Indirect Air Condensation Plant

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Filed: May 13, 1970
Appl. No.: 36,849

Foreign Application Priority Data
May 17, 1969 Germany P 19 25 234.7

U.S. Cl. 60/95 R, 165/113
Int. Cl. F01k 9/00
Field of Search 160/95 R; 165/113

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978,067 3/1963 Great Britain 60/96

ABSTRACT
A condensation plant for condensing superheated steam and the like, having a jet condenser for condensing the steam and a plurality of air-cooled cooling elements to feed cooling water to the condenser and to cool the condensate. Distribution means, including pumps and valves, are provided between the condenser and cooling elements which allow for the selective flow of the condensate and drainage of any individual portion of the plant. A vacuum line is included in the distribution means and is connected to the highest point of each cooling element. The pressure in the vacuum line is below atmospheric pressure and only slightly above the specific saturation pressure of the condensate corresponding to the water temperature in the upper part of the cooling elements. The vacuum line, along with providing a control function, also enables replacement of a single cooling element without shutting down the entire plant.

21 Claims, 5 Drawing Figures
3,660,980

INDIRECT AIR CONDENSATION PLANT

The present invention relates to an indirect air condensation plant having a jet condenser which condenses exhaust steam. In the cooling water or condensate discharge line of this plant, there is at least one pump which feeds the cooling water and condensate to subsequent, air-cooled cooling elements which are connected on their input side to distribution conduits and on their output side to collecting conduits, the main collecting or water-return conduit passing back via an interposed throttle member to the injection nozzles of the condenser.

In prior art plants of this type, a leveling vessel is arranged above the cooling elements and is connected through conduits to the highest points of each cooling element. A specific water level must be maintained within the leveling vessel in order to make certain that all the cooling elements are completely full of water during operation. If the water level in the leveling vessel drops, then the pump in the cooling water or condensate-discharge line of the jet condenser is adjusted to a larger delivery, while a rise in the water level in the leveling vessel to above the contemplated maximum water level results in a reduction in the delivery of the pump. Thus in the prior art, the pump in the cooling water or condensate-discharge line of the jet condenser is controlled as a function of the water level in the leveling vessel. In these known systems, a pressure which is considerably above atmospheric pressure prevails in the cooling elements as well as in the leveling vessel. This pressure is maintained by gas cylinders which contain an inert gas, such as nitrogen, under high pressure. These gas cylinders are connected, via a shut-off and pressure-control member, by corresponding conduits directly to the leveling vessel and to the connecting conduit between the leveling vessel and the cooling elements. Accordingly, a substantially higher pressure prevails, as can be seen from the direction of flow, behind the pump (which is connected in the cooling water or condensate discharge line in the cooling elements as well as in their distribution and collecting conduits) than in the jet condenser to which the main collecting conduit returns coming from the cooling elements. Since the lowest possible pressure must be maintained within the jet condenser in order not to reduce the performance of the machine connected in front of it, for instance a steam turbine, and such pressure is considerably below atmospheric pressure, it is necessary to reduce the pressure of the returning water to a corresponding extent before it enters the jet condenser. For this purpose, a corresponding throttle member is arranged in the main collecting conduit. This throttle member in the known system is controlled as a function of the pressure in the jet condenser, the desired pressure in the condenser being adjusted either manually or as a function of the turbine output and possibly also of the rate of flow of the steam through the turbine.

This known air condensation plant has the substantial disadvantage that a pressure considerably greater than atmospheric pressure must be maintained at all places, as seen from the direction of flow, behind the pump contained in the cooling water or condensate-discharge line up to the throttle member arranged in the main collecting conduit in the way airtightness is attempted to prevent the penetration of air into the condensate or cooling water and into the inside of the cooling elements or pipelines. Due to the pressure within the cooling circuit, the pump connected in the cooling water or condensate-discharge line must be fed not only with the drive power which it consumes in order to overcome the frictional and throttling losses, as well as the geodetic head, but in addition it also requires a considerably greater power, namely about 20 percent to 30 percent greater, in order to overcome the pressure difference between the vacuum and the jet condenser and the pressure in the cooling circuit. This means corresponding additional expenses for the energy to be supplied for the pump and also a considerable additional expense because of the heavy construction of the pump and its drive which are made necessary by the higher power. The operating expenses of the plant as well as the investment costs are therefore considerably higher.

Attempts have been made to recover a part of the additional power to be supplied by using a recovery turbine instead of a simple throttle member. As a result of this, however, the cost of setting up the plant is further increased and the overall construction of the plant is made substantially more complicated. This in its turn has the result that a corresponding increase in maintenance expenses, and the operation of the plant becomes correspondingly more difficult. For this reason, such a recovery turbine is generally dispensable with in favor of a simple throttle member. However, by doing this, one is forced to tolerate a considerable decrease in output which results from the throttling of the pressure produced by the pump.

Another disadvantage of the known air condensation plant is that it is not possible to maintain a constant delivery of the pump arranged in the cooling water or condensate-discharge line since, even in normal operation of the plant, the pressure in the jet condenser will change upon a change in the operating condition and particularly of the turbine output. The pressure in the cooling elements or in the cooling circuit, in fact, is, however, maintained below a given pressure in the known construction by the leveling vessel and in particular by the connecting of the cooling elements to the gas cylinders. Thus, the pressure difference which the pump must overcome varies as a function of the pressure in the jet condenser and case of the known condensation plant, so that one cannot operate without a corresponding adjustment of the pump. It is therefore necessary to have an adjustable pump as well as a control apparatus with which to actuate the control members of the pump. In the known condensation plant, this takes place as a function of the water level in the leveling vessel, for which purpose the latter is provided with a water-level detector and a corresponding control apparatus. This means a considerable additional expenditure in the erection of the plant and the operation thereof, resulting in increased maintenance expenses. Furthermore, such a variable pump operates with poor efficiency over relatively long periods of time, since it must be designed for the maximum output which is necessary in case of special operating conditions of the entire plant. These extreme conditions, however, only occur relatively rarely, so that during by far the greatest part of its operation, the pump operates with relatively poor efficiency and thus with corresponding losses in output.

