upstream and downstream of said surface, a separate flow control means in each of said branch conduits, a delivery conduit leading into said auxiliary turbine, said delivery conduit connecting with said tapping means and with said branch conduits, a valve in said delivery conduit, means responsive to the opening of said valve to generate a pressure reference signal, means to develop a signal representative of the pressure in said delivery conduit, servo-mechanism responsive to differences between said pressure representative and pressure reference signals to adjust both of said flow control means in the same sense, separate means to develop signals representative of the temperature of said delivery conduit and of said tapping means, means to develop a signal representative of a lower limit for the temperature of said tapping means, means to select between the signal representative of the temperature of said tapping means and the signal representative of said lower limit the one representative of higher temperature, and means responsive to differences between said selected signal and the signal representative of delivery conduit temperature to adjust said flow control means in opposite senses.

10. In a steam power plant having a steam channel including a high pressure turbine, a steam reheating surface and a low pressure turbine all connected in series in said channel, apparatus for the supply of steam to an auxiliary turbine, said apparatus comprising a tapping conduit for withdrawal of steam from a stage of said low pressure turbine, separate branch conduits for withdrawal of steam from said channel upstream and downstream of said surface, a separate valve in each of said branch conduits, a check valve in said tapping conduit, a delivery conduit leading into said auxiliary turbine, said delivery conduit connecting with said tapping conduit and with said branch conduits, a valve in said delivery conduit, means responsive to the opening of said last-named valve to generate a pressure reference signal, means to develop a signal representative of the pressure in said delivery conduit upstream of the valve therein, servo-mechanism responsive to differ-

ences between said pressure representative and pressure reference signals to adjust in the same sense the valves of said branch conduits, separate means to develop signals representative of the temperature of said delivery conduit and of said tapping conduit, means to develop a signal representative of a lower limit for said tapping conduit temperature, means to select between the signal representative of the temperature of said tapping conduit and the signal representative of said lower limit the one representative of higher temperature, and means responsive to differences between said selected signal and the signal representative of delivery conduit temperature to adjust the valves in said branch lines differentially.

No references cited.

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