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[54] **SYSTEM FOR OPTIMAL PRESSURE CONTROL IN A MULTI-STAGE EVAPORATION UNIT**

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Related U.S. Application Data

[63] Continuation of Ser. No. 165,621, July 23, 1971, abandoned.

[52] **U.S. Cl.** **202/173**; 202/180; 203/73

[51] **Int. Cl.** **B01d 3/02**

[58] **Field of Search** ..... 202/176, 177, 186, 185 R, 202/185 D, 185 E, 172, 173, 180; 203/73, 160

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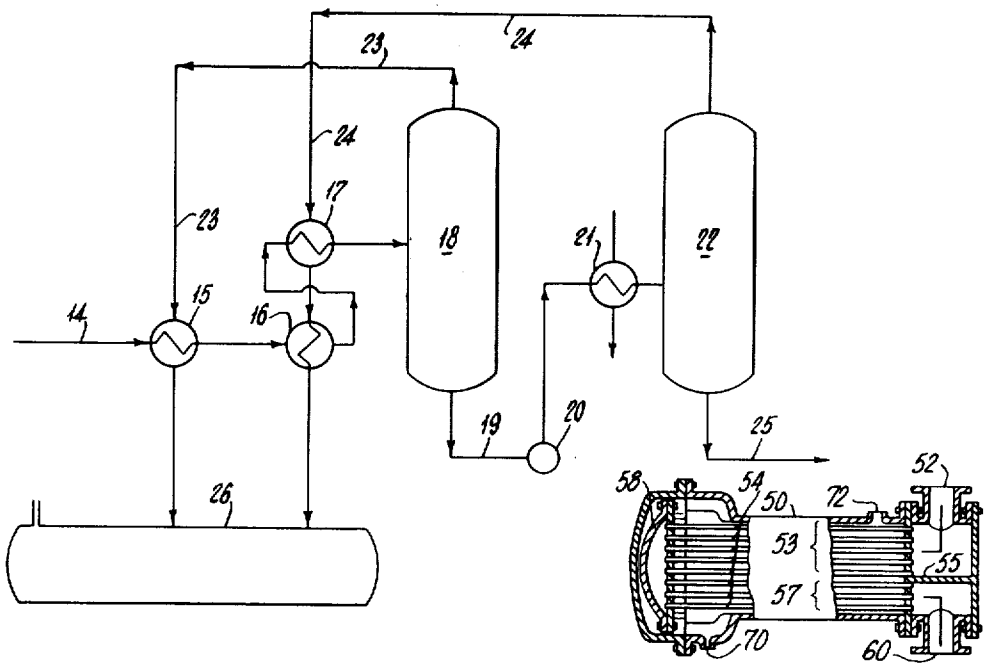
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[57] **ABSTRACT**

A system for optimal pressure control in a multi-stage evaporation unit comprising two or more series connected evaporation stages with at least one of the stages preceded by a heat source, where the fresh or feed solution is passed through heat exchangers in which it is heated by means of the vapors from the subsequent evaporation stages, and where a heat exchanger adapted to permit free flow of the vapor condensate through the heat exchanger inner portion or tube portion is arranged in the line through which the vapor leaves the higher-pressure evaporation stage.