For the same reasons as indicated above, the pressure difference on both sides of the throttle member also varies, since here also the pressure in front of the throttle member, as seen in the direction of flow, and therefore between it and the cooling elements, remains substantially constant due to the action of the gas cylinders. Behind the throttle member, as seen in the direction of flow, and therefore between the latter and the jet condenser, the pressure difference can vary considerably, depending on the condition of operation of the condenser. Accordingly, in the known condensation plant, the throttle member must also be regulated automatically and continuously as a function of the pressure in the condenser or the output of the machine arranged in front of it, such as a steam turbine. Thus also in this case expensive control apparatus are necessary and additional maintenance and repair expenses are incurred upon the operation of the plant.

Furthermore, the known air condensation plant has the disadvantage that there is a continuous consumption of inert gas, since this inert gas is introduced under pressure into the cooling elements and into the leveling vessel and is in part absorbed by the condensate or cooling water. The inert gas passes together with the cooling water back into the jet condenser where it is drawn off with the air suction and blown into the atmosphere. Thus, there takes place a continuous, and not inconsiderable, loss of inert gas which in the known plant must be counteracted by replacement of the gas cylinders, which naturally increases operating expenses. Furthermore, the leveling vessel and its connecting conduits to the cooling elements, must be well insulated and provided with a heating device in order to avoid freezing in winter.
The object of the present invention is to create an indirect air condensation plant which does not have the above-mentioned disadvantages but results in lower operating costs and is of simpler construction. This objective is achieved in accordance with the invention in the manner that the cooling elements are connected in the vicinity of their highest points to a vacuum line. The pressure in this line at the connecting points with the cooling elements is above, but preferably only slightly above, the instantaneous saturation pressure of the cooling water or condensate corresponding to the water temperature in the upper part of the cooling elements. In this way the result is first of all achieved that within the cooling elements, as well as practically in the entire cooling water or condensate circuit, the pressure lies below the atmospheric pressure. This pressure is in this connection kept as low as possible so that even, as seen in the direction of flow, shortly in front of the throttle member which is connected in the main collecting or water-return line, it is only relatively slightly above the condenser pressure. This has the advantage that the pump connected in the cooling water or condensate-discharge line can be operated with a substantially smaller, namely about 20 percent to 30 percent smaller, output than in the known construction in which the pump must continuously operate against the pressure of the inert gas. In the plant of the present invention, as a result of the vacuum prevailing in the cooling elements at their highest points and which may possibly be about 0.5 atm abs., the delivery stroke of the pump is considerably reduced which is equivalent to a substantial saving of drive power and thus leads in its turn to a reduction of the auxiliary energy requirement of the entire plant. However, in the condensation plant of the invention, not only are costs for energy and thus for operation saved, but because of the vacuum or the lower delivery as compared with the known construction, one can get along with a substantially weaker and therefore cheaper pump, which is also true in the same manner with respect to the pump drive. Furthermore, the pressure difference, in the direction of flow, in front of and behind the throttle member, is far lower than in the known condensation plant, so that even if a simple throttle member is provided, only a small amount of energy is lost. One can therefore dispense with a recovery turbine much more easily than in the known condensation plant, the recovery turbine by itself being 6 to 8 times as expensive to purchase as a simple throttle member. The energy losses occurring with the use of a simple throttle member are so small as a result of the slight pressure difference in front of and behind the throttle member in the plant of the invention that a large part thereof is counteracted alone by the fact that the high maintenance expenses for the recovery turbine and the purchase price thereof are done away with and by the advantages which result from the simpler operation and more dependable construction of the plant of the invention than the known construction.

Another substantial advantage of the air condensation plant of the present invention is that it is possible with it to keep the delivery head of the pump constant even upon variation of the pressure in the jet condenser. This is possible in particular because the pressure difference between the jet condenser and, for instance, the highest point of the cooling elements, is maintained approximately constant during operation. With the normally constant delivery quantity and the constant geodetic delivery head there thus also results a substantially constant delivery output of the pump. The pressure difference between jet condenser and cooling elements can be kept constant in the air condensation plant of the invention in a particularly simple manner. The cooling elements of the inventive plant have there pressure which lies below the atmospheric pressure and which is furthermore not fundamentally constant, in contradistinction to the known construction. The constant delivery head and, for the same quantity of delivery, the constant delivery output of the pump advantageously make unnecessary control thereof, so that the need for both an expensive construction of the pump itself and expensive control units for the pump can be dispensed with. The purchase price of the plant as well as its operating expenses are thereby kept lower. The operating cost for the pump is kept small, however, not only by the lower output required and the simpler maintenance and lesser susceptibility to disturbance, but also by the fact that the pump can be adjusted to a very specific delivery head and delivery output, so that it is operated with optimum efficiency, which naturally leads to a reduction of the operating expenses.

