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Chamberlin et al.

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[45] **Oct. 30, 1973**

[54] **MODULAR ARRANGEMENT OF FALLING FILM MULTIPLE EFFECT EVAPORATOR**

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[52] **U.S. Cl.**..... **159/13 A,** 159/17 C, 159/28 P, 165/166, 202/174

[51] **Int. Cl.**..... **B01d 1/22,** B01d 1/26, B01d 1/00, F28f 3/00, B01d 3/02

[58] **Field of Search** ..... 159/13 A, 13 R, 13 B, 159/17 C, 28 P; 165/166; 202/174

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[57] **ABSTRACT**

A falling film, multi-effect evaporator comprising a plurality of compartmented, modular shell sections separated by sheets of heat transfer material, the modular sections being arranged in sets and so disposed that liquor from lower compartments of one set of modular sections is raised to upper compartments of an adjacent set of modular sections, and vapor condensing in one set of modular sections provides the heat source to vaporize a portion of the liquor in another set of modular sections, the walls of the modular sections and the sheets of heat transfer material being the principal heat transfer surfaces incorporated in the evaporator.

8 Claims, 8 Drawing Figures

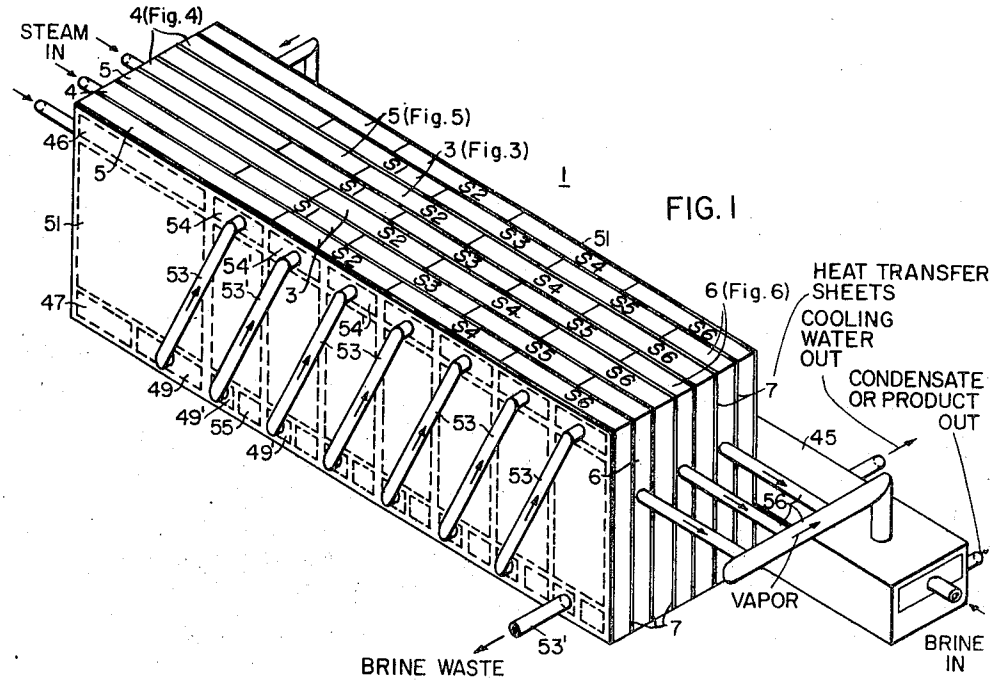


FIG. 1

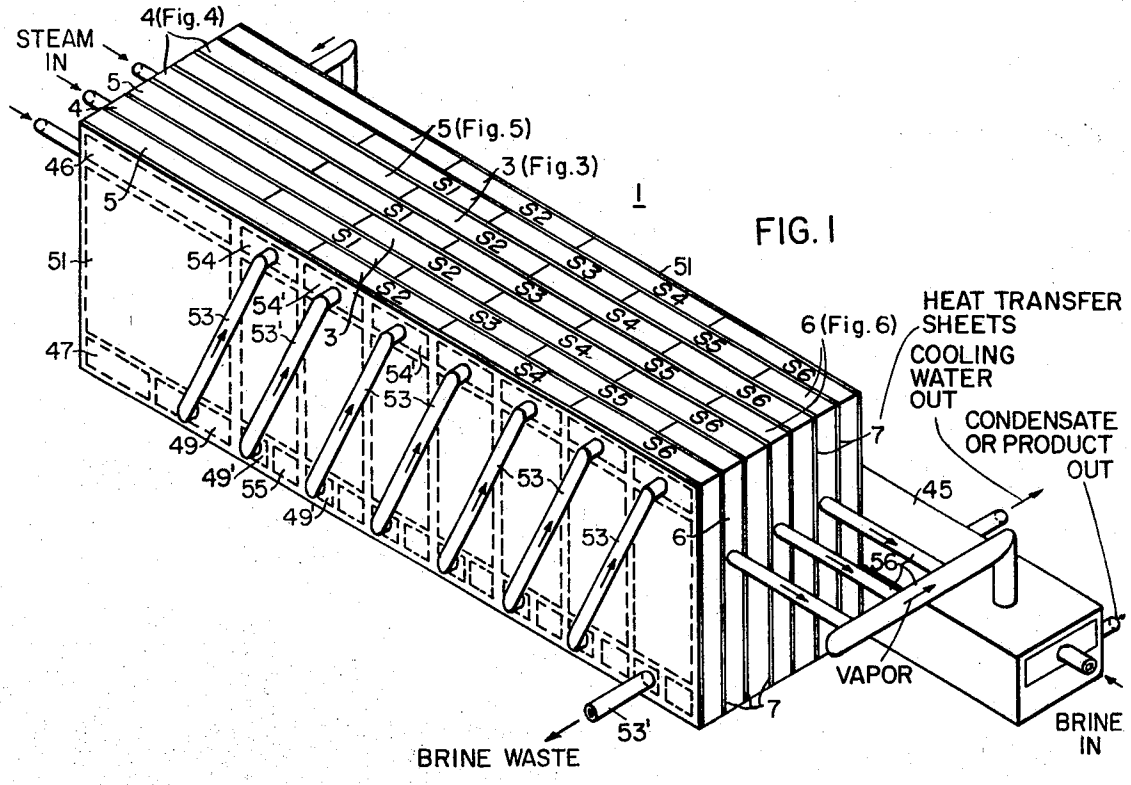

STEAM IN
4(Fig. 4)
5(Fig. 5)
3(Fig. 3)
1
HEAT TRANSFER SHEETS
6(Fig. 6)
COOLING WATER OUT
CONDENSATE OR PRODUCT OUT
VAPOR
BRINE IN
BRINE WASTE

FIG. 1

FIG. 2

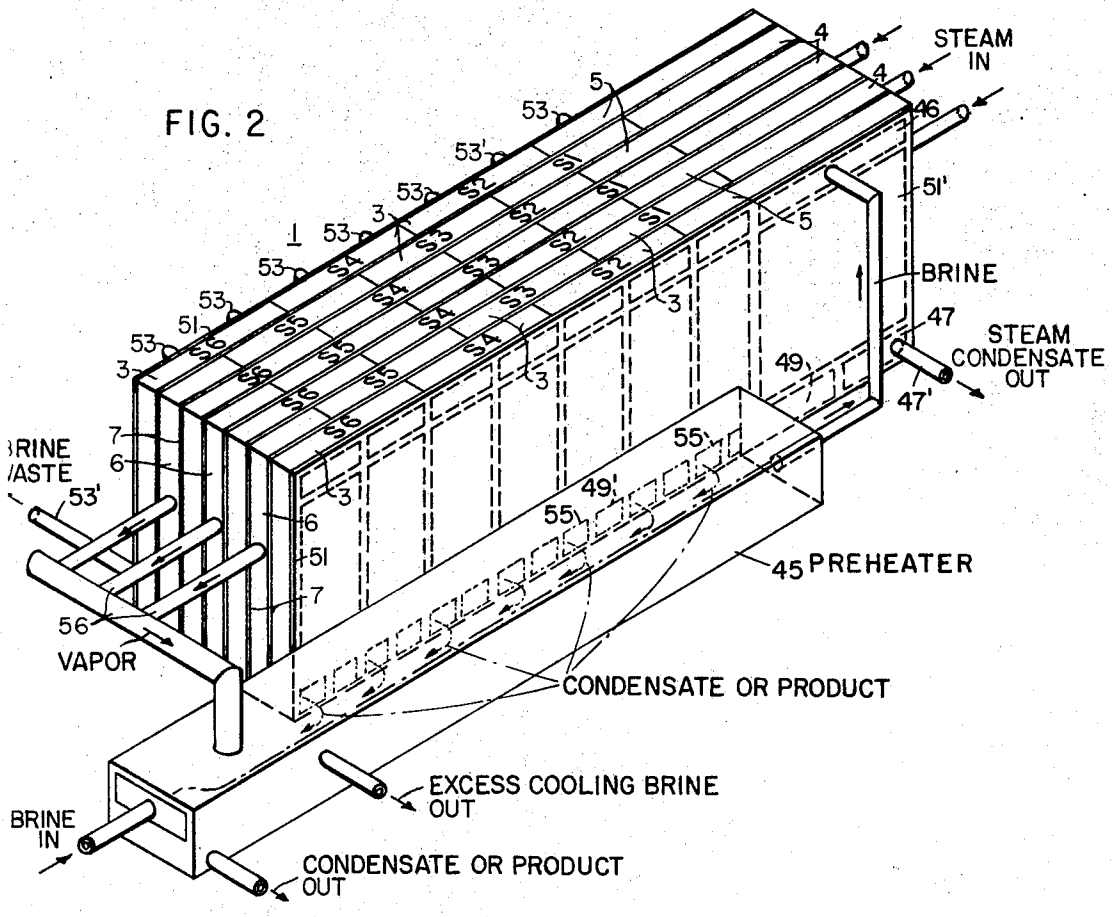
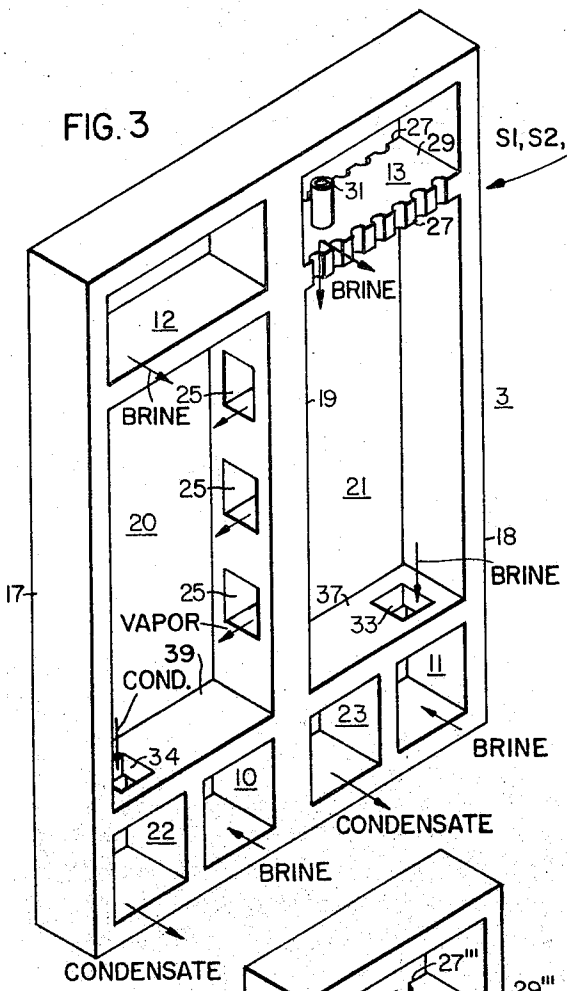

