Jan. 13, 1970 P. L. GEIRINGER 3,489,654

EVAPORATION SYSTEM AND PROCESS

Filed Jan. 9, 1967 3 Sheets-Sheet 1

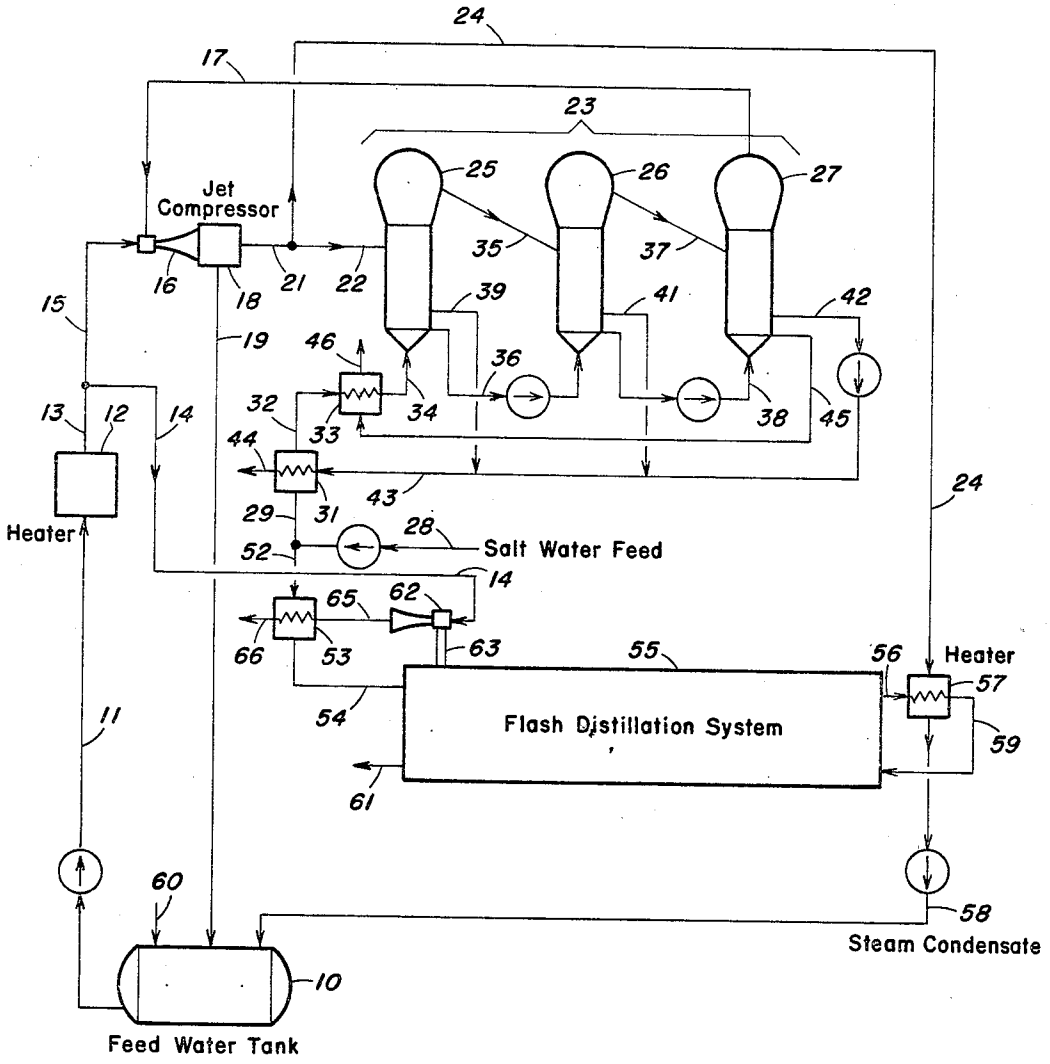


Fig. 1.