Another advantage of the air condensation plant of the present invention is the slight pressure difference, as seen in the direction of flow, in front of and behind the throttle member, which difference furthermore remains substantially constant for the reasons indicated above. Therefore, in the same manner as in the case of the pump, one can dispense with control and thus with corresponding control members and control apparatus for the throttle member. With the air condensation plant of the present invention, it is sufficient for the pump or the throttle member to have simple, manually actuated controls which are actuated only for the starting up of the plant and for exceptional operating conditions, while normal control either of the pump or of the throttle member is not necessary. Furthermore, with the air condensation plant of the present invention, it is also possible to do away with the consumption of inert gas present in the known design, since, in contradistinction to the known design, the plant can be operated completely without inert gas which is under high pressure. Finally, the provision of a leveling vessel as well as of the insulating therewith and being unnecessary, so that once again considerable costs are saved.

In one suitable embodiment of the invention, the vacuum line is connected to the air exhaust of the jet condenser. In this way it is possible to obtain a particularly simple construction of the air condensation plant which can accordingly be directed at correspondingly lesser expense. The vacuum in the vacuum line is obtained in this embodiment of the invention by the air exhaust which is in any event present on the jet condenser. This furthermore has the substantial advantage that the vacuum in the vacuum line and thus the vacuum at the highest points of the cooling elements establishes itself completely automatically as a function of the vacuum in the jet condenser. In this way there is a substantially constant pressure difference between jet condenser and cooling elements as well as, seen in the direction of flow, in front of and behind the throttle member. This leads to a substantially constant delivery head or delivery output of the pump and adjustment either of the pump or of the throttle member during normal operation is therefore unnecessary.

In another embodiment of the invention, the vacuum line is connected to the inside of the jet condenser. This embodiment is particularly recommended when assurance must be had that no cooling water or condensate will enter into the air exhaust of the jet condenser and when, due to local circumstances, it is to be feared that the cooling water or condensate will be removed from the cooling elements via the vacuum line. If this is the case, the cooling water of condensate is fed again to the jet condenser and thus to the circuit and is not lost. The pressure difference between the jet condenser and the cooling elements is maintained substantially constant also in this embodiment in the same way as in the preceding embodiment, namely, without special devices having to be provided. In principle, however, it is also possible for the vacuum line to be connected to a separate evacuation device.

Regardless of which of the aforementioned embodiments is selected in the individual case, one can, insofar as this is necessary at all, regulate the vacuum in the vacuum line or the evacuation device as a function of the water level present in the vacuum line. This can be done in various ways, for instance, by introducing a given amount of air per unit of time, via an adjustable shut-off element, into the vacuum line from the outside or by adjusting the evacuation device to a correspondingly different output. It is furthermore possible to connect the vacuum line only temporarily to the air exhaust or to the inside of the jet condenser or to the evacuation device.
which, for instance, can be effected by opening and closing a correspondingly interposed shut-off member. The regulation of the vacuum can possibly be effected in the manner that in each case, when the water level exceeds a predetermined minimum at the highest points of the cooling elements, the pressure in the vacuum line is decreased. With such a control it is advisable for a water-level detector to be arranged in several cooling elements of the plant and at least in one cooling element each of each group of cooling elements. Preferably a detector should be placed in several cooling elements of each group of cooling elements. In this way assurance is had that each cooling element is sufficiently filled with water and a reduction of the output of the plant by merely partially filled cooling elements is avoided. In this connection it is advisable to have the vacuum in the vacuum line and/or the evacuation device of each water-level detector independent of the other water-level detectors.

As a further development of the invention, a water trap can be arranged in the vacuum line. By means of such a water trap, the condensate or coolant which may be present in the vacuum line can be removed from the vacuum line. This is important in particular when the vacuum line is connected to the air exhaust of the jet condenser or to a separate evacuation device. When using a water trap, it is advisable to connect the water side thereof with the inside of the jet condenser or with a collecting or water-return line and to connect the air side with the air exhaust of the jet condenser or with the separate evacuation device. In general, it is preferred to connect the water trap on the water side with a collecting or water-return line since in this way it is possible to save the relatively long line between the water trap arranged in the vicinity of the cooling elements and the condenser which lies further away. Furthermore, in this embodiment it is advisable to arrange a shut-off element, which is adjustable as a function of the water level in the water trap, in the water-side connecting line between the water trap and the jet condenser or the collecting or water-return line.

In accordance with another feature of the invention, a shut-off element is arranged in the vacuum line directly at each cooling element but preferably only at the end of the vacuum line of each group of cooling elements. If, in accordance with the aforementioned preferred embodiment, a shut-off element is arranged only in each case at the end of the vacuum line of each group of cooling elements, then in this advantageous fashion it is possible to save a large number of shut-off elements. Nevertheless, it is possible in the air condensation plant of the invention to empty only a single cooling element of a group of cooling elements without it being necessary for the other cooling elements of the same group of cooling elements to be emptied also. This is of particular advantage especially when a single damaged cooling element must be replaced or repaired. However, this result can only be achieved in the plant of the present invention for the reason that the individual cooling elements are each connected to a vacuum line. It is therefore possible to maintain in the other cooling elements a sufficient vacuum so that a discharge of the water from said cooling elements is prevented while it flows out of the injured cooling element after the venting thereof. Even if a long time interval lies between the removal of a damaged cooling element and installation of a replacement, it is possible then to continue to keep the group of cooling elements in question in operation. However, it is advisable in such case to cover the flow openings resulting from the removal of the damaged cooling element.