STEAM IN
BRINE
STEAM CONDENSATE OUT
PREHEATER
VAPOR
CONDENSATE OR PRODUCT
EXCESS COOLING BRINE OUT
BRINE IN
CONDENSATE OR PRODUCT OUT

FIG. 3



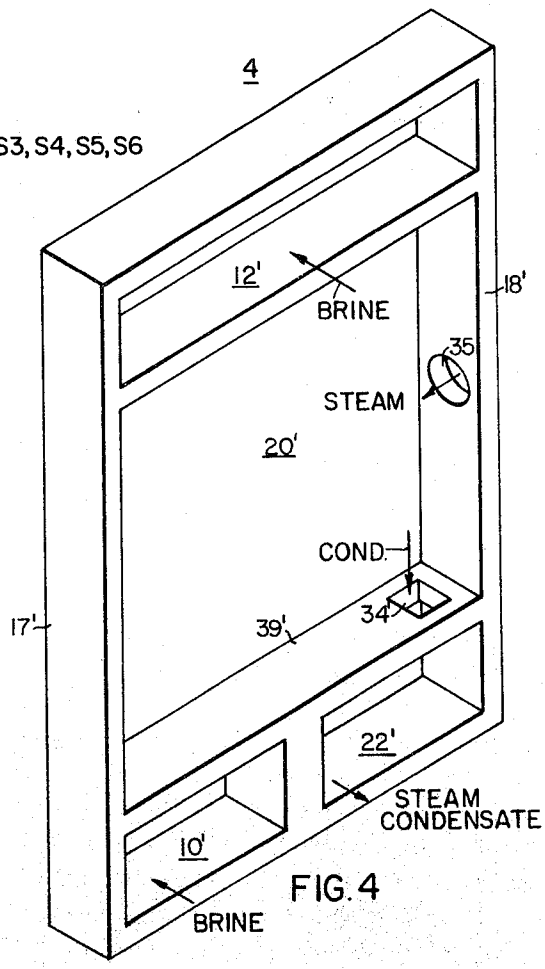


FIG. 4

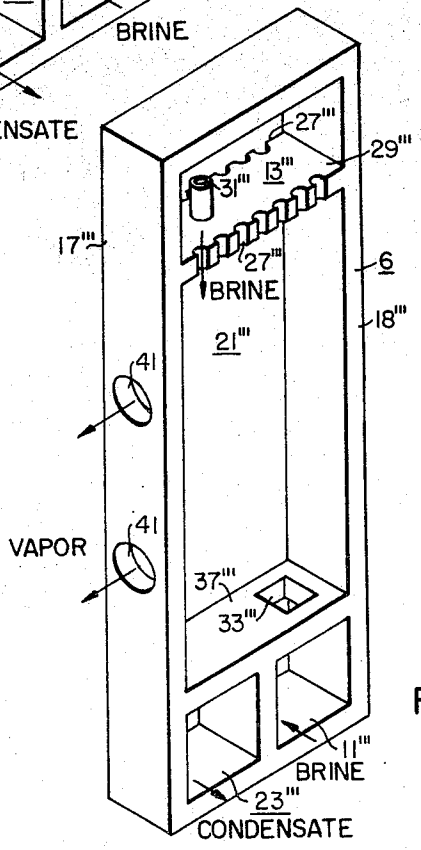


FIG. 6

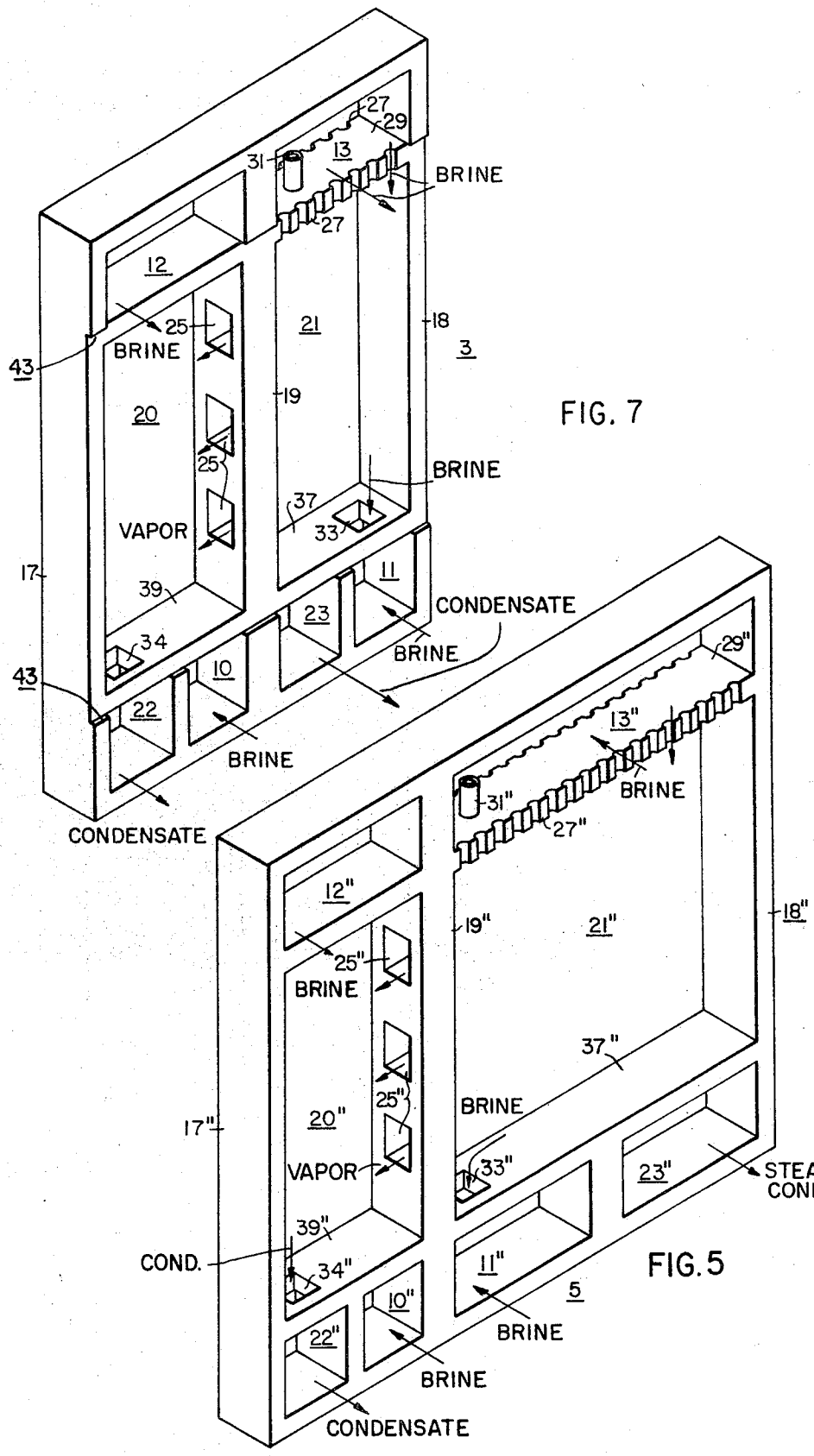

27
29
31
13
BRINE
27
12
25
BRINE
21
18
3
43
19
20
25
BRINE
37
33
VAPOR
17
39
11
CONDENSATE
23
34
BRINE
43
10
22
BRINE
CONDENSATE
29"
13"
BRINE
31"
27"
12"
19"
21"
18"
25"
BRINE
37"
25"
BRINE
17"
20"
VAPOR
33"
23"
STEAM
CONDENSATE
39"
COND.
34"
11"
10"
5
BRINE
22"
BRINE
CONDENSATE

