STEAM POWER STATIONS

Inventor: Pierre Henri Pacault, Ville D'Avray, France

Assignee: Babcock-Atlantique Societe Anonyme, Paris, France

Filed: July 10, 1973

Appl. No.: 377,952

Foreign Application Priority Data
July 13, 1972 France 72.25450
Jan. 26, 1973 France 73.02789
Jan. 26, 1973 France 73.02790

U.S. Cl. 60/652; 60/659

Int. Cl. F01K 3/00

Field of Search 60/659, 652

References Cited
UNITED STATES PATENTS
3,108,938 10/1963 Nettel et al. 60/73 X
3,451,220 6/1969 Buscemi 60/73

Primary Examiner—Martin P. Schwadron
Assistant Examiner—Allen M. Ostrager
Attorney, Agent, or Firm—Hopgood, Calimafde, Kalil, Blaustein & Lieberman

ABSTRACT

The steam power station includes an accumulator for storing heat drawn from the operating steam cycle during slack operating periods when the power network demand on the station is low, and restoring the heat to the steam cycle at peak or high-demand periods, to adapt the station to a variable demand network. The transfer of heat between the operating installation of the station, which includes a steam turbine, and the accumulator, is made by way of a heat-transfer fluid which is in heat-transfer relation with the steam of which at least a part has done mechanical work in the turbine. The heat-transfer fluid is reversibly circulated in heat-transfer relation with the steam in such a way that the heat-transfer from the steam to said fluid occurs at substantially the same temperature as the transfer from said fluid to the steam. The installation can also heat feed water returning to the steam generator by tapping off live steam for said heating at the outlet from the generator. The installation can have apparatus for separating into liquid and dry steam partially expanded steam issuing from the turbine, the liquid from that apparatus being vaporised by heat from a heat accumulator supplied with heat from the heat source of the installation; all the liquid is vaporised during high-demand periods while in slack periods all the liquid is restored to the feed water circuit to the steam generator.

29 Claims, 6 Drawing Figures
STEAM POWER STATIONS

BACKGROUND OF THE INVENTION

French Pat. No. 70 21245 of 10 June 1970 discloses a process of accumulating and restoring power, by effecting a reversible transfer of heat between an accumulating medium and at least a working or operating fluid of a steam power generating installation for adapting the installation to a variable-demand network.

A steam power station which is required to serve a variable-demand network, as described in the above-mentioned patent, comprises an installation for storing and restoring energy in the form of heat, to permit the operation of the source of heat energy of the installation to be rendered at least partly independent of fluctuations in the power demands made on the installation by the network.

In the station thus provided, a part of the heat produced by the heat source is stored in an accumulator during periods when the demands of the network are low, which periods may be referred to as slack hours or periods; the stored part of the heat is then restored to the steam cycle during high-demand periods, which may be referred to as peak hours. In the ultimate analysis, this makes it possible for the heat energy source to operate at a constant level of performance, and this is a particularly desirable circumstance when that source is a nuclear reactor.

Such a station generally comprises tappings taken from a driving turbine, which tappings supply heat in known manner to a water station and thus provide for reheating of water returning from the condenser to the boiler of the station.

SUMMARY OF THE INVENTION

The present invention has as one of its objectives to develop this process of accumulation and restoration of heat, to improve it, and to increase the thermodynamic efficiency thereof.

A further object is to make it possible for the drawing off and the restoration of heat to be effected at virtually equal temperature levels and thereby to attain a high degree of efficiency of storage and restoration of energy.

Accordingly, the invention provides for the adaptation of a steam power station to a variable-demand power network, the station comprising a heat source, a steam generator and at least one turbine, by transferring heat between the station installation and an accumulator which is arranged to draw heat from the installation by transfer with a heat-transfer fluid, the heat then being stored in the accumulator and subsequently restored as required for feeding the network. This transfer of heat between the installation and the accumulator is effected by the heat-transfer fluid being placed in heat-exchange relation with the steam from the steam generator, at least a part of the steam having performed mechanical work in the turbine.

The heat-transfer point between the installation and the accumulator can comprise a plurality of steam exchangers and reheaters operating at a series of temperature levels which are stepped or graduated between the temperature of the live steam at the steam outlet from the steam generator, and that of the feed water at the outlet of the tapping from the turbine from which said part of the steam is taken.