In one suitable embodiment of the invention, the vacuum line of at least each group of cooling elements can be connected separately to a known gas equalization line between the cooling elements and a water tank associated with them. The gas equalization line and the water tank are filled in the known manner with an inert gas, such as nitrogen. In this way it is possible to avoid having air, and particularly ambient oxygen, penetrate into the pipelines and into the cooling elements when the water is let out of them. Instead, they are filled with the inert gas. A gas equalization line between the water tank and the cooling elements and the filling of the equalization line and the water tank, which is substantially empty when the cooling elements are filled with an inert gas, such as nitrogen, is in itself already known in air condensation plants. This known principle can also be employed in the air condensation plant of the present invention. In this connection it is possible to connect the vacuum line of at least each group of cooling elements separately to such a gas equalization line. In principle, however, it is possible to also simultaneously connect the vacuum lines of several groups of cooling elements to one or more of such gas equalization lines.

In another embodiment of the invention, the vacuum line of at least each group of cooling elements can be connected separately to a separate inert gas supply device. If the plant has a separate evacuation device, it is advisable to connect the pressure side of the evacuation device temporarily to a gas equalization line or to the inert gas supply device. In this way it is possible to recover, by means of the evacuation device, the inert gas which has been used for the filling of the pipelines and cooling elements and to return it to a corresponding protective gas storage when the group of cooling elements in question is again filled with water. The inert gas is thus not lost and can be used again.

Although it is, in principle, not necessary in the condensation plant of the present invention to regulate the throttle member in the main collecting or water-return line, it is nevertheless possible in special cases to provide such a control. In this connection it is advisable to regulate the throttle member in the main collecting or water-return line as a function of the pressure in the cooling elements at their highest points. The regulation as a function of the pressure in the cooling elements is therefore of particular importance, since in this way assurance is had that the pressure in the cooling elements will always lie above the saturation pressure. In this way it is possible to prevent the water from being evaporated within the cooling elements and the steam from being withdrawn through the vacuum line. In another embodiment of the invention, the throttle member in the main collecting or water-return line is adjustable as a function of the pressure in the vacuum line in the vicinity of the cooling elements and of the temperature in the vicinity of the highest points of the cooling elements. In this embodiment of the invention, the fact is taken into consideration that the saturation pressure in the cooling elements is dependent on the instantaneous temperature and thus must be of a different value depending on the cooling action of the cooling elements and the temperature of the incoming condensate or cooling water. Since with a pure pressure measurement there is the danger that the saturation pressure at the time will unintentionally be exceeded in the negative direction, due to special temperature conditions, and that there is thus nevertheless an evaporation of the cooling water or condensate, it is more dependable not only to measure the pressure in the vacuum line but also to measure the temperature in the vicinity of the highest points of the cooling elements and take these measured values into consideration as control variables. However, if one only measures the pressure at the highest points of the cooling elements, this pressure must always be so far above the saturation pressure that the saturation pressure can never be reached, even in case of extreme temperature conditions. Thus, it would be necessary, however, for the sake of certainty, to tolerate a substantially higher pressure within the vacuum line, which naturally leads to an increase in the pump output. On the other hand, if one regulates the throttle member as a function of the pressure in the vacuum line and of the temperature in the vicinity of the highest points of the cooling elements, then it is possible to maintain a pressure in the vacuum line which lies just above the instantaneous saturation pressure.

In contradistinction to this, it is, however, also possible to regulate the throttle member in the main collecting or water-return line as a function of the pressure difference between the pressure in the vacuum line in the vicinity of the cooling
elements and the condenser pressure. With this embodiment of the invention, assurance is also had that the saturation pressure will not be reached or exceeded in the negative direction. This is due to the fact that the temperature at the highest points of the cooling elements is always less than the temperature in the jet condenser, since the cooling water or condensate is cooled on its path from the jet condenser to the cooling elements and particularly in the cooling elements themselves. As a result of the lower temperature in the vicinity of the highest points of the cooling elements, the saturation pressure at these points is also lower. Since there already prevails in the jet condenser a steam pressure which is lower than the saturation pressure at the higher water temperature in the jet condenser, it is entirely sufficient if the pressure in the vacuum line in the vicinity of the cooling elements is equal to or somewhat greater than the corresponding pressure in the jet condenser in order to prevent evaporation of water in the cooling elements. Accordingly, instead of a temperature measurement in the vicinity of the highest points of the cooling elements, one can also effect a pressure measurement in the jet condenser and use this pressure together with the pressure in the vacuum line in the vicinity of the highest points of the cooling elements as control variable for controlling the throttle member. Furthermore, in this control, the pressure difference between the pressure in the vacuum line in the vicinity of the cooling elements and the condenser pressure will be held approximately constant, which leads to a constant delivery of the pump interposed in the cooling water of condensate-discharge line. In order to effect this control, it is advisable to provide each group of cooling elements with at least one separate pressure detector as well as possibly at least one separate temperature detector.

Finally, it is also possible, in principle, in the plant of the present invention, to provide an expansion turbine in known manner in place of the throttle member. With the former, it is possible to recover the greatest part of the pump output, which leads to an even lower power consumption of the plant.

The means for accomplishing the foregoing objects and other advantages, which will be apparent to those skilled in the art, are set forth in the following specification and claims, and are illustrated in the accompanying drawings dealing with several embodiments of the present invention. Reference is made now to the drawings in which:

FIG. 1 is a schematic diagram of a plant in accordance with the invention having a vacuum line connected to the air exhaust of the jet condenser;

FIG. 2 is a schematic diagram of an alternate embodiment with a gas equalization line connected to the vacuum line;

FIG. 3 is a schematic diagram of another alternate embodiment having a vacuum line connected to the jet condenser;

FIG. 4 is a schematic diagram of a further alternate embodiment with separate evaporation device; and

FIG. 5 is a schematic diagram of a final embodiment having a water trap in the vacuum line.