2 Claims, 3 Drawing Figures



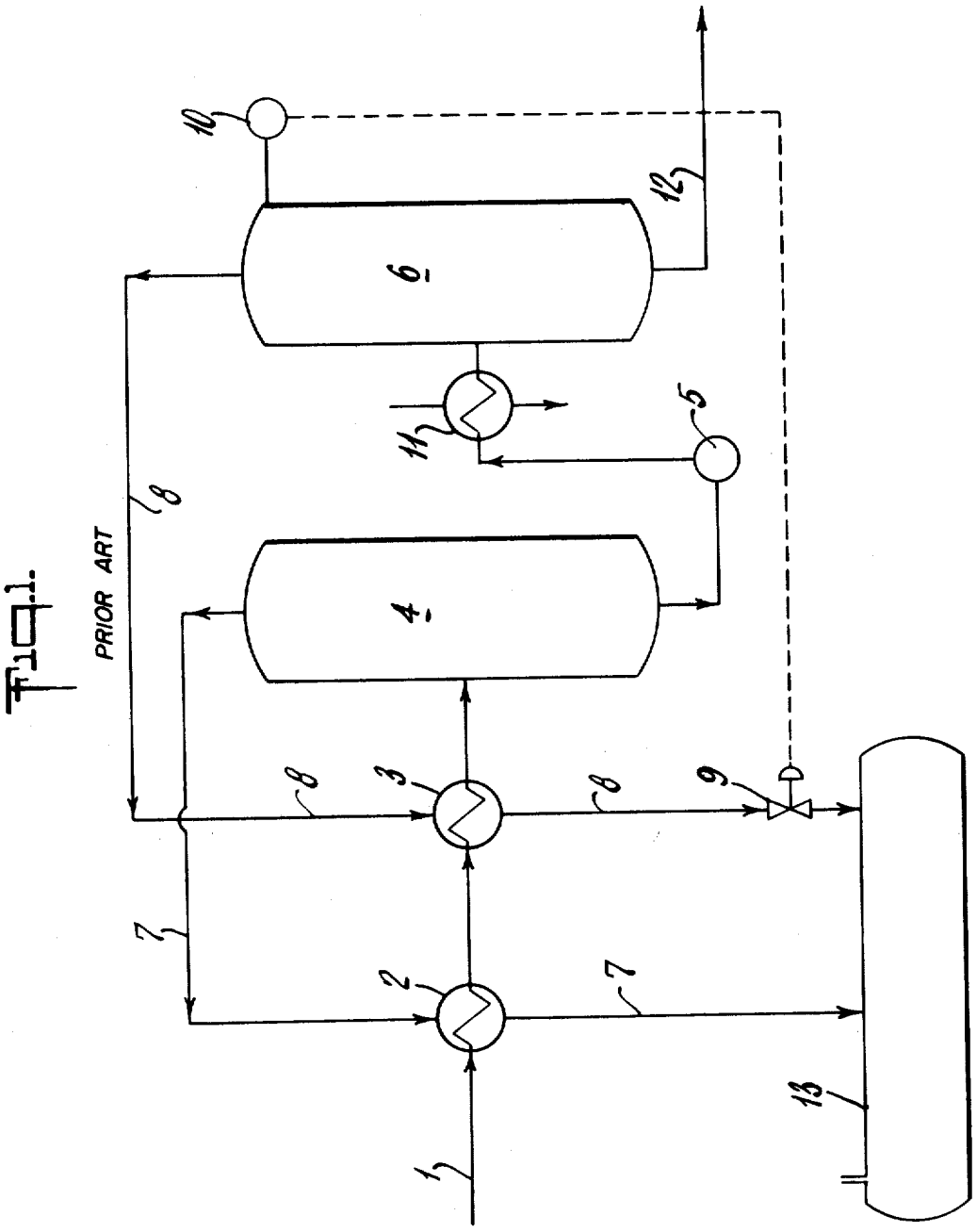


FIG. 1.

