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MULTI-STAGE FLASH EVAPORATORS

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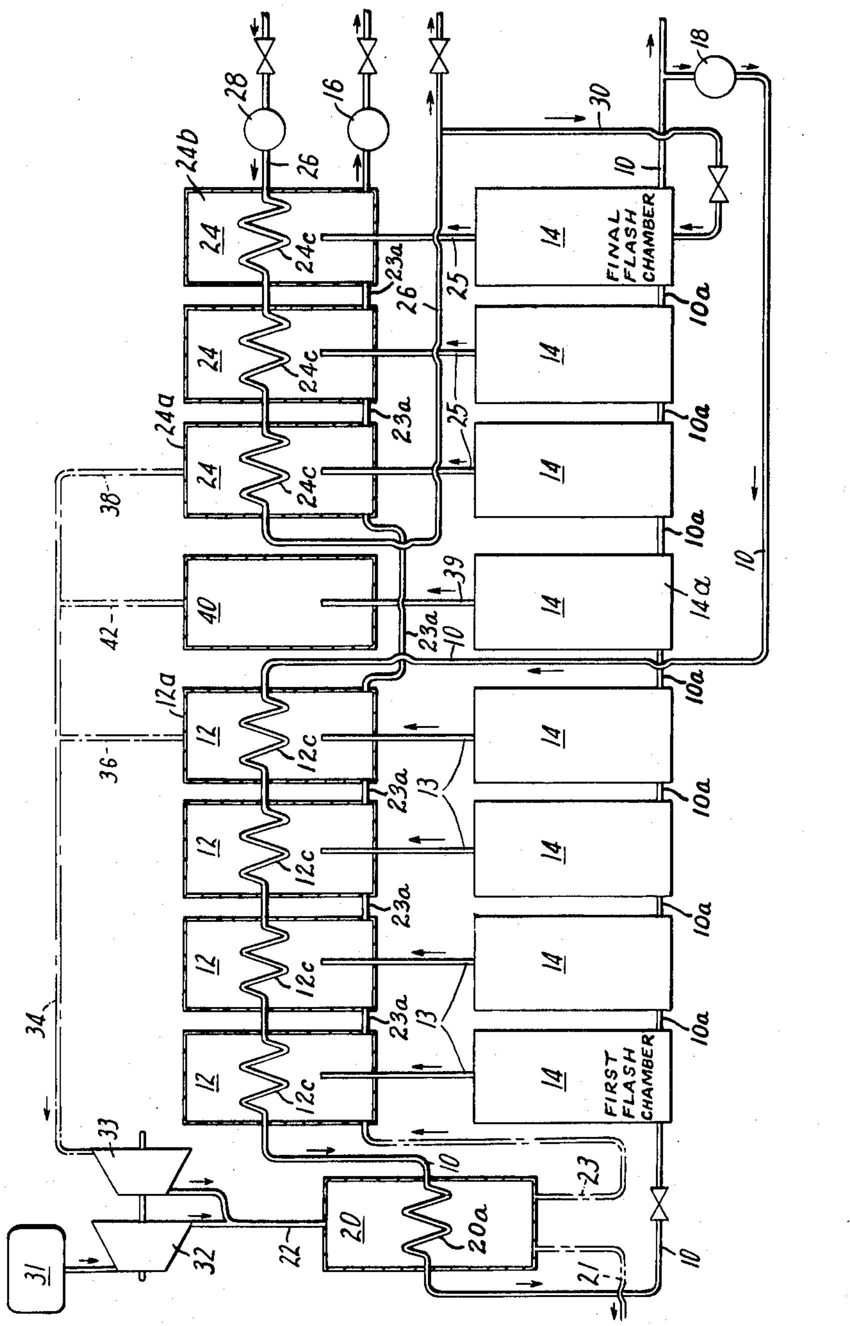

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MULTI-STAGE FLASH EVAPORATORS

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This invention relates to multi-stage flash evaporators, particularly evaporators for obtaining distilled water from impure water or sea water.