Referring to FIG. 1, steam turbine 1 receives steam from a steam boiler system (not shown) via line 2 and drives a machine, for instance, a generator 3. The turbine 1 can, of course, also consist of a plurality of individual turbines connected in series. In principle, it is also possible to use a steam engine instead of the steam turbine or that exhaust vapor which is to be condensed is obtained by some other means. This vapor furthermore need not necessarily be water vapor or steam, but can be any other vapors which are to be condensed.

The exhaust vapor from steam turbine 1 is fed via an exhaust steam line 4 to a jet condenser 5. Within the jet condenser 5 there are jet nozzles 5a from which water is sprayed into the steam which condenses and precipitates together with the injected cooling water thus forming a water bath 5b in the jet condenser 5. The cooling water or condensate of the jet condenser 5 flows through a cooling water or condensate-discharge line 6 out of the jet condenser 5.

In the cooling water or condensate-discharge line 6 there are provided two pumps 7 and 8. The pump 7, when necessary, conveys cooling water or condensate from line 6 as feed water to the steam boiler system (not shown). Between the pump 7 and the steam boiler system, there is a shut-off valve 9 which is operated either manually or automatically.

The pump 8 in the cooling water or condensate discharge line 6 serves as circuit pump 10 which conveys cooling water or condensate into a distributor line 10 from which the cooling water or condensate flows, via shut-off elements 11, to a plurality of groups of cooling elements each group of which consists of a plurality of individual cooling elements. In order to simplify the drawings, only a single group of cooling elements 12 with a total of four cooling elements has been shown, although actually a substantially larger number of cooling elements can be combined into a group and as a rule substantially more cooling element groups are present than have been indicated.

The cooling water or condensate flows from the distributor line 10, via the shut-off element 11a, to a group distributor line 13 and from there through the cooling elements 12 into a group collecting line 14. Each cooling element generally consists of finned-tube elements and have been only schematically indicated in the drawing. The cooled water in the group collecting line 14 is fed, via the shut-off element 11b, to a collecting line 15 and passes from there into a main-collecting or water-return line 16 which goes back to the turbine 1. Between the main-collecting or water-return line 16 there is a throttle member 17 which again throttles the pressure behind the pump 8, as seen in the direction of flow. The pressure in the entire circuit described above is higher than the pressure in the jet condenser 5. The vacuum in the jet condenser 5 is kept as low as possible since it is connected to the turbine 1. Instead of the simple throttle member 17 indicated, an expansion turbine can also be provided as recovery turbine which recovers the greater part of the output to the pump 8. After the cooled water has passed through the throttle member 17, it passes, via the spray nozzles 5a, back into the jet condenser 5 and serves as the cooling water.

Between the cooling water or condensate-discharge line 6 and the main-collecting or water-return line 16, there is a crossover connection 18 and normally closed shut-off element 19. Upon the starting of the system, and particularly in cold weather, the shut-off element 19 is opened so that the cooling water driven by the pump 8 flows, not through the cooling elements 12, but directly, via the opened shut-off element 19 and crossover connection 18 to the main-collecting or water-return line 16 and is fed from there, via the throttle member 17, to the jet condenser 5. Overcooling of the water is thus avoided.

In order to be able to empty both the jet condenser 5 as well as the lines 6, 10, 13 to 16 and the cooling elements 12, drain lines 20, 21 and 22 have been provided connected via shut-off elements 23, 24, 25 and 26, to the lines 6, 13 and 14. The drain lines 20 and 22 lead to two water tanks 27 and 28 which are adapted to receive the cooling water. In the arrangement shown, it is possible for the cooling elements 12 and their group distribution lines or group collecting lines 13 and 14, respectively, to be drained separately without also draining the cooling-water or condensate-discharge line 6, the distributor line 10, the collecting line 15 and the main collecting or water-return line 16. In such a case, the shut-off elements 11a and 11b are closed while opening the shut-off elements 25 and 26 as well as the shut-off element 29 leading to the water tank 27. Upon the venting of the cooling elements 12, the water then flows into the water tank 27 which is of correspondingly large size. When the cooling elements 12 are to be again filled with water, the shut-off element 29 is closed and a shut-off element 30 in the drain line 20 is opened. In this way the water tank 27 is connected with a pump 31 which operates the drain line 22 and the shut-off elements 25 and 26, will feed the water to the cooling elements 12 as well as the group distributor line 13 and the group collecting line 14. After the filling, the shut-off elements 25 and 26 are closed again while the shut-off elements 11a and 11b are opened, as a result of which the cooling elements 12 are again connected to the circuit.
For the draining of the cooling-water or condensate-discharge line 6 behind the pump 8, as seen in the direction of flow, as well as for draining the distributor line 10, the shut-off element 24 is opened. The water then flows into the water tank 27 via the drain lines 21 and 20 or, if the latter is already full, by opening the shut-off members 30 and 32 into the second water tank 28 which as a rule is somewhat larger than tank 27. This water tank 28, however, is only used if the cooling elements 12 and the pipelines of the circuit are to be drained and therefore the water amount to be removed is greater than the capacity of the smaller water tank 27. The water tank 28 is able, by the opening of another shut-off member 33, to receive, via the drain line 22, water from the cooling elements 12 and the distributing or collecting lines 13 and 14. If the jet condenser 5 is also to be drained, this can also be done by opening the shut-off element 23, in which case then the section of the cooling-water or condensate-discharge line 6 between the two pumps 7 and 8 is also drained. Draining of the main-collecting or water-return line 16 and of the collecting line 15 is effected by opening the shut-off elements 19 and 24, via the drain lines 21 and 28. Thus the entire circuit as well as individual section thereof can be drained separately.