Thus, in one embodiment of the invention, there is drawn from the turbine an amount of steam which is greater than that required by the reheaters (which form a so-called water station), and the heat represented by the amount of steam in the excess of that required by the water station is stored. This can be effected by means of a shunt flow circuit on the water circuit, which shunt flow forms an intermediate transmission agent between said excess amount of steam and the heat-carrier fluid of the storage installation.

The invention also provides for the drawing of live steam from the boiler during slack hours, on the one hand for superheating of the exhaust steam from the high-pressure stage of the turbine and on the other hand for increasing the amount of heat stored, again by means of a shunt flow on the water circuit. In peak hours, when it is desired to produce the maximum power from the station, almost all the tappings on the turbine, and any taking-off of live steam from the live steam circuit through the turbine arrangement, are suppressed. In this case it is the stored heat in the accumulator which provides for reheating of the feed water returning to the boiler from the condenser arranged downstream of the turbine, and for reheating of the steam supplied to the low-pressure stage of the turbine.

It will be noted that, if it is desired to maintain constant under all operating conditions, the water reheating and steam resuperheating temperatures, and this is a condition which it is generally desirable to observe, the maximum flow of stored heat, which can be used in restoration periods, is limited in dependence on said temperatures and the nominal output of steam produced in the boiler. Because of this limitation on the amount of heat restored, the station may be incapable of absorbing, during peak hours, all the heat which can be stored during the slack hours.

The present invention therefore has the further object of removing or reducing this disadvantage, that is to say, increasing the capacity for absorption and restoration of the stored heat and reducing or eliminating the difference between the amount of heat offered to the storage installation during slack periods and that which can be used by the operating steam cycle during peak periods, in a station of the kind described above.

Another object is to do this without increasing the number of steam tappings on the turbine, while permitting the temperature of the flow of feed water back to the steam generator to be maintained at a constant level.

For this purpose, the invention proposes mounting on the feed water line to the boiler, downstream of said water station reheaters, a supplementary water reheater which is supplied with heat by live steam taken from the steam generator. This supplementary reheater, which can be referred to as a feed water superheater and which is set in operation during slack hours, has the effect of substantially increasing the inlet temperature of the return water to the boiler, relative to that which can be achieved in said water station; this inlet temperature, which is kept at a substantially constant level under all operating conditions increases in proportion the restoration capacity of the heat storage installation, during peak periods.

Still with the object of reducing or eliminating the difference between the storage capacity and the restoration capacity of the heat storage means, the invention proposes another arrangement which is located more
particularly within the framework of steam power generating stations with a steam cycle in which the basic heat source produces only steam with a low degree of superheating, and in which the exhaust steam of the high-pressure stage of the turbine or turbines contains a substantial amount of moisture, to the point of necessitating an operation of drying the exhaust steam by separation into liquid and vapour phases before re-superheating. This is the case in particular of stations in which the heat source is a nuclear reactor. In the previously proposed drying and re-superheating apparatuses, the water produced by separation is reintegrated into the feed water return circuit to the boiler.

The invention therefore has the additional object of causing vaporisation of this water, as required, with heat from the storage installation. Advantageously, such vaporisation occurs only in restoration periods or at peak hours, whereas in slack periods the condensate water drained from the dryer-resuperheater is reintegrated into the water circuit in accordance with known arrangements. Advantageously, the steam produced in this way is recycled to the drying apparatus for separation and re-superheating.

This arrangement presents a particular advantage in nuclear steam power stations, as it facilitates keeping the reactor under constant operating conditions, this being done by making use of an apparatus, namely the dryer-superheater, which is generally associated with such stations.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a diagrammatic view showing the application of the invention to a steam power station using steam produced by a fossil or nuclear fuel, illustrating the circulation of heat-carrier fluid during a storage period.

FIG. 2 shows the installation of FIG. 1 but illustrating the direction of circulation of the heat-carrier fluid during a restoration period.

FIG. 3 shows an alternative form of the installation of FIG. 1 in which the accumulator and the heat-carrier fluid circuits are arranged outside of the steam power station.

FIG. 4 shows a supplementary utilisation or working installation associated with that of FIGS. 1 or 2.

FIG. 5 shows another embodiment of the installation with a reheater for the feed water, using live steam as the heating fluid.

FIG. 6 shows another embodiment of the installation, provided with a dryer-resuperheater for the wet steam, the installation being arranged to vapourise the liquid drained or blown-off from this apparatus.

**DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The power station of FIG. 1 has a steam generator 1 to supply steam to a turbine-generator unit which comprises a high-pressure stage 2, a low-pressure stage 3, a condenser 4, and an alternating-current generator 5. Tappings from the high and low pressure stages supply the respective cascades of reheaters 6, 7 and 8, and 9, 10 and 11.

The path taken by live steam and condensation water in operation of the station is shown by a solid line from outlet 12 of the steam generator 1 to a re-injection connection 13 for re-injection into the steam generator 1. Disposed on this path, viewing successively in a down-stream direction of flow, are a branch connection 14, the high-pressure stage 2, a separator 16, a tube arrangement or nest 17 of a resuperheater 15, the low-pressure stage 3, the condenser 4, an extraction pump 20, the reheaters 11 and 10, the tube arrangement or nest 21 of a feed water reheater 18 in which is incorporated a feed pump 22, and a junction connection 23.

A heat-carrier or heat-transfer liquid circulates along two circuits or paths indicated by arrows, one of which paths is arranged in shunt relative to the other and each of the paths including a circulating pump. The first path is shown in broken lines and successively comprises, starting from a branch connection 24, a pump 25 which discharges in an invariable direction, a tube arrangement or nest 26 of the resuperheater 15, a tube arrangement or nest 27 of the reheater 18, the reheater 9, the cascade of reheaters 8, 7 and 6, an exchanger 28 for exchanging between the heat-carrier fluid and live steam which is taken from the live steam flow line at the branch connection 14. The fluid is then returned to the junction connection 24.

The second path for the flow of heat-carrier fluid is provided by dash-dotted lines and passes successively from the branch connection 24, by way of an accumulator 29, a circulating pump 30 whose direction of fluid flow through the accumulator 29 can be reversed, valves 31 and 32 which are mounted in series in the circuit respectively upstream and downstream of the pump 30, valves 33 and 34 and a restrictor means 35 which is in a shunt circuit relative to the pump 30. The second path is connected to said first heat-carrier fluid circuit at a branch connection 36.

A regulator 37 which is in a shunt circuit with respect to the pump 25 controls its output flow in dependence on the temperature of the feed water taken off at point M at the outlet of the arrangement 21. The restrictor member 35 is controlled by suitable means, such as the speed regulator of the turbine for example, defining the output power demanded.

In a first mode of operation of the above-described installation, as shown in FIG. 1, valves on the tappings feeding the reheaters 6, 7, 8 and 9 are open. The pumps 25 and 30 deliver fluid in the same direction towards the accumulator 29, the valves 31 and 32 are open and the valves 33 and 34 are closed. The regulating member 35 and 37 control the outputs of the associated pumps 30 and 25 respectively, in dependence on the above-mentioned criteria. At the exchanger 28, the heat-carrier liquid takes off heat from the steam passing through the exchanger 28 and the liquid which is thereby re-heated is passed on the one hand through the accumulator 29 to which it gives up its heat and on the other hand is displaced by the pump 25 which discharges it to the steam resuperheater 15 (preceding the low-pressure stage 3 of the turbine), to reheater 18 and the reheaters 6, 7, 8 and 9. At its discharge from the accumulator 29 the heat-carrier fluid is passed by the pump 30 to the branch connection 36 which is common to the said first and second circuits for the heat-transfer fluid.

Under these conditions, the installation simultaneously produces electrical power and a heat reserve. The electrical power produced is less than the nominal power but the heat energy produced by the heat source of the generator 1 can be, as desired, lower than or equal to the nominal value.
The outputs of the pumps 25 and 30 are balanced in the following manner: if the temperature of the feed water as measured at the point M at the outlet from the tube arrangement 21 of the reheater 18 decreases for example, the output of the pump 25 will increase and thus increases the heat exchange at the tube arrangement 21, by giving up heat to the feed water. This part of the flow is then subjected to successive reheating in the reheaters 6, 7, 8 and 9 and again takes heat from the live steam at the exchanger 28.

On the other hand, an increase in the power required by the network causes a reduction in the output of the pump 30, that is to say, the flow of heat-carrying fluid branched off at the connection 24 to the accumulator decreases and the accumulation of heat follows this alteration. The limit phase of this mode of operation corresponds to a zero output from the pump 30, in which case all the heat taken off by the heat-transfer liquid is instantly restored to the working fluid. The installation then operates at its nominal power and there is no longer any heat storage.