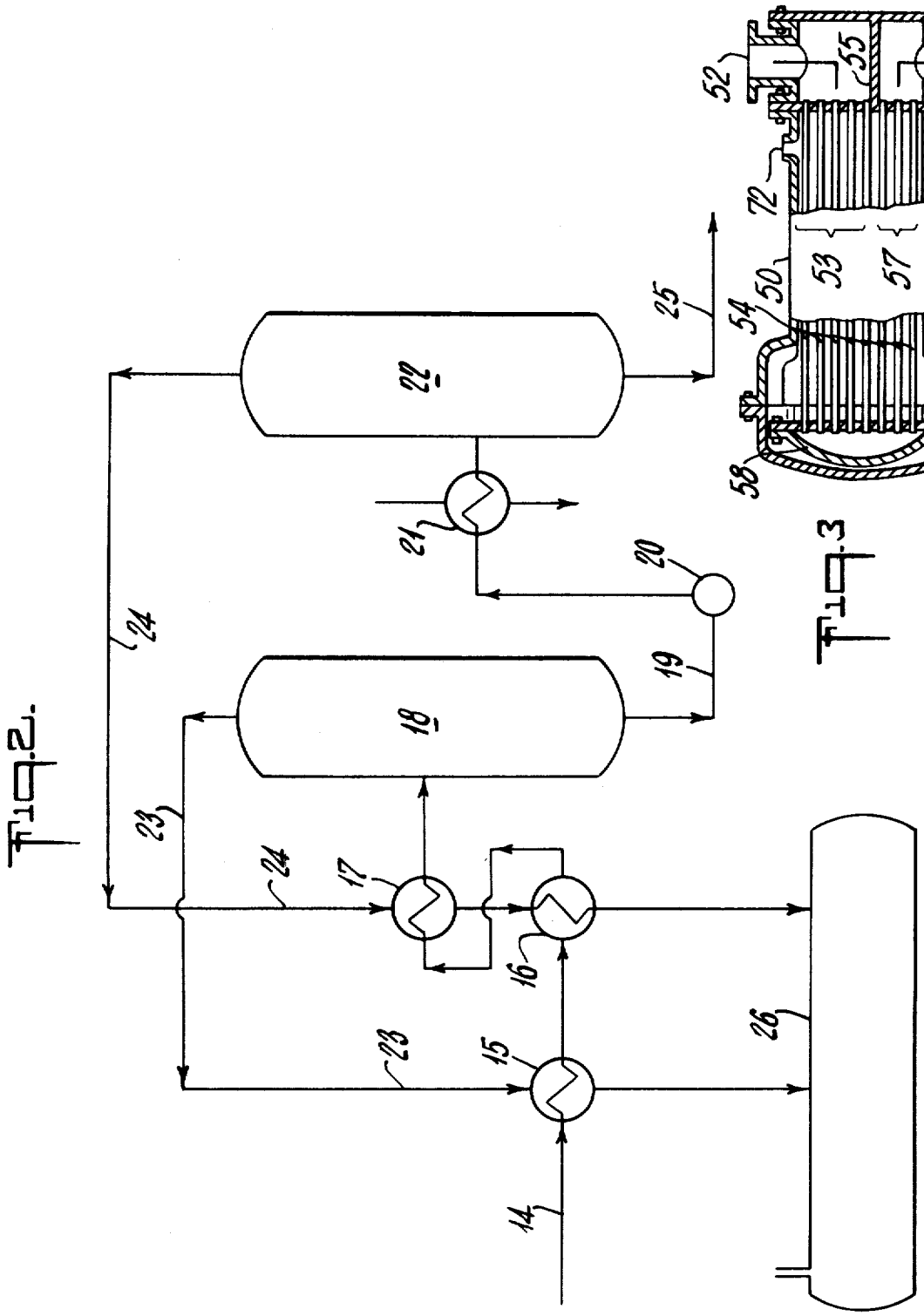


Fig. 2.

Fig. 3

SYSTEM FOR OPTIMAL PRESSURE CONTROL IN A MULTI-STAGE EVAPORATION UNIT

This is a continuation of application Ser. No. 165,621, filed July 23, 1971 now abandoned.

FIELD OF THE INVENTION

This invention relates to a system for optimal pressure control in a multi-stage evaporation unit, wherein one or more evaporation stages, at least one of which is preceded by a heat source, are connected in series, and the fresh or feed solution passes through heat exchangers where it is heated with vapors from the preceding or subsequent evaporation stages.

DESCRIPTION OF THE PRIOR ART

It is known that particular pressure conditions may be maintained between the individual evaporation stages, by providing each evaporator with a pressure regulator acting as a potential interference factor and regulating a control valve to adjust the pressure to the selected theoretical value in the event of pressure deviations. The control valve is arranged in the line through which the vapor effluent leaves the evaporation stage, and this line is arranged in the outer or shell portion of a heat exchanger or condenser in which the fresh or feed solution is heated.

For safety reasons the dimensions of the heat exchanger should be such as to permit it to condense a slightly larger quantity of vapors than actually leave the evaporation stage, while maintaining the desired pressure conditions. As a result, the heat exchanger would always be partially flooded and so never work up to its full efficiency.

The partial flooding of the heat exchanger results in a storage of the high-pressure condensate at high temperatures. When solvents susceptible to temperature are used the decomposition products will cause corrosion and/or deposit formation, necessitating a periodical overhauling of the plant, which in turn reduces the throughput capacity of the latter. Moreover, there is the risk that a build-up of inert gases in the condensing system may cause the pressure control valve to open, thereby expanding larger amounts of vapors along with the inert gases. The above applies to evaporation units operating according to either the counter-flow or the parallel flow principle.

SUMMARY OF THE INVENTION

It is an object of the instant invention to avoid the above mentioned disadvantages encountered with pressure control in conventional units and provide a trouble safe system ensuring complete utilization of the heat exchanger capacities while at the same time condensing the vapors in the heat exchangers or condensers completely.

The invention, relates to a system for optimal pressure control in a multi-stage evaporation unit, wherein two or more evaporation stages, at least one of which is preceded by a heat source, are connected in series, and the fresh solution passes through heat exchangers in which it is heated by means of the vapors from the subsequent evaporation stages, characterized in that a heat exchanger adapted to permit free flow of the vapor condensate through the heat exchanger inner portion or tube is arranged in the line through which the vapor leaves the higher-pressure evaporation stage.