The filling of the lines, including the cooling elements 12 in case of complete draining, is effected by closing the shut-off elements 29 and 33 and by opening the shut-off elements 30 and 32 in which case the water then is passed by means of the pump 8 into the tanks 27 and 28 via the drain line 22 and the shut-off elements 25 and 26, back into the cooling circuit.

The cooling water or condensate-discharge line 6, the distributing line 10, the collecting line 15 and the main collecting line 16 are also filled via the drain line 22 when the shut-off elements 11a and 11b open.

The water level in the jet condenser 5 is maintained between a maximum value and a minimum value by a control device 34. The control device 34 duly actuates the shut-off elements 23 and 24. When the water level is too high, the shut-off element 24 is opened a certain amount. The opening of the shut-off element 24 takes place as a result of the corresponding control pulse over the control line 24a by which the shut-off element 24 is connected with the control device 34 at the jet condenser 5. When the shut-off element 24 is opened, water flows through the line 21 and the line 20 into the water tank 27 and thus out of the cooling circuit, since behind the pump 8, as seen in the direction of flow, a relatively high pressure prevails in the cooling-water or condensate-discharge line 6 as a result of which the water is forced into the tank 27. However, the water level in the jet condenser 5 drops too much, the shut-off element 23 rather than the element 24 is opened. It also receives the corresponding control pulse via a control line 23a. When the shut-off element 23 is opened, water flows out of the tank 27, via the line 20, into the cooling-water or condensate-discharge line 6 inasmuch as, in the region just in front of the pump 8 in the cooling-water or condensate-discharge line 6, a very low pressure prevails which causes the water to be drawn out of the water tank 27 and into the cooling circuit. On the other hand, if the water level within the jet condenser is normal, the shut-off elements 23 and 24 are both closed.

Above the cooling elements 12, there is a vacuum line 35 which is connected to the highest points of each element and leads, via shut-off elements 36, to a main vacuum line 35a. The vacuum line 35a is connected to the air exhaust 37 of the jet condenser 5. In this way there is produced in the main vacuum line 35a, at the point of connection in the vicinity of the jet condenser 5, the same vacuum as in the jet condenser 5 itself, which is, for instance, about 0.1 to 0.2 atmospheres. By leakage, separation of air from the cooling water or the like, a somewhat higher pressure of, for instance, about 0.3 atmospheres absolute is obtained at the points of connection of the vacuum line 35a to the highest points of the cooling elements 12. This pressure is higher than the pressure prevailing in the jet condenser 5, which pressure lies above the saturation pressure even at the higher temperature present in the jet condenser 5. By the partial cooling of the condensate in the cool-

...ing elements 12 and the resultant lower water temperature, the pressure in the region of the connecting points between the vacuum line 35 and the cooling elements 12, which pressure is definitely above the saturation pressure at the temperatures prevailing in the cooling elements 12. Evaporation of the water in the cooling elements 12 is thus definitely avoided.

If a cooling element 12a, for example, becomes damaged, the shut-off elements 11a and 11b of the corresponding group distribution line 13 and group collecting line 14 are first of all closed. Furthermore, the shut-off element 36 of the corresponding vacuum line 35 is closed. Thereupon the upper flange connection 38 of the damaged cooling element 12a is loosened. After the loosening of the flange connection 38, air penetrates into the damaged cooling element 12a so that by opening the shut-off elements 25, 26 and 29, the water contained in the damaged cooling element 12a flows into the water tank 27. The amount of water which discharged is so determined that the damaged cooling element 12a is just emptied. The other cooling elements 12 of the same group, which are connected to the same vacuum line 35, however, remain filled with water, in contradistinction to the known plant, if a replaceable vacuum is maintained at their highest points. The vacuum at the highest points of the other cooling elements 12 of the same group is maintained in the manner that immediately after the loosening of the flange connection 38 on the damaged cooling element 12a, the vacuum line 35 is sealed off thereby a blind flange and the valve 36 is immediately opened again. Therefore, air can penetrate only into the damaged cooling element 12a so that the water contained therein can flow out. After the loosening of the lower flange connections 39 of the damaged cooling element 12a, the latter can be removed and this flange 39 can also be closed by a corresponding blind flange. The remaining cooling elements 12 of the group can then be again placed in full operation by opening the valves 11a and 11b. The draining of the entire group of cooling elements or of the associated group-distributing or group-collecting lines 13 and 14 is not necessary in this case which constitutes an advantage. It means a substantial shortening of the lost time of the other cooling elements 12 of the same group. Of course, it is not necessary to apply blind flanges to the flange connections 38 and 39 if a replacement cooling element is inserted immediately upon removal of the damaged cooling element 12a. The filling of the newly inserted cooling element 12c can be readily described by feeding water by means of the pump 31. However, as a rule this is only done when the pump 8 stops for some reason. If this is not the case, the filling of the newly inserted cooling element 12 takes place via the cooling-water of condensate-discharge line 6, the distributing line 10 and the group distributing line 13. The water required for this filling is taken from the jet condenser 5. As a result of this, the water level of the jet condenser decreases but it is brought back to the normal level, as already described, by opening the shut-off element 23 and by water flowing from the water tank 27.