FIG. 7

FIG. 5

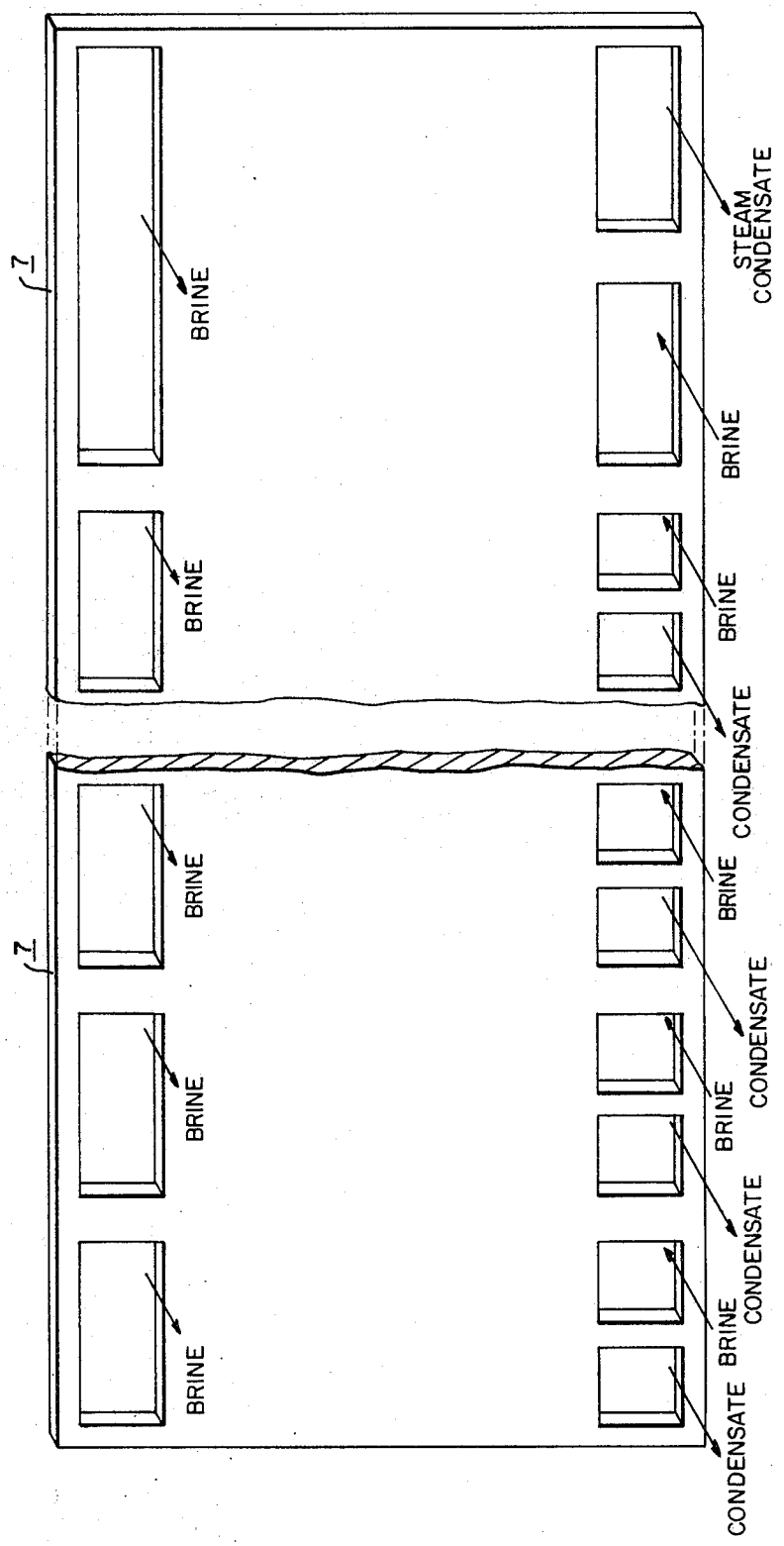

7
7
BRINE
BRINE
BRINE
BRINE
BRINE
BRINE
BRINE
BRINE
BRINE
BRINE
STEAM CONDENSATE
BRINE
BRINE
CONDENSATE
BRINE
CONDENSATE
BRINE
CONDENSATE
BRINE
CONDENSATE

FIG.8

MODULAR ARRANGEMENT OF FALLING FILM MULTIPLE EFFECT EVAPORATOR

BACKGROUND OF THE INVENTION

This invention relates to falling film, multi-effect evaporators and more particularly to such evaporators formed from modular shell sections.

Multiple effect distillation, in which a preheated feed liquor is concentrated by a series of evaporation and condensation stages at progressively lower pressure and temperature, has historically maintained a thermodynamic advantage over multistage flash distillation, in which heated brine is passed through successive flash chambers in counterflow relation with the passage of condensing fluid through heat exchange elements in the respectively Successive condenser chambers.

In recent years the multistage flash distillation has been preferred, becasue of advantages resulting from horizontal long tube design including: first, heat is transferred to a subcooled brine stream avoiding the scaling situation known to exist when nucleation occurs on a brine heat transfer surface, and secondly, the arrangement of the stages permits the use of simple repetitive elements in the form of tubes extending through a number of stages with each of the stages in a given flash range being similarly arranged.

The thermodynamic advantages of the falling film, multiple effect evaporator include: first, operating without recycling the brine resulting in operating the multi-effect cycle with a lower concentration brine having a lower boiling point; no high head recycling pump is needed; the maximum operating temperature for multi-effect distillation is 25° to 50° higher because of the lower concentration of scale forming constituents in the brine; and the production of vapor from a falling film elminates the decrement of the means temperature differential, which occurs when heat is stored and transferred as sensible heat.

SUMMARY OF THE INVENTION

In general, a falling film, multi-effect evaporator made in accordance with this invention comprises a plurality of modular compartmented shell sections having walls therein dividing the modular shell sections into upper, central and lower compartments, and a plurality of sheets of heat transfer material imposed between rows of the modular shell sections. The walls of the modular shell sections and the sheets are the principal heat transfer surfaces incorporated in the evaporator. The modular shell sections are effectively arranged in sets to provide sufficient temperature pressure differentials between adjacent sets of modular shell sections to provide a vapor lift or thermosiphon to lift liquid from the lower compartments of one set of modular shell sections to the upper compartments of an adjacent set of modular shell sections, and the sheets are effective to provide the heat transfer surface necessary to transmit heat from a set of modular shell sections, in which vapor is being condensed, to an adjacent set of modular shell sections, in which liquid is being evaporated.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of this invention will become more apparent from reading the following detailed description in connection with the accompanying drawings, in which:

FIG. 1 is an isometric view of an evaporator made in accordance with this invention;