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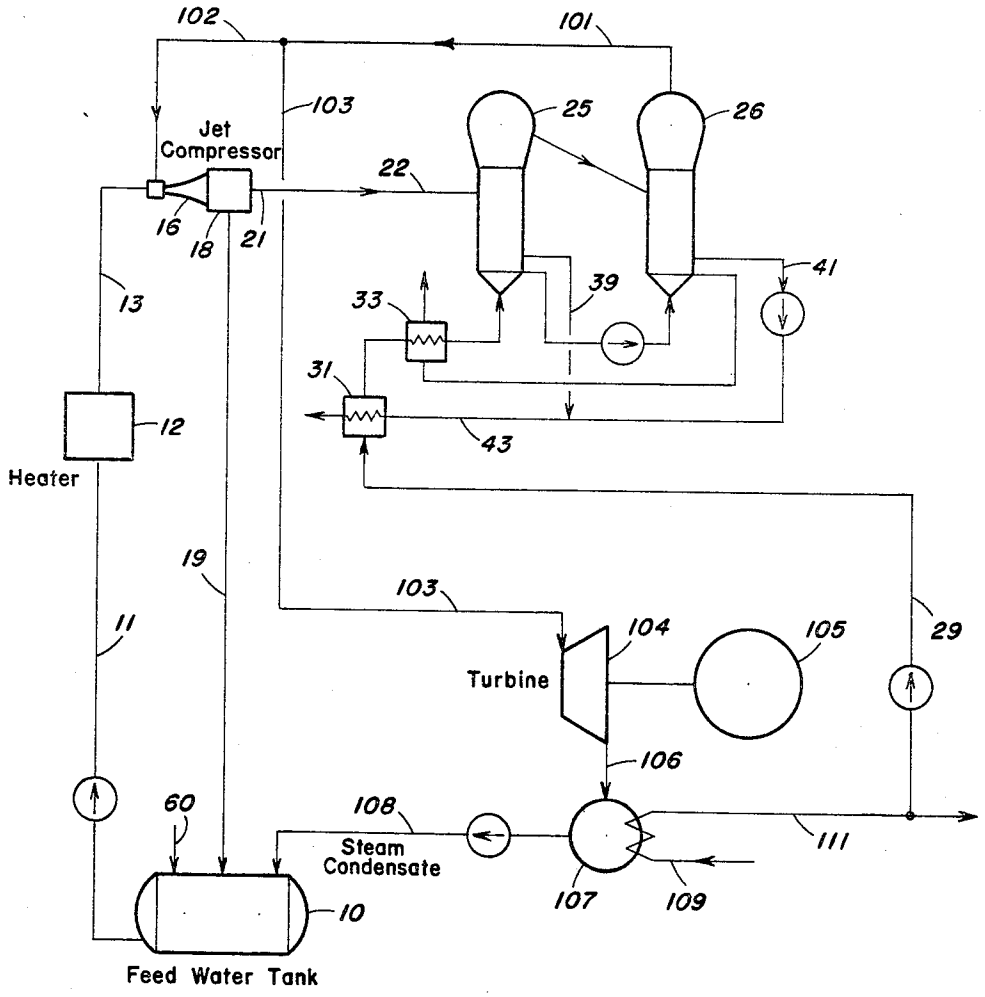


Fig. 2.

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Filed Jan. 9, 1967 3 Sheets-Sheet 3