In such evaporators the brine or liquid to be evaporated is passed through a series of heaters the last of which is generally heated by live steam supplied from an external source. In many evaporators, and particularly in evaporators for distilling sea water, the top brine temperature to which the circulating brine may be heated in the steam heated chamber is limited by various operational and design considerations, and particularly by the onset of scale deposition with higher operating temperatures. In the case of evaporators for distilling saline water such as sea water, this generally limits the permissible top brine temperature to below 200° F., so that all the heaters in the evaporator operate at sub-atmospheric pressures. This arrangement has the advantage that low grade waste steam can be used in the steam heated chamber. In some cases however, the only steam supply available to the evaporator is steam under considerable pressure, and in these installations it therefore becomes desirable to provide means which use this high pressure steam supply to the best advantage.

The present invention has been devised with this consideration in mind, and according to the invention a multi-stage flash evaporator comprises three or more stages each having a flash chamber and an associated heater or vapour receiver, and a heater heated by live steam from an external source which is arranged to be traversed by the liquid to be evaporated before it enters the flash chambers, in which the steam-heated chamber has an inlet connected to the delivery side of a mechanical compressor, such as a rotary compressor or piston compressor, the inlet side of the compressor being connected to an intermediate stage of the evaporator so as to withdraw therefrom vapour of the liquid being evaporated and deliver such vapour to the steam-heated chamber.

Preferably the said inlet or another inlet in the steam-heated chamber is connected to the delivery side of a steam turbine so that the steam-heated chamber receives live steam which has been expanded in the turbine. The turbine can then be used to drive the compressor, and it is advantageous where this arrangement is used for the turbine and the compressor to be so constructed and arranged that, during operation, the pressure of the exhaust steam from the turbine is approximately equal to the pressure of the compressed vapour delivered by the compressor.

In order that the invention may be thoroughly understood, an evaporator arrangement in accordance with it will now be described, by way of example, with reference to the accompanying drawing which shows the arrangement schematically.

The flash evaporator shown in the drawing comprises a brine path **10** which passes through a series of heater-condensers **12** each having a heat exchanger **12***c* therein wherein the brine is gradually brought to a higher temperature by the latent heat of condensation of vapour which is passed into the heater-condensers **12** through passages **13** from a series of flash chambers **14**. Distillate which condenses in the heater-condensers **12** is passed from one heater condenser to another through

conduits **23***a* and then is removed by a distillate extraction pump **16**, and the liquid in the flash chambers **14** which is not evaporated is similarly removed from the final flash chamber, the liquid being passed from one flash chamber to the next by conduits **10***a*. A circulating pump **18** is provided in the flow path **10** for circulating the brine.

A steam-heated chamber **20** is provided which is traversed by the liquid passing through heat exchanger **20***a* immediately before it is passed into the flash chambers **14**, and this steam-heated chamber **20** is heated by steam supplied through the pipe line **22**. Further heater-condensers **24** are supplied with vapour through passages **25** from the flash chambers forming the last few flashing-off stages, and these heater-condensers **24** are circulated by fresh cool liquid which serves to remove excess heat from the circulatory system. The fresh liquid flows along a path **26** which includes heat exchangers **24***c* and is circulated by a pump **28**. After leaving the heater-condenser **24***a*, part of the slightly preheated stream of fresh liquid is discharged to waste while the remainder enters the final flash chamber **14** through a pipeline **30**. Here the fresh liquid mixes with unevaporated brine which has already been circulated along the flow path **10**, and the resultant mixture is withdrawn from the final flash chamber in order that part of the mixture may be discharged to waste while the other part is recirculated to the heater-condensers **12** with the aid of the pump **18**. Thus, all the brine used for evaporation enters the evaporating system through the pipeline **30**.