FIG. 2 is an isometric view similar to FIG. 1, but viewed from the opposite direction;

FIG. 3 is an isometric view of a standard compartmented modular shell section utilized to form the evaporator;

FIG. 4 is an isometric view of a steam inlet, compartmented, modular shell section utilized to form the evaporator;

FIG. 5 is an isometric view of a first effect, compartmented, modular shell section utilized to form the evaporator;

FIG. 6 is an isometric view of a last effect, compartmented, modular shell section utilized to form the evaporator;

FIG. 7 is an isometric view of a standard, compartmented, modular shell section having a recess on one face thereof for receiving a heat transfer sheet and

FIG. 8 is a perspective view of a sheet of heat transfer material utilized in this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in detail, FIG. 1 shows a falling film multi-effect evaporator 1 comprising a plurality of compartmented modular shell sections or modules 3, 4, 5 and 6 separated by sheets of heat transfer material 7, such as aluminum brass, 90–10 copper-nickel, and other alloys. The modules 3 are effectively arranged in sets S1, S2, S3, S4, S5 and S6 to provide sufficient pressure and temperature differentials between adjacent sets to provide the driving force for a liquid lift to lift liquid, generally brine, from lower brine collecting compartments 10 and 11 in one set of modules to upper brine distributing compartments 12 and 13 in an adjacent set of modules. The sheets of heat transfer material 7 are so disposed, relative to the modules to effectively provide the heat transfer surface necessary to transmit heat from one set of modules, in which vapor is being condensed, to an adjacent set of modules, which liquid is being evaporated.

The modules 3, as shown in FIGS. 1 and 2, are interdigitated, as they are arranged in longitudinal rows and are staggered with a sheet of heat transfer material 7 interposed between adjacent modules in transverse direction.

As shown in FIG. 3, one group of the modular shell sections or modules 3 has parallel walls 17 and 18, and a central vertical wall portion 19 dividing the module 3 in half. Each half has an upper brine distributing compartment 12 or 13, a central compartment 20 or 21 and a pair of lower compartments 10 and 22 or 11 and 23. The central wall portion 19 is generally twice as thick as the wall portions 17 and 18, so that the central compartment 20 of one set of modules 3 will align with the central compartment 21 of an adjacent set of modules 3. The central wall portion 19 is shown to have three ports 25 placing the central compartments 20 and 21 in communication with each other. One of the upper brine distributing compartments 13 has scalloped edges 27 on a wall portion 29 separating the upper distributing compartment 13 from the central compartment 21. An upwardly extending vent pipe 31 is in communication with compartments 13 and 21 and is disposed normal to the wall portion 29. A port 33 places the central compartment 21 in communication with the lower out-

board brine drain compartment **11**. A port **34** places the central compartment **20** in communication with the lower outboard condensate compartment **22**. Thus, of the eight compartments disposed in the module **3** five are in communication to provide internal passageways for the various fluids as they progress through the evaporator.

FIG. **4** shows another group of modular shell sections or modules, the steam inlet modules **4**. Each steam inlet module **4** has an upper brine distributing compartment **12'**, a central compartment **20'**, a lower brine compartment **10'**, and a lower condensate compartment **22'**. A port **34'** places the central compartment **20'** in communication with the lower condensate compartment **22'**. The port **35** is disposed in wall **18'** for admitting steam into the central compartment **20'**.

Another group of modular shell sections or modules, the first effect sections, is shown is FIG. **5** and comprises a pair of parallel wall portions **17''** and **18''**, and a dividing wall portion **19''**. The wall portion **19''** is generally twice as thick as the wall portion **17''** and **18''**. A central compartment **21''** is shown to be in communication with a brine distributing compartment **13''** via scalloped edges **27''** of a dividing wall **29''**, with a central compartment **20''** via ports **25''**, and with a lower brine compartment **11''** via a port **33''**, which is disposed in a wall portion **37''**. The central compartment **20''** is in communication with a lower condensate compartment **22''** via a port **34''**, which is disposed in a wall portion **39''**. A lower brine collecting compartment **10''** is disposed adjacent compartments **20''** and **22''**, and a lower steam condensate compartment **23''** is disposed adjacent compartments **21''** and **11''**.

Another group of modular shell sections or modules incorporated in the evaporator is the last effect modules **6**. The last effect module **6**, as shown in FIG. **6**, comprises a pair of parallel walls **17'''** and **18'''**, an upper brine distributing compartment **13'''**, a central compartment **21'''** and a pair of lower compartments **11'''** and **23'''**. The central compartment **21'''** is in communication with the upper brine distributing compartment **13'''** via the scalloped edges of a wall portion **29'''** and with the lower compartment **11'''** via a port **31'''**. Round ports **41** are disposed in the wall **17'''** to provide an exit for vapor formed in the central chamber **21'''**.

FIG. **7** shows a modification of the modular shell section or module **3** herebefore shown in FIG. **3**. The modified module **3**, as shown in FIG. **7**, has a notch **43** extending across one face thereof forming a recess for receiving the sheet of heat transfer material **7**. If the notch **43** is not provided in the modules the sheets of heat transfer material are provided with upper and lower ports which register with the upper and lower compartments, so that registering upper and lower compartments are in communication and registering central compartments have sheets of heat transfer material **7** interposed therebetween.