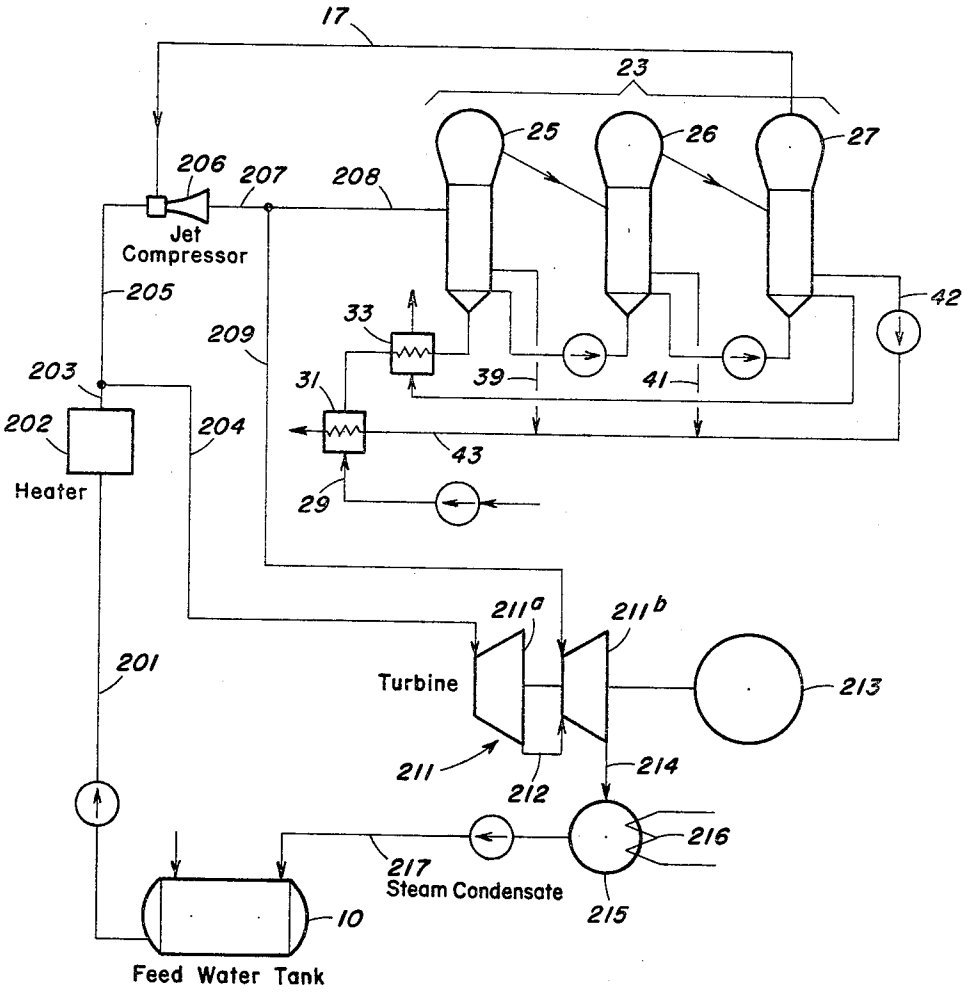


Fig. 3.

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United States Patent Office 3,489,654
Patented Jan. 13, 1970

3,489,654

EVAPORATION SYSTEM AND PROCESS

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Continuation-in-part of application Ser. No. 355,963, Mar. 30, 1964. This application Jan. 9, 1967, Ser. No. 607,972

Int. Cl. B01b *3/06, 3/00*

U.S. Cl. 203—26 8 Claims

ABSTRACT OF THE DISCLOSURE

An evaporation system containing at least one effect wherein steam is withdrawn from the system, compressed in a jet compressor by high temperature, high pressure water and the higher pressure steam returned to the system to meet a portion of the heat requirements therefor. Excess steam generated in the system may be used to furnish a portion of the heat requirements for a flash distillation system or may be employed in a turbine to generate power.

This application is a continuation-in-part of application Ser. No. 355,963, filed Mar. 30, 1964, now abandoned.

This invention relates to an improved system and method for effecting the evaporation of a liquid and more particularly relates to the evaporation of water.

The use of vapor compression for effecting the evaporation of liquids is known in the art and in general, such systems employ a power driven rotating or reciprocating compressor. These compressors require considerable investment, operating and maintenance expenses. In addition, during compression, the steam becomes superheated and consequently requires de-superheating before being reused.

An object of this invention is to provide a new and improved system and method for evaporating a liquid.

Another object of this invention is to provide a system and method for evaporating a liquid that has improved efficiency.

A further object of this invention is to provide a system and method for evaporating a liquid that effects vapor compression with simpler and less costly equipment.

Still another object of this invention is to provide a method and system for evaporating a liquid that reduces operating costs.

A still further object of this invention is to provide a system and method that is particularly adapted to the evaporation of brine, brackish water, waste water and the like.