As already indicated, an important aim of the present invention is to utilise to the best advantage the pressure drop obtainable from the so-called "live" steam supplied from the external source **31**. This is achieved by passing the steam supply through a steam turbine **32** before it reaches the steam-heated chamber **20**, the turbine being coupled to a rotary compressor **33** so that the steam is used to compress a quantity of brine vapour which is withdrawn by the compressor from one of the intermediate stages of the evaporator. The compressed vapour is then passed, together with the exhaust steam from the turbine, into the steam-heated chamber **20** where the steam and vapour mixture is condensed. The distillate thus formed in the steam-heated chamber **20** can be removed through the pipe-line **21** as boiler feed water or supplied through the pipeline **23** to the final heater-condenser **12**. At the same time, the quantity of live steam required to operate the evaporator under a certain set of conditions can be reduced by a quantity corresponding approximately to the quantity of vapour which is compressed in the rotary compresssor **33**. This produces an appreciable saving in steam and heat consumption which can vary between wide limits depending on the thermodynamic cycle used in the evaporator. Apart from the turbine **32** and the compressor **33**, very little additional equipment or expenditure is required, and in fact a reduction in the heater surfaces in the heater condensers **24** is possible. Preferably, the turbine **32** and the compressor **33** are so designed that the pressure of the exhaust steam from the turbine is approximately equal to the pressure of the compressed vapour delivered by the compressor.

The quantity of vapour withdrawn from the intermediate stage by the compressor **33** will depend, for any given live steam conditions, on the pressure in the evaporator stage from which the vapour is extracted and the pressure in the steam-heated chamber **20** into which it is discharged. The ratio of vapour withdrawn to live steam supplied will rise considerably if the ratio of the higher to the lower of the two above-mentioned pressures is reduced, but on the other hand, the thermodynamic performance of the plant is best when the evaporator is operated with as high a top brine temperature as possible and as low a vapour temperature in the coldest heater-condenser **24*b*** as is practicable.

It is to be noted that the brine vapour is withdrawn by the compressor **33** from an intermediate stage of the evaporator and not from the first or last stages. This is because we have found that a very considerable improvement in the ratio of vapour withdrawn to live steam supplied and therefore in the steam consumption of the plant, can be achieved if the compressor **33** is made to withdraw vapour from a flash chamber or a heater condenser operating at a pressure between the highest and the lowest pressures obtaining in the plant. The selected point of vapour extraction should preferably be the highest pressure fresh heater-condenser **24*a*** if more than one such heater is used, or the lowest pressure heater-condenser **12*a***. Broken lines **34**, **36** and **38** are shown in the drawing to illustrate the pipeline connections between the heater condenser **24*a*** or the heater condenser **12*a*** and the suction side of the compressor **33** if either of these arrangements is adopted. Alternatively, a specially arranged flash chamber **14*a*** connected by a passage **39** to a simple vapour receiver **40** instead of to an associated heater can be used, the chamber **14*a*** and its receiver **40** forming an intermediate stage of the evaporator, and the receiver **40** being connected by the pipeline **34** and a branch line **42** to the suction side of the ejector **32**.

An investigation of the thermodynamics of the arrangements described above shows that no thermodynamic losses are involved in withdrawing vapour from the highest pressure heater-condenser **24*a***, since heat is still rejected at that level from the plant, and the extraction of vapour at an intermediate pressure increases the quantity of vapour handled by the compressor **33**. The same applies if the suction side of the compressor is connected to a special receiver **40** or its associated flash chamber **14*a*** arranged as described above. A certain thermodynamic loss is involved in connecting the suction side of the compressor **33** to the coldest heater condenser **12*a***, but the loss is small as this heater operates at a temperature level approaching the level at which heat is rejected altogether from the plant, and the thermodynamic loss may be more than offset by gains resulting from improved performance of the turbine and compressor.

It may be expedient in some circumstances to withdraw vapour from a heater-condenser **12** operating at a pressure above that in the heater-condenser **12*a***. On the other hand, it may be found that the increased quantity of vapour handled by the compressor **33** with such an arrangement does not offset the thermodynamic disadvantages following the extraction of vapour at a temperature level at which heat can be usefully transferred to the circulating brine.

It may be found desirable to reduce the temperature of the brine leaving the steam-heated chamber **20** below the maximum permissible limit given by consideration of scale formation. In certain cases the reduction in the basic net gained output ratio (i.e. the ratio of the distillate produced to the steam consumption) of the evaporator, due to such reduction in temperature can be more than offset by the saving in steam consumption due to the lower pressure rise required within the compressor **33**. This applies particularly to sea water evaporators operating with fairly small temperature and pressure differences between the low pressure and high pressure ends of the plant.