In a second mode of operation of the installation as shown in FIG. 2, if the power called for by the network exceeds the nominal output value of the installation, the regulating members cause a reversal of the direction of fluid delivery of the pump 30, so that fluid flows into and through the accumulator from the pump 30, closure of the valves 31 and 32, and opening of the valves 33 and 34, and also the progressive closure of the valves on the tappings to the reheaters 6, 7, 8 and 9. Under these conditions, the pump 30 draws off at the branch connection 36 a part of the heat-carrying fluid flow and through the valves 33 and 34 passes it to the accumulator 29 where it takes off heat before being re-injected into the fluid circuit which includes the pump 25. Restoration of the accumulated heat energy therefore occurs.

Any increase beyond the nominal power of the power required by the network therefore causes an increase in the output of the pump 30 and thereby restoration of the stored energy. In the limit phase of this mode of operation, the output of the pump 30 reaches a maximum equal to the output of the pump 25, the valves on the reheaters 6 to 9 then being completely closed. Under these conditions the installation provides its maximum power.

The installation can pass from one mode of operation to the other in either direction, (i.e. from the FIG. 1 to the FIG. 2 mode or vice-versa) without disturbing the distribution of the temperature levels in the various components of the installation.

The accumulator 29, as described in the above-mentioned French patent, is generally formed of refractory material but in some cases such solid filling can advantageously be replaced by a volume of heat-carrier liquid.

It will be noted that the taking off and restoration of heat from and to the steam circuit occur at two temperature levels which are virtually equal. Also the steam heat exchangers operate at a series of temperature levels which are stepped between the outlet temperature of the steam at the generator 1 and the temperature at the outlet of the tapping for the exchangers.

By regulating the flow rate of the heat-carrier fluid, the power of the installation can be continuously modulated between values ranging from 50 to 100% of the nominal power.

In FIG. 3, the invention is applied to a steam power station similar to that of FIG. 1, but with the accumulator 29 and the heat-carrier fluid circuit being disposed outside the enclosure of the station. Similar components to those in FIGS. 1 and 2 are denoted by the same references. In the FIG. 3 installation, the heat exchange occurs, both as regards storage and as regards restoration, by way of a single exchanger 39 which comprises, in the flow circuit of the heat-carrier liquid a single tube arrangement or nest 38 and in the circuit of the thermodynamic fluid of the station, in this case water, two separate tube arrangements or nests 40 and 41.

A pump 51 whose direction of displacement of fluid through the accumulator 29 can be reversed, provides for the circulation of the heat-carrier liquid through the tube arrangement 38 and the accumulator 29.

The water circuit of the tube arrangement 40 comprises, starting from a branch connection 43 upstream of the reheater 7, a group of two pumps 49 and 50 which are operated in accordance with the particular mode of operation for storage or restoration by a set of associated valves 47 and 48, a branch connection 48 from which the circuit is connected on the one hand by way of a pump 58 and the exchanger 15 to a junction point A and on the other hand, during a heat storage period, by way of a valve 45 and a water-live steam heat exchanger 44 to a branch connection 42 downstream of the reheater 6.

Starting from a mixer 52 which is positioned between the feed pump 22 and the reheater 9, the circuit of the tube arrangement 41 is joined either, during a storage period, through a valve 53 and a pump 54 to a branch connection 55 downstream of the reheater 9, or, during a restoration period, through a valve 56 and a pump 57 to a branch connection 58 between the reheaters 9 and 10; the valves 53 and 56 are operably associated with each other to provide the above-described alternative flow of fluid.

From a take-off point 60 at the outlet of the steam generator 1 and through a valve 46, the circuit through the live steam side of the exchanger 44 is connected by way of a pump 59 to a junction connection 61.

In a first mode of operation of this installation, the valves 46, 45, 48 and 53 are open and the valves 47 and 56 are closed. The direction of circulation of the fluids is shown by the solid-line arrows.

The feed water taken off at the connection 42 is reheated by the heat given up by the live steam in the exchanger 44. At the branch point 8, a part of this flow of reheated feed water is taken by the pump 58 and passed to the resuperheating exchanger 15; the other part of the reheated feed water flow circulates in the tubes 40 of the exchanger 39 in which it transfers heat to the heat-transfer liquid. At the outlet from the tubes 40, the water is delivered by the pump 50 back to the main water line at the junction connection 43.