These and other objects should be readily apparent from the following detailed description of the invention when read with reference to the accompanying drawings wherein:

FIGURE 1 is a simplified schematic flow diagram of an embodiment of the invention;

FIGURE 2 is a simplified schematic flow diagram of another embodiment of the invention; and

FIGURE 3 is a simplified schematic flow diagram of a further embodiment of the invention.

The objects of this invention are broadly accomplished by providing an evaporation system which utilizes a stationary jet compression system for reenergizing low pressure vapor withdrawn from an evaporation system. The excess vapor generated by the use of the jet compressor is utilized for other purposes, such as in a turbine to generate power or as a source of heat for a multi-stage evaporation system.

More particularly, steam withdrawn from one of the lower pressure effects of a multi-effect vapor compression evaporation system, is drawn into a jet compressor by

a motive fluid, such as high temperature, high pressure steam or water, preferably water, wherein the pressure of the steam is raised to a higher pressure. The steam at a higher pressure is then introduced into a higher pressure effect of the multi-effect vapor compression evaporation system to supply the heat requirements therefor.

In accordance with one embodiment of the invention, the excess steam produced in the vapor compression system is used to supply heat to a feed to a multi-stage flash evaporation system. In accordance with other embodiments, the excess steam is passed through a turbine to generate power. The excess steam generated in the system may be passed to other uses directly from the jet compressor or all of the steam withdrawn from the jet compressor may be passed to the vapor compression evaporation system, with a portion of the steam generated in the lower pressure vapor compression effect being passed to the vapor compressor and the remaining portion being passed to other uses. Thus, excess steam may be defined as that quantity of steam which cannot be utilized in the multi-effect vapor compression evaporation system.

The motive fluid for the jet compressor may be at a pressure between about 450 and 1750 p.s.i.g., or as high as 2000 p.s.i.g., preferably between about 1000 and about 1500 p.s.i.g. The jet compression system may comprise one or more jets arranged in parallel or series or a combination of both and the term "jet" or "jet compression system" as used herein includes such combinations. The vapor compression evaporation system contains at least one effect, generally two or more effects, with the choice of the exact number of effects and both the particular effect at which the low pressure vapor is withdrawn and the particular effect at which the higher pressure vapor is introduced being within the scope of those skilled in the art. In general, the lower pressure vapor is withdrawn from one of the initial effects and the higher pressure vapor withdrawn from the jet compressor is introduced into the first effect.

The motive fluid may be either water or steam, with water being more economical for effecting compression of vapor over a narrow pressure range. The high temperature water develops steam and due to the high density thereof, attains a lower velocity compared to superheated steam.

The invention will be further described with reference to the accompanying schematic drawings in which valves and the like have been omitted to simplify the description thereof. The choice of particular operating equipment and the placing of suitable valves and the like are considered to be within the scope of those skilled in the art. The invention is particularly described with reference to the evaporation of brine, but it is to be understood that the invention is equally applicable to the evaporation of other liquids, including brackish water, chemical or sewage effluent waste water, and the like. The multi-effect evaporation system and particular evaporating effects employed are those known in the art and are operated in a manner known in the art, e.g., feed water thereto is pretreated to remove scale forming chemicals.

Referring now to FIGURE 1, water at an elevated temperature, and pressure, for example about 1000 to about 1500 p.s.i.g., from a feed tank **10** is passed through line **11** and a high pressure heat exchanger **12**, wherein the temperature of the water is raised to about 400°–600° F. The heat exchanger **12** may be a high pressure boiler wherein the water is heated by indirect heat transfer with a suitable heat transfer agent, for example, with a gas turbine exhaust gas. The heated water from heat exchanger **12** is passed through line **13** and a portion there-

of passed through line **14** to maintain a vacuum in a flash evaporation system, as hereinafter described. The remaining portion of water in line **13** is passed through line **15** and introduced into a jet compressor **16**. The introduction of the high pressure, high temperature water into the jet compressor **16**, draws low pressure steam, for example at a pressure of 16 p.s.i.a., in line **17**, into the jet compressor **16** wherein the pressure of the steam is raised to a higher pressure, for example, 25 p.s.i.a. The low pressure steam in line **17** is obtained from the last effect of a multi-effect distillation system as hereinafter described. A steam-water mixture is passed from the jet compressor **16** into a vapor-liquid separator **18** wherein the steam and water are separated. The water is withdrawn from the separator **18** through line **19** and returned to the feed tank **10**.