The embodiment shown in FIG. 2 corresponds substantially to the embodiment of FIG. 1 except that between the water tank 27 and the vacuum line 35 there is a gas equalization line 40 which, via shut-off elements 41, can be connected directly with the vacuum line 35. In normal operation, the water tank 27 is empty and is filled merely with an inert gas, for instance nitrogen, in order to avoid corrosion. The same is true of the gas equalization line 40 which leads to the shut-off elements 41. The inert gas is supplied from water tank 28 which is connected to the tank 27 via shut-off and control valve 42. If water is now removed from the group of cooling elements 12, then instead of air, the inert gas which is displaced from the water tank 27 is introduced into the cooling elements 12 and high points of the cooling distribution and group collecting lines 13 and 14, respectively, so that no air can penetrate into them. It is advisable in such case, however, to close the shut-off element 36 of the vacuum line 35 in order to prevent the inert gas from being drawn in.
The embodiment shown in FIG. 3 also corresponds substantially to the embodiment of FIG. 1 except that the main vacuum line 35a is not connected to the air exhaust 37 but is directly connected to the inside of the jet condenser 5. In this arrangement, substantially the same conditions prevail as in the case of the embodiment of FIG. 1 with the further advantage that when water is withdrawn via the vacuum lines 35 and 35a from the cooling elements 12, this water is fed back to the cooling circuit via the jet condenser 5. Withdrawal of water via the air exhaust 37 of the jet condenser 5 into the atmosphere and a corresponding loss of cooling water is thereby avoided in an advantageous fashion. It is even possible to intentionally and continuously draw off a small amount of water from the vacuum lines 35 and 35a via the cooling elements 12 to ensure that the cooling elements 12 are at all times filled with water. To accomplish this, it is merely necessary to adjust the delivery of the pump 8 and the throttle action of the throttle member 17 properly.

In the embodiment of the invention shown in FIG. 4, the basic principle of the embodiments described above has been retained. The main vacuum line 35a is, however, connected in FIG. 4 to a separate evacuation device 44. The evacuation device 44 operates as a function of the water level present in the cooling elements 12. For this purpose, at least two cooling elements 12b are each provided with water level detectors 44a. The latter can each individually regulate the operation of the evacuation device 44 over lines 44b. This can be done for instance in the manner that the evacuation device 44 is only placed in operation when the level within the cooling elements 12b has dropped below a minimum mark. This can take place in particular when the pressure in the vacuum line 35 has become too great, due to the penetration of the air from the outside or the separation of inert gases, and the water within the cooling elements 12 has been forced down thereby. The evacuation device 44, after the opening of the shut-off elements 36, is connected until the air which has penetrated or the inert gases which have been given off have been removed and the water level has thereby again returned to normal. Thereupon the shut-off elements 36 are advisedly closed again and the evacuation device 44 is disconnected. It is furthermore also possible to keep the evacuation device 44 connected at all times and merely to open or close the shut-off elements 36 as a function of the water level detectors 44a. The latter is particularly to be recommended in cases of a large number of groups of cooling elements and thus numerous vacuum lines 35, at least one vacuum line 35 being connected at all times specifically to the evacuation device 44.

The pressure in the cooling circuit and thus also in the vacuum line 35 is regulated in this embodiment substantially by a controller 45 which is arranged on the throttle member 17 in the main collecting or water-return line 16. The controller 45 can operate on the one hand solely as a function of the pressure in the vacuum line 35, for which purpose a pressure detector 46 is connected to the vacuum line 35. However, it is better if the controller 45 operates not only as a function of the pressure in the vacuum line 35, but also as a function of the temperature in the vicinity of the highest points of the cooling elements 12 since this temperature determines the saturation pressure at these points and can vary. Accordingly, in the embodiment of FIG. 4 each group of cooling elements has at least one temperature detector 47 which transmits its measured value over measurement line 47a in the same way as the pressure detector 46 via measurement line 46a to the controller 45. Since at the highest points of the cooling elements 12, a lower temperature always prevails than the temperature present in the jet condenser 5, it is sufficient for the pressure in the vacuum line 35 to be equal to or somewhat greater than the pressure in the jet condenser 5 in order to make certain that the pressure in the vacuum line 35 does not lie below the saturation pressure at the highest points of the cooling elements 12. One can therefore, instead of having a temperature detector 47 on a cooling element 12 of each cooling element group, also provide a pressure detector 48 on the jet condenser 5 and transmit the value to the controller 45 over the measurement line 48a. The controller 45 then compares the pressure of the pressure detector 46 and of the pressure detector 48 with each other and by proper adjustment of the throttle member 17 sees to it that the pressure in the vacuum line 35 is at most equal to the pressure in the jet condenser 5 and preferably somewhat above same. In the last mentioned embodiment, the temperature detector 47 and its measurement line to the controller 45 are unnecessary.

As a further difference from the embodiments of FIGS. 1 to 3, the condensation plant of FIG. 4 has a separate inert-gas supply device 49 which consists of an inert-gas storage 50 and of gas cylinders 43 and of a shut-off and control device 42. The separate inert-gas supply device 49 can be connected via a connecting line 51 and shut-off elements 41 directly to the vacuum line 35 over which, upon the draining of the cooling elements 12 and the other lines of the cooling circuit, they are filled with inert gas. Furthermore, the pressure side of the evacuation device 44 is connected, via a gas return line 52 and the connecting line 51, with the inert-gas supply device, a shut-off element 53 being arranged in the gas return line 52. In normal operation, the shut-off element 53 is closed while another shut-off element 54 is opened to the pressure-side blow-off line 55 of the evacuation device 44. The gas return line 52 and the last mentioned shut-off elements serve to return the inert gas in the cooling elements 12 as well as in the lines of the cooling circuit into the inert-gas storage 50 when the cooling elements 12 and the cooling circuit are again filled with gas. For this purpose, the shut-off element 54 is closed while the shut-off elements 36 and 53 are opened. Upon the connecting of the evacuation device 44, it conveys the inert gas from the cooling circuit, the cooling elements 12 and the vacuum line 35, via the gas return line 52 and the connecting line 51, back into the inert-gas storage 50.