The water-steam mixture taken off at the mixer 52 gives up heat to the heat-carrier liquid in the tube arrangement 41 of the exchanger 39, and is delivered by the pump 54 back to the main feed water line to the generator 1, at the junction connection 55.

The pump 51 provides for circulation of the heat-carrier liquid in the direction indicated by the solid-line arrow through the accumulator 29 to which it gives up the heat taken from the hot steam upon which the heat-carrier liquid flowed through the exchanger 39. In this mode of operation, the installation simultaneously...
produces electrical power and a heat reserve. The electrical power produced is lower than the nominal power. As described above, the output of the pumps 51, 50, 54, 58 and 59 is controlled by means controlling the call for power of the network and the temperature of the feed water of the steam generator 1.

When the power called for by the network exceeds the nominal value of the installation, regulating means cause the installation to pass to the restoration mode of operation; this causes closure of the valves 46 and 45 at the exchanger 44 and the valves 48 and 53 which are placed upstream of the pumps 50 and 54 respectively, while the valves 47 and 56 located downstream of the pumps 49 and 57 respectively are opened. The direction of flow of the heat-carrier liquid in the accumulator 29 is thus reversed. The direction of the flows in the circuits in this restoration mode is shown by the broken-line arrows.

The water taken off at the branch connection 43 is circulated by the pump 49 towards the tube arrangement 40 of the exchanger 39 in which the heat-carrier liquid imparts heat thereto, and this reheated water is passed into the resuperheating exchanger 15 from which it rejoins the main feed water line back to the steam generator 1, at junction connection A. The pump 57 takes off water from the connection 58 on the main feed water line and passes it through the tube arrangement 41 of the exchanger 39 in which it is reheated, to the mixer 52. Restoration of accumulated thermal energy occurs.

In this mode of operation also, the output of the pumps 51, 49, 57 and 58 is controllable by regulating devices in dependence on the demand for power made by the network.

FIG. 4 shows an alternative form of an installation arranged substantially as shown in FIG. 1 or FIG. 2, in which the accumulator 29 is directly associated with a utilisation or working circuit which utilises the heat of the fluid flowing through the accumulator.

For this purpose, the heat accumulator 29 which is part of the power station is connected in shunt across two exchangers 62 and 63 in which the heat-carrier liquid circulates.

The heat storage and restoration transfers occur at the level of the exchanger 62, as described above; in parallel with this, the heat-carrier liquid can give heat by way of exchanger 63 to a utilisation circuit 64. Regulation means control the rate of flow of the heat-carrier liquid through the two exchangers.

Such an installation can for example be used simultaneously for the production of electrical power and for industrial heating (heating by way of the circuit 64).

The installation of FIG. 5 has a steam generator 71 operated by a nuclear reactor to supply saturated or slightly superheated steam to the high-pressure stage 72 of a steam turbine. The exhaust from the high-pressure stage 72, with a high humidity content, is passed to a dryer 73 in which it is separated into liquid and gaseous phases. The dry steam issuing from the dryer 73 then circulates in a resuperheater exchanger 74 in which the heating fluid is water taken from a connection 77 on the feed water line back to the generator 71, and passed to the exchanger 74 by way of a branch connection 77. This feed water line has a water station comprising six reheaters 81 to 86 connected to tappings on the high and low-pressure stages of the turbine, and a live-steam reheater R7, to which reference will be made again later. This water which circulates through the exchanger 74 is returned to the feed water line at a connection A after having passed through the exchanger 74.

The part of the flow of water taken off at the connection 77 which does not go to the exchanger 74 is passed to an exchanger 78 in order to act therein as a heating fluid, and returns to the water line at a connection 79. Moreover, water taken from the feed water line and coming from a mixing reheater R4 circulates as a heating fluid in an exchanger 80 and returns to the feed water line at a connection 81. In the exchangers 78 and 80, the heating water gives up its heat to a heat-carrier fluid which travels through a closed circuit comprising a tank 82, a pump 83 and the exchangers 78 and 80. The cold-heat carrier fluid is drawn off at the bottom of the tank 82 by means of the pump 83 and passes through the exchangers 80 and 78 in counter-flow relative to the water, and the thereby heated heat-carrier fluid returns to the top of the tank 82 which thus forms a heat accumulator.