The higher pressure steam is withdrawn from separator **18** through line **21** and a portion thereof pased through line **22** to supply the heat requirements for a multi-effect distillation system, generally indicated as **23**. The remaining portion of the steam is passed through line **24** to meet a portion of the heat requirements of a flash evaporation or distillation system, as hereinafter described.

The distillation system is illustrated as having three effects, effects **25**, **26** and **27**, respectively, but it is to be understood that more or less effects, for example only one effect, may be employed with the exact number of effects employed to obtain optimum conditions being within the scope of those skilled in the art. A feed for the distillation system **23**, such as brine, in line **28** is passed through line **29** and heat exchanger **31** wherein the brine is heated by indirect heat transfer with product water from the distillation system **23**. The heated brine from heat exchanger **31** is passed through line **32** and heat exchanger **33** wherein the brine is further heated by indirect heat transfer with the brine eliminated from the distillation system **23**. The heated brine from heat exchanger **33** is passed through line **34** and introduced into the first effect **25** of the distillation system **23**. A portion of the brine in the first effect **25** is vaporized to steam by indirect heat transfer with the steam introduced therein through line **22**, concurrently condensing the steam. The steam generated in the first effect **25** is withdrawn therefrom through line **35** and introduced into the second effect **26**. The unvaporized brine in the first effect **25**, is withdrawn therefrom through line **36** and introduced into the second effect **26** wherein a further portion is vaporized to steam by indirect heat transfer with the steam introduced through line **35**. The steam is condensed as a result of the indirect heat transfer.

The steam generated in the second effect **26** is withdrawn therefrom through line **37** and introduced into the third effect **27**. The unvaporized brine in the second effect **26** is withdrawn therefrom through line **38** and introduced into the third effect **27** wherein a further portion is vaporized to steam by indirect heat transfer with the steam introduced through line **37**. The steam introduced through line **37** is condensed as a result of the heat transfer. The steam generated in the third effect is withdrawn therefrom through line **17** and passed to the jet compressor **16**, as hereinabove described.

The steam condensate from effects **25**, **26** and **27** is withdrawn through line **39**, **41** and **42**, respectively, combined in line **43** as product water and passed through heat exchanger **31**, to indirectly heat the feed to the distillation system **23**. The product water from heat exchanger **31** is passed through line **44** to storage or use.

The unvaporized brine from the third effect **27** is withdrawn therefrom through line **45**, passed through heat exchanger **33** to indirectly heat the feed to the distillation system **23** and passed through line **46** to waste.

A portion of the feed brine in line **28** is passed through line **52** and heat exchanger **53** wherein the temperature of the brine is raised by indirect heat transfer with steam and non-condensible gases being exhausted from a flash distillation system, as hereinafter described. The heated brine from heat exchanger **53** is passed through line **54** and introduced into a flash evaporation system, schematically indicated as **55**. The evaporation system **55** is of a type known in the art and the exact number of stages employed therein is deemed to be well within the scope of those skilled in the art.

The brine is passed through the condenser tubes (not shown) of the flash distillation system **55** and further heated therein by indirect heat transfer with the vapor generated in the system. The preheated brine is withdrawn from the flash evaporation system **55** through line **56** and passed through heat exchanger **57** wherein the brine is heated by indirect heat transfer with excess steam from the jet compressor introduced through line **24**. As a result of the indirect heat transfer, the steam is condensed and passed through line **58** to the feed tank **10**. Make-up water is introduced into the feed tank **10** through line **60**.

The heated brine from heat exchanger **57** is passed through line **59** to the flash evaporation system **55** wherein the brine is flashed in successive evaporation stages as known in the art. The product water is withdrawn from the flash evaporation system **55** through line **61**.