The embodiment of FIG. 5 corresponds substantially to the embodiment of FIG. 2 with the difference that a water trap 56 is arranged in the main vacuum line 35a. The object of the water trap 56 is to remove any water possibly contained in the main vacuum line 35a. Furthermore, the water trap 56 has the result that a continuous flow to the water trap 56 is present within the vacuum line 35 or 35a whereby air bubbles are removed from the vacuum line 35 and the formation of air pockets is avoided. Furthermore, the continuous flow of water in the vacuum line 35 and 35a prevents their freezing in case of low outside temperatures, which is similarly true also for the water in the water trap 56. The latter is connected on the air side, via a connecting line 57, to the air exhaust 37 of the jet condenser 5. In addition to this, the water trap 56 prevents the connecting line 57, which in practice has a relatively large length, from freezing in the manner that the water trap 56 sees to it that no water penetrates into the connecting line 57. On the water side, the water trap 56 is connected via a second connecting line 58 with the jet condenser 5 so that the water which has been removed is returned to the cooling circuit. In order to be able to regulate the level of the water within the water trap 56, an adjustable shut-off element 59 is provided in the connecting line 58, it being opened to a greater or lesser extent as a function of the level of the water in the water trap. However, it is not absolutely necessary to return the water side connecting line 58 to the jet condenser 5 since this line in practice would have a relatively large length and can freeze in winter. In order to do away with such a long line, it is also possible to connect the water trap 56 on the water side via a connecting line 58a with the collecting line 15 and to return the separated water there to the cooling circuit. The connecting line 58a will then be substantially shorter. The considerably longer connecting line 58 to the jet condenser 5 can then advantageously be done away with.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims.
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rather than the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore to be embraced therein.

What is claimed is:

1. A condensation plant for condensing exhausts such as steam and the like comprising a jet condenser having at least one jet nozzle therein and operatively connected to receive exhausts to be condensed, a plurality of air-cooled cooling elements having inputs and outputs and arranged in groups, a distribution system connecting said condenser to said cooling elements and comprising a condensate-discharge line connected to receive condensate from said jet condenser and feed it to the inputs of said cooling elements, at least one pump means in said discharge line, a water-return line connected to the outputs of said cooling elements and to the jet nozzle of said condenser, a throttle member in said water-return line, and a vacuum line means operatively connected to the highest point of each of said cooling elements, said vacuum line means for maintaining a pressure at said highest points of said cooling elements which is below atmospheric pressure and above the saturation pressure of the condensate at the temperature of the condensate in the upper parts of the cooling elements.

2. A condensation plant according to claim 1, further comprising an air exhaust on said jet condenser, said vacuum line being also connected to said air exhaust.

3. A condensation plant according to claim 1, wherein the vacuum line is connected to the inside of the jet condenser.

4. A condensation plant according to claim 1, further comprising a separate evacuation device, said vacuum line being connected to said separate evacuation device.

5. A condensation plant according to claim 1, further comprising means for adjusting the pressure in the vacuum line as a function of the water level present in the cooling elements.

6. A condensation plant according to claim 5, further comprising water-level detector means provided in several cooling elements of the plant, and at least in one cooling element of each group of cooling elements.

7. A condensation plant according to claim 6, wherein each water-level detector means can adjust the pressure in the vacuum line independently of the other water-level detector means.

8. A condensation plant according to claim 1, further comprising a water trap mounted in the vacuum line.

9. A condensation plant according to claim 8, wherein said water trap additionally comprises means for connecting its water side with the inside of the jet condenser or the water-return line, and means for connecting its air side with the air exhaust of the jet condenser or an evacuation device.

10. A condensation plant according to claim 9, further comprising a shut-off member connected to the water side of said water trap, means to control said shut-off member as a function of the water level in the water trap.

11. A condensation plant according to claim 1, further comprising a shut-off element in the vacuum line at least at the end of each group of cooling elements.

12. A condensation plant according to claim 1, further comprising a gas equalization line, a water tank, means to connect the vacuum line of at least each group of cooling elements connected separately to said gas equalization line between the cooling elements and said water tank, means to fill the gas equalization line and the water tank with an inert gas.

13. A condensation plant according to claim 1, further comprising an inert gas supply device and means to connect the vacuum line of at least each group of cooling elements separately to said inert gas supply device.

14. A condensation plant according to claim 12, further comprising means to connect the pressure side of an evacuation device temporarily with a gas equalization line.

15. A condensation plant according to claim 1, further comprising means to adjust the throttle member in the water-return line as a function of the pressure in the cooling elements at their highest points.

16. A condensation plant according to claim 1, further comprising means to adjust the throttle member in the water-return line as a function of the pressure in the vacuum line within the region of the cooling elements and the temperature in the region of the highest points of the cooling elements.

17. A condensation plant according to claim 1, further comprising means to adjust the throttle member in the water-return line as a function of the pressure in the vacuum line in the region of the cooling elements and the pressure in the jet condenser.

18. A condensation plant according to claim 15, wherein each group of cooling elements is provided with at least one separate pressure detector and with at least one separate temperature detector.

19. A condensation plant according to claim 1, further comprising an expansion turbine mounted in the return line and serving as a throttle member.

20. A condensation plant according to claim 1, wherein said vacuum line means comprises means for maintaining a pressure at said highest points of said cooling elements which is below atmospheric pressure and only slightly above the saturation pressure of the condensate at the temperature of the condensate in the upper parts of the cooling elements.

21. A condensation plant according to claim 5, comprising an evacuation device connected to the vacuum line, said evacuation device for regulating the pressure in said vacuum line as a function of the water level in the cooling elements.

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