The resuperheated steam issuing from the exchanger 74 is admitted to low-pressure stage 84 of the turbine in which it continues to expand until it reaches the condenser 86, and the condensate returns to the steam generator 71 after having passed through the water station (R1 to R6) and the reheater R7.

Whereas, at its outlet from the conventional water station (R1 to R6), the feed water to the boiler is at a temperature which is slightly lower than the saturated steam temperature at the pressure level of the tapping which feeds the reheater R6 (the difference between these temperatures being that required to ensure that the heat exchanges take place), the supplementary reheater R7 has the effect of increasing the temperature of said feed water up to the level (or almost to that level, with only a slight difference) of the saturated steam temperature at the pressure level of the steam generator 71. A pump 85 takes the condensate of the live steam supplied to the reheater R7 and reintegrates it into the feed water line to the generator 71. The heat removed at the steam generator, which is represented by this live steam to the reheater R7, is returned thereto by way of the feed water and this heat, circulating in the closed circuit from the generator 71 to the reheater R7 and conversely, changes neither the amount of steam supplied to the installation nor its temperature. The only effect of the reheater R7 is to raise the water inlet temperature at the steam generator 71.

An advantage of this arrangement becomes apparent when operating the installation at peak hours, that is to say, during periods of restoring the heat stored in the accumulator 82. (In the drawing, the directions of flow indicated by the broken-line arrows occur only during such periods).

At peak hours, when the turbine is called upon to provide the maximum possible power, all the tappings except those feeding R1 and R2, and all live steam tappings, are suppressed, so that all the live steam is passed to the high-pressure stage 72. Water taken from the feed water line at the connection 87, which is virtually at the temperature of the condenser 86, circulates in the exchanger 80, is reheated therein by taking the stored heat from accumulator 82 by heat exchange with the heat-carrier fluid, and returns to the feed water line, at the mixing reheater R4. Another flow of
water, taken from the water line at the connection 79 immediately downstream of the reheater R4 circulates in the exchanger 78, is likewise reheated therein by taking the accumulated heat of the heat-carrier fluid, arrives at the branch connection 77', then passes through the resuperheater exchanger 74 and returns to the feed water line at the point A, to be reintegrated back into the steam generator 71. During such periods of restoration, the heat required in order that the water supplied to the steam generator 71 is at the same temperature as during the low-demand periods of operation, that is to say, at the feed water temperature obtaining at the outlet of the reheater R7 when the latter is operating, can and preferably must be taken from the accumulator 82.

Putting the reheater R7 into operation in slack hours therefore provides a stronger flow of the heat which is restored at peak hours and permits on the one hand an increase in the peak power and on the other hand permits the storage, during slack hours, of a larger amount of heat from the basic heat source, which makes it possible to reduce or eliminate operating variations thereof, such a possibility being particularly attractive when the heat source is a nuclear reactor.

In the FIG. 6 installation a steam generator 91 supplies saturated or slightly superheated steam to a high-pressure stage 92 of a steam turbine. The exhaust from the high-pressure stage 92, with a high humidity content, is passed into a dryer-resuperheater 93 in which drying occurs, in known manner, by phase separation. A pad or mattress 94 partitions the body of the apparatus 93 into two chambers or compartments 95 and 96. The hot steam passes into the lower chamber 95 and passes through the mattress 94 which retains the humidity of the steam. In the lower chamber 95, the steam passes round a nest of resuperheater tubes in which there circulates a hot fluid in the form of live steam taken from the outlet of the steam generator 91 at a connection 97. The flow issuing from the resuperheater tubes is passed to the water station (corresponding to R1 to R6 in Figure 5) and more precisely to a reheater 98 which is most downstream on the water feed line to the generator 91.

The resuperheated steam issuing from the compartment 96 is passed to a low-pressure stage 99 of the turbine to continue its cycle of expansion, condensation, reheating and return to the steam generator, in known manner.