The vacuum required in the flash evaporation system **55** is produced by a two-stage jet, generally indicated as **62**, connected to the system **55** through line **63**. The jet **62** is operated by the high temperature high pressure water obtained from the heater **12** through line **14**. The non-condensible gases and steam are withdrawn from the jet **63** through line **65** and passed through heat exchanger **53** to indirectly heat the brine feed to the flash evaporation system **55**. The steam and non-condensible gases are withdrawn from the heat exchanger **53** through line **66** and the steam may be condensed (not shown) and used as make-up water to the system through line **60**.

In FIGURE 2, there is illustrated a modification of the embodiment illustrated in FIGURE 1, with like parts being designated by like numerals. The jet compressor **16**, the means for generating the water motive fluid for the jet compressor **16**, the distillation system, the means for feeding brine to the distillation system, function in a manner similar to the embodiment illustrated in FIGURE 1 except that two effects instead of three effects are employed. This embodiment differs from the embodiment illustrated in FIGURE 1, in that all of the steam from the jet compressor **16** is passed to the distillation system and excess steam is withdrawn from the second effect and used for operating a turbine.

Referring now to FIGURE 2, steam is withdrawn from the second evaporator effect **26** through line **101** and a portion thereof introduced into the jet compressor **16** through line **102**. The remaining portion of steam is passed through line **103** to a low pressure condensing turbine **104**, driving a power generator **105**. The power generated may be used, for example, to produce more water by driving a compressor for a mechanical vapor compression system. The steam is withdrawn from turbine **104** through line **106**, condensed in condenser **107** and passed through line **108** to the feed tank **10**. The steam is condensed in condenser **107** by brine passed therethrough through line **109**. The partially heated brine from condenser **107** is passed through line **111** as feed to the distillation system, through line **29** and heat exchangers **31** and **33** either arranged in series (as shown) or in parallel (not shown).

In FIGURE 3, there is illustrated another modification of the embodiment illustrated in FIGURE 1, with like parts being designated by like numerals. The distillation system and the means for feeding brine to the system function in a manner similar to the embodiment of FIGURE 1. This embodiment differs from the embodiment of FIGURE 1 in that the jet compressor is driven by steam and in that excess steam is used in a two-stage high and low pressure turbine.

Referring now to FIGURE 3, water in feed tank **10** is passed through line **201** and a heat exchanger **202**, such as

a high pressure boiler, wherein the water is converted to high pressure steam. The steam from boiler **202** is passed through line **203** and a portion thereof passed through line **204** to a turbine, as hereinafter described. The remaining portion of steam in line **203** is passed through line **205** and introduced into a jet compressor **206**. The steam draws low pressure steam in line **17**, obtained from the last evaporation effect **27** of the distillation system **23** into the jet compressor **206** wherein the pressure of the steam is raised to a higher pressure.

The higher pressure steam is withdrawn from jet compressor **206** through line **207** and a portion thereof passed through line **208** to the distillation system **23**. The remaining portion of steam in line **207** is passed through line **209** to the low pressure part **211***b* of a two-stage high pressure-low pressure turbine **211**.

The high pressure steam in line **204** obtained from boiler **202** is passed to the high pressure part **211***a* of the turbine **211**. The exhaust steam from the high pressure part **211***a* is passed through line **212** to the low pressure part **211***b* of the turbine **211**. The turbine **211** operates a power generator **213**.

Exhaust steam from the low pressure part **211***b* of the turbine **211** is withdrawn through line **214**, condensed in condenser **215**, supplied with a suitable heat transfer agent through line **216**, and passed through line **217** to the feed tank **10**.

Numerous modifications of the present invention are possible in the light of the above teachings. Thus, for example, the excess steam produced by the vapor compression system of the embodiment of FIGURE 1, could be used as a steam source for a multi-effect evaporation system instead of as a heat source for a multi-stage flash evaporation system. More particularly, a portion of the excess steam from the last effect of the distillation system is passed to the first effect of a multi-effect evaporation system. The above modification and other modifications should be apparent to those skilled in the art from the teachings contained herein.