The sheets of heat transfer material **7** may be flat sheets or they may be corrugated or embossed to increase their heat transfer surfaces utilizing sheet material for the heat transfer surfaces of the heat transfer surfaces which are easily cleaned and/or replaced.

The multi-effect, falling film evaporator, as shown in FIGS. **1** and **2**, has associated therewith a preheater **45**, through which brine flows and is heated before entering the brine distributing compartments **12'** and **13''** of the modules **4** and **5**. First effect modules **5** are sandwiched between steam supply modules **4** with a sheet of heat transfer material **7** interposed therebetween. The sheets of heat transfer material generally extend the length of the evaporator. The upper brine supply compartments **12'** of the modules **4** register and are in communication with the upper brine compartment **13''** of the module **5**; lower brine drain compartments **10'** **11''** register and are in communication; condensate drain compartments **22'** and **23''** register and are in communication; and the compartments **20'** and **21''** register, however, a sheet of heat transfer material separates these compartments. A gasket or other sealing material generally shaped to fit the face of the modules forms a seal between mating surfaces providing integrity between the communicating components.

A pump (not shown) causes heated brine from the preheater **45** to flood the compartments **12'** and **13''**, which form a first brine supply conduit **46**, and flows through the scalloped edges **27''** of the first effect modules **5** and down one side of the heat transfer sheets **7**. Steam from a boiler (not shown) supplies the source of heat. The steam flows into the compartments **20'** via ports **35**, contacts the sheets of heat transfer material **7**, and condenses. The condensate flows through the ports **34'** into a condensate drain conduit **47** formed by the compartments **22'** and **23''** and then back into a condensate system (not shown) via duct **47'**. Upon condensing on the heat transfer sheet **7** in compartments **20'**, the steam gives up its heat of vaporization and a small amount of its sensible heat to a film of brine flowing down the opposite side of the heat transfer sheets in compartments **21''**, vaporizing a portion of this brine film. The remaining of this brine flows downwardly through the ports **33''** into the brine drain compartments **22''**, which register with brine drain compartments **10'** to form a first lower brine drain conduit **49**.

Final brine waste is removed from compartment **10** of module **S6**-via conduit **53'** as seen in FIG. **1**.

Interdigitated with the first effect modules **5** is the first set of modules **S1**. As shown in FIGS. **1** and **2**, the set of modules **S1** comprises three standard modules **3** so disposed that compartments **13, 21, 23** and **11** register with compartments **12'', 20'', 22''** and **10''** respectively. Sheets of heat transfer material **7** are interposed between compartments **20''** and **21**, while the remaining compartments form conduits, which extend transversely of the evaporators. Closure sheets **51** which extend the length of the evaporator close the ends of the transverse conduits and central compartments **20** and **21** of the modules adjacent thereto. The closure sheets **51** and **51'** are disposed parallel to the heat transfer sheet **7** and are insulated on the outer side thereof to reduce heat loss from the evaporator.

A first lift conduit **53** is in communication with the first brine drain conduit **49** formed by the chambers **10'** and **11''** and with a second brine supply conduit **54** formed by the chambers **12''** and **13**. Because of the low height of the modules the pressure differential between these chambers **21''** and **21** is sufficient to provide a vapor lift or thermosiphoning to lift the brine from the first drain conduit **49** to the second brine supply conduit **54**. The pressure differential between adjacent sets of modules is caused by the difference in the saturated vapor pressure associated with reductions in

temperature in consecutive downstream sets of modules. This temperature and pressure differential allows some of the liquid in the lift conduit to vaporize and drive a slug of liquid, disposed above the vapor, up the conduit to provide a vapor lift or thermosiphon for the liquid in the lift conduit. Thus, the temperature difference and associated pressure difference between adjacent sets of modules is sufficient to provide a vapor lift to lift brine from the drain conduit in communication with the central compartment in one set of modules to the supply conduit supplying the film of brine to the central compartments of the adjacent downstream set of modules.

Brine from the brine supply conduit **54** flows past the scalloped edges **27** of the wall portion **29** forming a film of brine on the side of the sheet of heat transfer material **7** adjacent chambers **21**, and vapor from the first effect module **5**, which enters the chamber **20''** through ports **25''**, condenses on the sheets of heat transfer material giving up its heat of vaporization and a small amount of sensible heat to vaporize the film of brine flowing down the other side of the sheets of heat transfer material **7** in chambers **21**. The condensate from chambers **20''** flows into chambers **22''** via ports **34''** and then flows to the preheater via a first product condensate drain **55** formed by the chambers **22'** and **23''**. Unvaporized brine flows into chamber **11** via port **33** and then to a second lift conduit **53'** via a second brine drain conduit **49'** formed by the chambers **10''** and **11**. The second lift conduit **53'** is also in communication with a third brine supply conduit **54'** formed by the chambers **13** and **12** of the sets of modules **S1** and **S2**, respectively. The modules of sets **S1** and **S2** are so disposed that chambers **13, 21, 23** and **11** of the **S2** set of modules register, respectively, with the chambers **12, 20, 22** and **10** of the **S1** set of modules, sheets of heat transfer material **7** are interposed between the chambers **20** and **21** of adjacent modules and the closure sheets provide the end closures for the various compartments and conduits. Vapor formed in chambers **21** flows to chambers **20** of the **S1** set of modules **3**, condenses on one side of the heat transfer sheets **7** and vaporized brine flowing down the other side of the heat transfer sheets in chambers **21** of the **S2** set of modules. Vapor formed in chamber **21** of the **S2** set of modules flows to the chamber **20** of the **S2** set of modules to vaporize brine in the chamber **21** of the **S3** set of modules, and so on in successively numbered sets, until vapor condensing in chamber **20** of the **S6** set of modules **3** vaporizes brine in chambers **21'''** of the last effect modules **6**. The vapor from chamber **21'''** flows to the preheater via ports **41** and conduits **56** where the vapor is condensed by brine entering the preheater. Brine not evaporated in the various evaporation chambers has a very high concentration of salt and other solids and therefore is blown down to waste.