The water retained in the compartment 95 of the apparatus 93 is taken therefrom by an extraction pump 100 which directs it to a branch connection controlled by a two-position valve 101 from which it is either returned to a mixing reheater 102 in said water station or is circulated as a cold fluid in a heat exchanger 103 which is fed as required with hot heat-carrier fluid by a line 104 which is itself fed with heat in a thermal energy storage and restoration installation of the kind described above. This installation, as it has already been described, is not repeated in FIG. 6, except as regards its novel portion which is associated with the exchanger 103. In slack hours, this installation stores the heat produced by the basic heat source, in excess of that required to satisfy the network demand, and the liquid drained from the apparatus 93 is passed to the degassing mixer 102, as is effected in existing power stations. On the other hand, at peak hours and in accordance with the invention, this drained liquid from the apparatus 93 is passed into the exchanger 103 and there converted into steam, from which a line 106 passes to the dryer-resuperheater 93. This thus gives a supplement of low-pressure steam at the expense of the heat stored in the slack hours, the effect of which is on the one hand to increase the maximum power which can be offered to the network and on the other hand to increase the amount of heat which can be stored, which amount cannot exceed, under balanced conditions, that which can be restored.

In order to take an example drawn from current practice, the liquid taken from the separator-resuperheater can form approximately 7% of the flow of low-pressure steam to the stage 99 of the turbine in peak hours.

The above-described arrangement also permits the water drained off to be distributed, in intermediate operation, between the apparatuses 102 and 103.

What is claimed is:

1. A method of operating a steam power station with a variable-demand network, the station comprising a generating installation including a heat source, a steam generator, at least one steam turbine, and an accumulator adapted to draw heat from the installation by transferring a heat-transfer fluid; said method comprising the steps of storing said heat and subsequently restoring it to the installation for operation of same, characterized by the fact that the heat-transfer fluid for the transferring of heat between the installation and the accumulator is in heat-exchange relation with steam of which at least a part has performed mechanical work in said turbine.

2. A steam power station comprising: a generating installation having a heat source, a steam generator, at least one steam turbine; an accumulator means adapted for heat exchange to or from a steam circuit of said installation by way of a flow of heat-transfer liquid; reversible circulation means for the circulation of said heat-transfer liquid in heat-exchange relation with steam; and means for controlling said circulation in such a way that the taking off and the restoration of heat from and to the installation take place at two temperature levels which are virtually equal.

3. A station according to claim 2 including a plurality of heat-transfer liquid-steam exchangers for the transfer of heat to said accumulator means, said exchangers operating at a series of respective temperature levels which are stepped between the outlet temperature of the steam at the steam generator and the temperature at the outlet of a tapping to said exchanger from said steam circuit.

4. A station according to claim 3 wherein said exchangers comprise a live steam exchanger and a cascade of reheaters fed by high-pressureappings and at least one low-pressure tapping from said steam circuit.

5. A station according to claim 4 including a plurality of heat exchangers for restoring heat to the installation, wherein the turbine has a low-pressure stage and a condenser connected thereto, and wherein said restoration heat exchangers comprise a steam resuperheater upstream of the low-pressure stage and a reheater means for reheating the flow of feed water from the outlet of the condenser back into the steam generator.

6. A station according to claim 5 including first and second pumps and a flow circuit connected to each pump, for circulating heat-transfer fluid through the exchangers, the reheater means and the accumulator.
means, said circuits being operatively associated with each other.

7. A station according to claim 6 wherein said first circuit comprises said first pump for pumping the heat-transfer fluid in an invariable direction through said steam reheater, the feed water reheater means, reheater means tapped from the steam circuit and the live steam exchanger, and wherein the second said circuit comprises said second pump, said accumulator means and means for reversing the direction of flow through the accumulator means, one circuit being connected in shunt relative to the other circuit.

8. A station according to claim 7 including means for regulating the output of said first pump in dependence on the temperature of the feed water at the outlet of the reheater means.

9. A station according to claim 7 including means for determining the demand for power made on the station, and regulating means controllable by said determining means for controlling the output of said second pump in dependence on the demand for power of said network.

10. A station according to claim 9 wherein said determining means comprises a turbine speed regulator means.

11. A station according to claim 10 including means for controlling said second pump to displace fluid in the same direction as said first pump during a period of restoration of heat.

12. A station according to claim 11 including valve means in the circuit of the regulating means, and valve means in the tappings feeding the reheater means, the valve means being actuated if the power demand on the installation exceeds that of the heat source to cause the direction of circulation in said second pump to be reversed and the output to be regulated between a zero value and a maximum equal to the output of said first pump.

13. A station according to claim 2 wherein said accumulator means has a filling comprising heat-carrier liquid.

14. A station according to claim 2 wherein the flow of the heat-transfer fluid can be regulated whereby the output of the installation is modulated continuously between values ranging from 50 to 100% of nominal power.