The evaporation system of the invention which employs a jet compressor or compressors has numerous advantages over evaporation systems heretofore known in the art. The efficiency of the system is very high since all excess steam is utilized either as a power source or as a source of heat for another evaporation system. The equipment is much simpler than mechanical compression systems in that the compressor and drive are eliminated and in that the steam produced is saturated thereby eliminating the need for a de-superheater. In addition, operating costs are reduced by the substitution of stationary jet compression nozzles for highly sensitive rotating machinery which is subject to scaling and costly maintenance.

Numerous modifications of the invention are possible in light of the teachings contained herein. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as particularly described.

What is claimed is:

1. A process for evaporating an impure liquid to effect recovery of a distilled liquid comprising:

(a) introducing a first portion of the impure liquid to be evaporated into a multi-effect evaporation zone;

(b) vaporizing liquid within said multi-effect evaporation zone to produce vapor of the corresponding liquid;

(c) condensing a portion of said vapor from the multi-effect evaporation zone to recover distilled liquid;

(d) introducing another portion of the vapor derived from the impure liquid in the multi-effect evaporation zone into a jet compression zone;

(e) introducing a high pressure, high temperature liquid as a motive fluid for said jet compression zone, to raise the pressure of said another portion of vapor thereby producing compressed vapor;

(f) passing one portion of said compressed vapor to the multi-effect evaporation zone to provide heat requirements therefor;

(g) introducing a second portion of said liquid to be evaporated into a flash evaporation zone;

(h) evaporating liquid in said flash evaporation zone;

(i) condensing vapor produced in the flash evaporation zone to recover distilled liquid; and

(j) passing a second portion of the compresed vapor produced in step (e) in an indirect heat transfer relaship with liquid in the flash evaporation zone to provide heat requirements therefor.

2. The process as defined in claim **1** wherein the liquid motive fluid is at a pressure between about 450 and 1750 p.s.i.g.

3. The process as defined in claim **2** wherein the impure liquid to be evaporated is an aqueous liquid and the motive fluid is water.

4. The process as defined in claim **3** wherein the motive fluid is at a temperature between about 400° F. and 600° F.

5. The process as defined in claim **1** wherein the second portion of the compressed vapor is condensed as a result of the heat transfer in step (j) and further comprising compressing the condensate from step (j), heating said compressed condensate and employing said heated and compressed condensate as the motive fluid in said jet compression zone.

6. The process as claimed in claim **5** and further comprising passing the impure liquid feed to the multi-effect evaporation zone in an indirect heat transfer relationship with the distilled liquid recovered from the multi-effect evaporation zone.

7. The process as defined in claim **6** and further comprising maintaining a vacuum in said flash evaporation zone by passing high tempearture, high pressure water as motive fluid through another jet compression zone maintained in fluid flow communication with the flash evaporation zone.

8. An apparatus for evaporating an impure liquid to effect recovery of a distilled liquid comprising:

(a) a multi-effect evaporation system;

(b) means for introducing a first portion of the impure liquid to be evaporated into the multi-effect evaporation system;

(c) means for vaporizing liquid within said multi-effect evaporation system to produce vapor of the corresponding liquid;

(d) means for condensing a portion of said vapor from the multi-effect evaporation system to recover distilled liquid;

(e) a liquid operated jet compressor;

(f) means for introducing another portion of the vapor derived from the impure liquid in the multi-effect evaporation system into the jet compressor;

(g) means for introducing a high pressure, high temperature liquid into the jet compressor as a motive fluid therefor to raise the pressure of said another portion of vapor thereby producing compressed vapor;

(h) means for passing one portion of said compressed vapor to the multi-effect evaporation system to provide heat requirements therefor;

(i) a flash evaporation system;

(j) means for introducing a second portion of said liquid to be evaporated into the flash evaporation system;

(k) means for evaporating liquid in the flash evaporation system;

(l) means for condensing vapor produced in the flash evaporation system to recover distilled liquid; and

(m) means for passing a second portion of the compressed vapor produced in the jet compressor in an indirect heat transfer relationship with liquid in the

flash evaporation system to provide heat requirements therefor.

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U.S. Cl. X.R.

202—174; 203—88, 100