The advantages gained by means of the invention can be appreciated by comparing the results obtained using an evaporator of conventional design with the results obtained after the same evaporator has been modified so as to be in accordance with the invention. Thus, in a typical evaporator having a gained output ratio of 8:1, each lb. of steam supplied direct to the heat input section would produce in the evaporator 8 lb. of vapour all of which would condense to form 8 lb. of distillate. The gross water output would therefore be 9 lb. made up of 1 lb. from the heat input section condensate plus 8 lb. of distillate. But as 1 lb. of this would have to be returned to the boiler as feed water, the net output would be 8 lb. water from 1 lb. steam, which corresponds to the gained output ratio of 8:1.

If now the same evaporator is modified so as to operate in accordance with the invention, the following takes place. Each ⅓ lb. of steam passed through the turbine provides sufficient energy to compress ⅔ lb. of vapour in the compressor so that, when the turbine exhaust steam is mixed with the compressed vapour, 1 lb. of heating steam is available to be fed to the heat input section. This again produces 8 lb. of vapour in the evaporator, but as ⅔ lb. of this vapour is withdrawn to be recompressed, only 7⅓ lb. condenses to form distillate. By adding to this the 1 lb. of steam condensed in the heat input section, the gross output of water is 8⅓ lb. Of this quantity of ⅓ lb. is required for boiler feed water, so that the net output is, as in the operation described above, 8 lb. However, as the steam consumed from the boiler is now ⅓ lb. only, the effective gained output ratio is now 8:⅓ or 24:1.

It is of course true that the steam supply to the turbine **32** now has to be at a comparatively high pressure, but the additional fuel required to generate this steam is insignificant compared with the saving resulting from the fact that the quantity of steam required has been reduced by two-thirds. Where the source of supply **31** takes the form of a boiler, the latter will be cheaper to construct and install due to its much smaller size.

Should the source **31** of high pressure steam become unavailable for any reason, the plant shown in the drawing can easily be arranged to run on a low grade pressure steam supply by supplying the steam direct to the steam-heated chamber **20** instead of through the turbine **32**. In such circumstances the compressor can either be cut out of the evaporating cycle or, alternatively, driven by some other form of prime mover.

It is to be understood that the connections between the turbo-compressor and the heater or heaters, and also between the turbine and the steam supply source **31**, include valves or other means for controlling the steam supply and the withdrawal of the vapour, and for dealing with the various conditions encountered when starting up or shutting down the plant.

I claim:

1. A multi-stage flash evaporator comprising: a series of flash chambers including a first flash chamber, a plurality of intermediate flash chambers and a last flash chamber, first feed conduit means connected to said first flash chamber, interconnecting conduits connecting said flash chambers in series to enable feed liquid introduced into said first flash chamber to flow therefrom through the series of flash chambers to said last flash chamber, a first series of heater condenser chambers, a second series of heater condenser chambers, flash vapor conduit means connecting each heater condenser chamber of said first series with vapor space in a respective one of a first group of said flash chambers including said first flash chamber and several further flash chambers immediately succeeding it in the flash chamber series, further flash vapor conduit means connecting each heater condenser chamber of said second series with vapor space in a respective one of a second group of said flash chambers including said last flash chamber and at least one further flash chamber immediately preceding it in the flash chamber series, drain conduit means to drain distillate from all said heater condenser chambers, a first plurality of heat exchangers disposed one in each of said first series heater condenser chambers and interconnected in series to form a first heat exchanger flow line for the flow of cooling fluid from one heat exchanger to another through the series, second feed conduit means connected to one end of said first heat exchanger flow line to deliver feed liquid thereto, first outlet conduit means connected to the other end of said first flow line, a steam-heated chamber, a compressor, third feed conduit means delivering steam from said compressor to said steam-heated chamber, a further heat exchanger disposed in said steam-heated chamber and having an inlet connected to said first outlet conduit means, and an outlet connected to said first feed conduit means, whereby feed liquid flowing in said first flow line is delivered to the series of flash chambers by way of said further heat exchanger, a second plurality of heat exchangers disposed one in each of said second series heater condenser chambers and interconnected in series to form a second heat exchanger flow line for the flow of cooling fluid, fourth feed conduit means connected to one end of said second heat exchanger flow line to deliver feed liquid thereto, second outlet conduit means connected to the other end of said second flow line, fifth feed conduit means connecting said second outlet conduit means to one of said second group flash chambers, and vapor conduit means connecting the inlet side of said compressor to vapor space in one of said intermediate flash chambers.