The invention has solved the problem by installing in the line through which the vapor effluent leaves the higher-pressure evaporation unit, a heat exchanger as a throttling means adapted to permit unimpeded passage of the vapor condensate and assume the pressure expanding function formerly performed by the pressure control valve. The effluent discharged at the outlet of the heat exchanger or condenser mainly consists of condensate which on account of the said throttling means acts as a vapor or gas lock when the pressure in the pertinent evaporation stage is too low due to the vapor volume exceeding many times the condensate, and which only permits the passage of uncondensable gases present in small amounts.

DETAILED DESCRIPTION OF THE INVENTION

In a preferred embodiment of the system of this invention the heat exchanger consists of a shell-and-tube heat exchanger, wherein the throttling is desirably effected in the tube portion, for example, by decreasing the cross-section of the passage through the tubes in the flow direction.

In the following part of the specification one embodiment of the system of the invention is described in comparison with a known system, by the aid of drawings, of which

FIG. **1** is a representation of an embodiment of a known two-stage evaporation unit;

FIG. **2** is a representation of an embodiment of the system of the invention applied to a two-stage evaporation unit;

FIG. **3** is a sectional view of a typical two pass, shell-and-tube heat exchanger.

The evaporation unit shown in FIG. **1** is operated according to the counter-flow principle, and the fresh solution, such as a furfural-hydrocarbon solution, passes through line **1** through the tube portions of heat exchangers **2** and **3** to evaporator **4** operating under nearly atmospheric pressure. The unevaporated portion of the solution is pumped via pump **5** to higher-pressure evaporator **6.**

The vapor leaving the first evaporator stage **4** passes via line **7** through the shell portion of heat exchanger **2,** and the vapor leaving evaporator **6** passes through the shell portion of heat exchanger **3,** and in vapor line **8** subsequent to heat exchanger **3** there is a control valve **9** which is adjusted according to the selected stage pressure by pressure regulator **10** arranged in evaporator **6.**

The bottom phase of evaporator **4** is passed to heat exchanger **11** arranged intermediate evaporators **4** and **6;** this heat exchanger is designed as a heater heating the liquid stream to the desired temperature. The low-solvent product is withdrawn from the unit through line **12.** The solvent condensates are collected in solvent tank **13.**

This shows that the two-stages evaporation of FIG. **1** represents a control system adapted to maintain the stage pressures at the desired level. If more stages are involved the number of control systems required is to be increased correspondingly.

Basically, the two-stage evaporation unit shown in FIG. **2** is similar to that of FIG. **1,** with the exception that according to the invention it requires no control system for the stage pressures. In this unit, the fresh solution passes via line **14** through the tube portion of heat exchanger or condenser **15,** through the shell por-

tion of heat exchanger **16**, and finally, through the tube portion of heat exchanger **17** to evaporator **18**. From there the liquid solution is passed by means of pump **20** via line **19** over a conventional heater **21** (e.g. steam condenser, hot oil exchanger, etc.) to evaporator **22**. The vapor which is withdrawn from evaporator **18** via line **23** now flows through the shell portion of heat exchanger **15**, heating the fresh solution, and condensing. The vapor from evaporator **22** operating at a higher pressure is next passed via line **24** through the shell portion of heat exchanger or condenser **17** in which most of it is condensed. The condensate and the remainder vaporous portion are then passed through the tube portion of heat exchanger **16**, where the still uncondensed portion of the vapor is condensed. The low-solvent product is withdrawn from the unit via line **25**. The solvent condensates are collected in solvent tank **26**.

The cross-sectional area of the tube of heat exchanger **16** can, for example, remain constant in flow direction and be adapted to permit the passage of the condensed vapor at a relatively low pressure drop. The pressure difference existing between evaporator **22** and pool **26** is mainly reduced in the initial tube section of heat exchanger **16** where both the condensed and the uncondensed vapors move along at a high rate.