15. A station according to claim 2 wherein the accumulator means and the heat-transfer fluid circuits are positioned outside the generating installation.

16. A station according to claim 15 including an intermediate exchanger outside the installation, said taking off and restoration of heat occurring by way of said intermediate exchanger.

17. A station according to claim 16 wherein the heat-transfer fluid circuit includes two exchangers which are connected in shunt to the accumulator means, one of said exchangers providing for the heat storage and restoration transfers with the heat source and the other feeding a heat-utilisation circuit such as an industrial heating system.

18. A station according to claim 2 wherein at least half of the steam which is brought into heat-exchange relation with the heat-transfer liquid has performed mechanical work in a said turbine.

19. A station according to claim 2 further including a reheater for heating the feed water flow to the steam generator, and a conduit means for supplying live steam to the reheater from the steam generator for heat transfer to the feed water.

20. A station according to claim 19 comprising a heat accumulation means capable of storing as required heat from said heat source and restoring as required the stored heat to the steam cycle of the installation.

21. A method of producing power for a variable-demand network by means of a steam power station comprising, a generating installation having a heat source, a steam generator, at least one steam turbine, an accumulator means adapted for heat exchange to or from a steam circuit of said installation by way of a flow of heat-transfer liquid, reversible circulation means for the circulation of said heat-transfer liquid in heat-exchange relation with steam, a line for returning condensed water from the turbine back to the steam generator, a reheater for heating the feed water flow to the steam generator, and conduit means for supplying steam from the steam generator to the reheater for heat exchange with the feed water; wherein said method comprises operating the feed water reheater at low-demand periods only.

22. A method according to claim 21 wherein, in high-demand periods when the feed water reheater is not operating, accumulated heat is restored to the steam cycle in the measure required to produce a water intake temperature to the steam generator which is higher than the water intake temperature to said reheater when said reheater is operating.

23. A method according to claim 22 wherein said water intake temperature to the steam generator is substantially equal to its outlet temperature from said reheater when the reheater is operating.

24. A steam cycle power station according to claim 2, further including a water station tapped from the steam circuit, a reheater downstream of the water station for the feed water to the steam generator, and means for feeding live steam from the steam generator to the reheater as the heating fluid.

25. A method of producing power for a variable-demand network by means of a steam cycle power generating installation comprising a steam generator, a machine driven by a steam expansion cycle, a water station tapped from the steam circuit, a reheater downstream of the water station for the feed water to the steam generator, and means for feeding live steam from the steam generator to the reheater as the heating fluid; said method comprising the steps of operating the water station and the feed water reheater during low-demand periods, while accumulating heat from the basic heat source of the installation, heat thus accumulated being restored to the steam cycle during high-demand periods, in the measure required to produce a feed water inlet temperature to the steam generator, which is higher than the outlet temperature from the water station when the water station is operating.

26. A steam cycle power generating installation having a heat source, a steam generator, a dryer-resuperheater apparatus for separating partially expanded damp steam into liquid and dry steam and resuperheating thereof, a heat accumulator fed with heat by the heat source of the installation, a heat exchanger supplied with heat from the heat accumulator for vaporising purge liquid from said dryer-resuperheater apparatus, and means for recirculating to said installation the steam thereby produced.
27. An installation according to claim 26, comprising means for passing the purge liquid selectively to said heat exchanger or to the water return circuit to the steam generator.

28. An installation according to claim 26 including means for recycling steam produced in said heat exchanger to the dryer-resuperheater apparatus.

29. A method of producing power for a variable-demand network by means of a steam cycle power generating installation comprising a heat source, a steam generator, a dryer-resuperheater apparatus for separating partially expanded damp steam into liquid and dry steam and resuperheating thereof, a heat accumulator fed with heat by the heat source of the installation, a heat exchanger supplied with heat from the heat accumulator for vaporising purge liquid from said dryer-resuperheater apparatus immediately as it issues therefrom, and means for recycling steam produced in said heat exchanger to the dryer-resuperheater apparatus, wherein the amount of purge liquid converted into steam in said dryer-resuperheater apparatus is varied in the same direction as the variation in power demand by the network, with, as required, total vaporisation of the purge liquid during peak periods and total reintegration of the purge liquid into the water circuit during slack periods.

* * * * *