2. An evaporator according to claim **1**, wherein the inlet side of the compressor is connected to one of said first series heat condenser chambers that receives flash vapor from the last flash chamber of said first group of flash chambers.

3. An evaporator according to claim **1**, wherein the inlet side of the compressor is connected to one of said second series heater condenser chambers that receives flash vapor from the first flash chamber of said second group of flash chambers.

4. An evaporator according to claim **1**, and comprising feed delivery means delivering feed liquid withdrawn from said last flash chamber to said second feed conduit means.

5. An evaporator according to claim **1**, wherein condensed steam from said steam heated chamber is delivered to the first series heater condenser chamber that is connected to said first flash chamber.

6. A multi-stage flash evaporator comprising: a series of flash chambers including a first flash chamber, a plurality of intermediate flash chambers and a last flash chamber, first feed conduit means connected to said first flash chamber, interconnecting conduits connecting said flash chambers in series to enable feed liquid introduced into said first flash chamber to flow therefrom through the series of flash chambers to said last flash chamber, a first series of heater condenser chambers, a second series of heater condenser chambers, flash vapor conduit means connecting each heater condenser chamber of said first series with vapor space in a respective one of a first group of said flash chambers including said first flash chamber and several further flash chambers immediately succeeding it in the flash chamber series, further flash vapor conduit means connecting each heater condenser chamber of said second series with vapor space in a respective one of a second group of said flash chambers including said last flash chamber, drain conduit means to drain distillate from all said heater condenser chambers, a first plurality of heat exchangers disposed one in each of said first series heater condenser chambers and interconnected in series

to form a first heat exchanger flow line for the flow of cooling fluid from one heat exchanger to another through the series, second feed conduit means connected to one end of said first heat exchanger flow line to deliver feed liquid thereto, first outlet conduit means connected to the other end of said first flow line, a steam-heated chamber, a compressor, third feed conduit means delivering steam from said compressor to said steam-heated chamber, a further heat exchanger disposed in said steam-heated chamber and having an inlet connected to said first outlet conduit means, and an outlet connected to said first feed conduit means, whereby feed liquid flowing in said first flow line is delivered to the series of flash chambers by way of said further heat exchanger, a second plurality of heat exchangers disposed one in each of said second series heater condenser chambers and interconnected in series to form a second heat exchanger flow line for the flow of cooling fluid, fourth feed conduit means connected to one end of said second heat exchanger flow line to deliver feed liquid thereto, second outlet conduit means connected to the other end of said second flow line, fifth feed conduit means connecting said second outlet conduit means to one of said second group flash chambers, and vapor conduit means connecting the inlet side of said compressor to vapor space in one of said intermediate flash chambers.

7. A multi-stage flash evaporator according to claim **6** wherein said steam-heated chamber is connected to the delivery side of a steam turbine to receive live steam which has been expanded in said turbine, said compressor being driven by said turbine.

8. A multi-stage flash evaporator according to claim **6** wherein said steam-heated chamber is connected to the delivery side of a steam turbine to receive steam which has been expanded in said turbine, said compressor being driven by said turbine, and wherein said turbine and said compressor are so constructed and arranged that, during operation, the pressure of the exhaust steam from said turbine is approximately equal to the pressure of the compressed vapour delivered by said compressor.

9. A multi-stage flash evaporator according to claim **6** wherein all the flash chambers supply flash vapor to a respective heater-condenser chamber with the exception of one intermediate flash chamber, a vapour receiver being connected to vapor space in said one intermediate flash chamber and the inlet side of said compressor being connected to the said receiver.

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