Conveniently, the heat exchanger cross-sectional areas are reduced either continuously or step-wise in flow direction so as to increase the amount of condensing vapors in the initial section of the heat exchanger. The heat exchanger **16** may be a shell-and-tube heat exchanger having successive sections in which the number of tubes arranged parallel to each other successively decreases in flow direction. One embodiment of a typical heat exchanger **16** of the shell-and-tube type having two successive sections in which the number of tubes arranged parallel to each other successively decreases in flow direction is shown in FIG. **3**. In this FIG. **3**, two pass, shell-and-tube heat exchanger **50** corresponds to heat exchangers **15, 16, 17**, and **21** in FIG. **2**. Condensate and vapor from the shell side of heat exchanger **17**, FIG. **2**, for example, enter exchanger **16** as represented in greater detail by exchanger **50**, FIG. **3**, through inlet **52** and flow through the first pass **53** consisting of the five top rows of tubes **54**. Baffle **56** prevents the incoming stream from entering prematurely the lower pass **57** of the three lower rows of tubes **54**. condensate and any remaining vapor after traversing the top pass of the exchanger are reversed in direction by header **58**, then flow through the bottom pass **57** of the three lower rows of tubes **54**, and finally leave condenser **50** through outlet **60**. Fresh solution from the tube portion of heat exchanger **15**, FIG. **2**, enters the shell portion of heat exchanger **50** through inlet **72**, circulates around the tubes **54**, and leaves through outlet **70**.

It follows that the two-stages unit shown in FIG. **2** does not require a control system to maintain the stage pressure but is adapted to automatically adjust the pressure and to ensure complete condensation.

As none of the condensation surfaces of the condenser needs to be flooded for control purposes, the heat exchange surfaces may be used to their full extent and the vapor condensation temperature adjusts itself to the lowest possible level. There is no storage of vapor condensate anywhere in the system, and so the decomposition of solvent is avoided. Also, the heat exchange surface available in the system is used optimally for vapor condensation, which means that the adjusting pressure and hence the condensation temperature are kept at their lowest possible levels.

The instant specification describes evaporation unit applying the counter-flow principle, but it may easily be applied by someone skilled in the art to a unit applying the parallel flow principle, which also excludes the necessity of pressure control by pressure sensors and control valves. Other than in the aforementioned examples, the system of this invention may be applied also in multi-stage evaporation units with decreasing pressure and temperature — seen in flow direction from the initial stage.

The invention may also be used for the concentration of aqueous salt solutions, e.g. desalting of sea water by multi-stage distillation, evaporation of sugar solutions, and concentration of diluted urea solution, etc. Furthermore, the invention may be used advantageously for the concentration of aqueous raw alcohols and for the separation of hydrocarbon cracking products by distillation. Finally, it may be used to separate a component from an extraction mixture, like separating furfural from a hydrocarbon extract by distillation, etc.

What is claimed is:

1. In a system for optimal pressure control in a multistage evaporation unit having at least two series connected first and final evaporators, the improvement comprising:

a. the first evaporator being preceded by first and second heat exchangers,

b. said final evaporator being a higher-pressure evaporator relative to said first evaporator,

c. both said first and second heat exchangers comprise shell-and-tube heat exchangers, for receiving the vapor effluent leaving said higher-pressure evaporator,

d. supply line means for passing fresh feed solution through said two heat exchangers in which they are heated by the vapor effluent from said final high pressure evaporator

e. the shell portion of said second heat exchanger receives the vapor effluent first,

f. the tube portion of said first heat exchanger receiving vapor condensate from said second heat exchanger,

g. a third shell-and-tube heat exchanger is connected in said fresh feed solution supply line means in series with said first and second heat exchangers.

h. said fresh feed solution supply line means being connected to the tubes of said third shell-and-tube heat exchanger, and

i. a vapor effluent line extending from said low pressure evaporator to the shell of said third shell-and-tube heat exchanger for more efficient heating of said fresh feed solution and condensing of the vapors from the low pressure evaporator.

2. A pressure control system for a multistage evaporator unit having low and high pressure series-connected evaporators and pump means for drawing liquid solution from the low pressure evaporator to the high pressure evaporator comprising,

a. fresh liquid feed solution supply line means for the low pressure evaporator,

b. first and second heat exchanger means connected in series in said fresh liquid feed solution supply line means,

c. high pressure vapor line means from the high pressure evaporator to a condensate tank, said high pressure vapor line means being first connected to said second heat exchanger means,

d. said high pressure vapor line means extending from said second heat exchanger means to said first heat exchanger means before continuing to said condensate tank, a vapor effluent being passed through said high pressure vapor line means,

e. said second heat exchanger means being a tube-and-shell heat exchanger means in communication with said high pressure vapor line means for heating said fresh liquid solution for the low pressure evaporator and for supplying condensate and the remaining vaporous portion to said first heat exchanger means, and

f. said first heat exchanger means being a shell-and-tube heat exchanger means in communication with said high pressure vapor line means for generating additional condensate for increasing resistance to flow in said first heat exchanger means for maintaining pressure in said high pressure vapor line means to accordingly eliminate the requirement for a control valve and to increase the temperature of the fresh liquid feed to said low pressure evaporator for increased efficiency.

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