Brine not evaporated in the compartments **21** of the set of modules **S1** flows downwardly through the ports **33** and into the chambers **11**. The chambers **11** and chambers **10** of modules of sets **S1** and **S2** form the second brine drain conduit **49** which is in communication with the brine lift conduit **53'** to lift brine to chambers **12** of the **S1** set of modules and chambers **13** of the **S2** set of modules to provide a supply of brine to form a film of brine on one side of the sheets of heat transfer material in compartments **21** of the **S2** set of modules. This film of brine is partially evaporated by the heat given up by the condensing vapor on the other side of the sheets of heat transfer material. In a similar manner brine not evaporated in previous sets of modules is supplied successively to the sets **S3, S4, S5, S6** and finally to the last effect module **6**. Brine not evaporatec in the last effect module **6** has a very high concentration of salt and other solids and therefore it is blown down to waste, as noted earlier.

The modules, thus arranged, from an evaporator which has a low initial cost per Btu of heat transferred or per square foot of heat transfer surface; which provides thermal and hydraulic stability over a wide operating range, thus allowing the number and size Of stages to be changed easily to optimize the operation thereof; which provides a minimum pressure drop between stages, thus increasing the life of the evaporator, since pits caused by corrosion of the heat transfer surface tend to stop short of perforation, when there is a low pressure gradient across the heat transfer surfaces; which facilitates replacement and cleaning of the heat transfer surfaces, since they are sheet material; which is cheaper to produce, because of the multiplicity of standard parts and the elimination of much of the external piping; and which will evaporate brine at a lower cost than other evaporators herebefore made.

We claim:

1. A falling film, forward flow, multi-effect evaporator comprising

a plurality of relatively thin, prismatic, modular, compartmented shell sections disposed in a plurality of parallel rows along their longer dimensions, each modular shell section having thru openings on its opposite, large faces and having walls therein dividing said modular shell section into (1) an upper, liquid conveying compartment with a perforate floor to distribute liquid streams as a film on heat transfer surfaces, (2) a vertically partitioned central compartment one subchamber of which receives the liquid streams and the other subchamber of which receives released vapor from the streams thru the partition perforations, and (3) a lower compartment also subdivided into separate chambers to receive concentrated liquid and condensed vapor respectively thru perforate floors of said subchambers,

a plurality of separator sheets of heat transfer material interposed between said rows of said modular shell sections said walls of said sections and said sheets providing the principle heat transfer surfaces, said sheets being disposed to effectively provide said heat transfer surfaces between said rows, necessary to transmit heat from a set of sections in which vapor is being condensed, to the immediately downstream set of sections in which liquid film is being evaporated,

said sections being arranged in sets which comprise a plurality of parallel disposed, modular sections, said sets extending in a direction perpendicular to the rows, at least one set interdigitating with two adjacent sets to provide sufficient temperature and pressure differentials between adjacent sets of sections to provide a vapor lift to raise liquid from said lower liquid compartments of one set of sections to said upper liquid conveying compartments of that adjacent set of sections which is immediately downstream of said one set, with respect to liquid and vapor flow.

2. An evaporator as set forth in claim 1, wherein the modular shell sections are generally at the same elevation.

3. An evaporator as set forth in claim 1, wherein the modular shell sections each have at least four compartments therein and at least two of said compartments are in communication with each other.

4. An evaporator as set forth in claim 1, wherein a group of the modular shell sections have four compartments therein with two of said four compartments being in communication with each other, and

a group of the modular shell sections having eight compartments therein with five of said eight compartments being in communication.

5. An evaporator as set forth in claim 1, wherein the modular shell sections have parallel walls and have compartments therein having parallel walls.

6. An evaporator as set forth in claim 1, wherein

a group of the modular shell sections has a central vertical wall portion dividing the modular shell sections in said group in half, each half having an upper compartment, a central compartment, and a pair of lower compartments,

said central compartments being in communication with each other,

one central compartment being in communication with an adjacent outboard lower compartment, and

the other central compartment being in communication with an adjacent upper compartment and with an adjacent outboard lower compartment.

7. An evaporator as set forth in claim 1, wherein the modular shell sections have parallel walls,

a group of the modular shell sections has a vertical central wall portion dividing the modular shell sections in half,

each half having an upper compartment, a central compartment and a pair of lower compartments,

said compartments each having parallel walls,

each central compartment being in communication with the other central compartment and with an outboard lower compartment adjacent thereto,

one of said central compartments also being in communication with said upper compartment adjacent to it.

8. An evaporator as set forth in claim 1, wherein the modular shell sections have parallel walls, the modular shell sections being higher than they are wide, and wider than they are thick.

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