

(21) Application No 7908147

(22) Date of filing

8 March 1979

(43) Application published

8 Oct 1980

(51) INT CL³ B01D 1/26

(52) Domestic classification

B1B 302 303 403 603

GC

(56) Documents cited

GB 1474177

GB 1406632

GB 1220373

GB 1174423

GB 1115705

(58) Field of search

B1B

(71) Applicant

Risto Saari

Harjula

02440 Luoma

Finland

(72) Inventor

Risto Saari

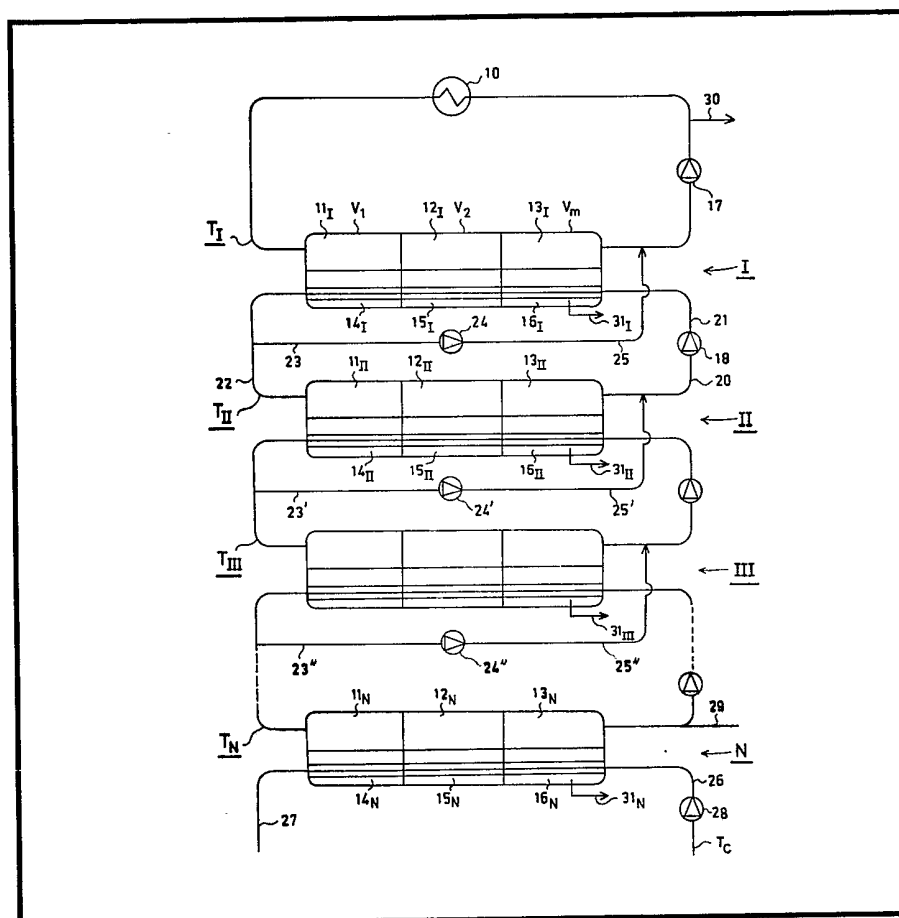
(74) Agents

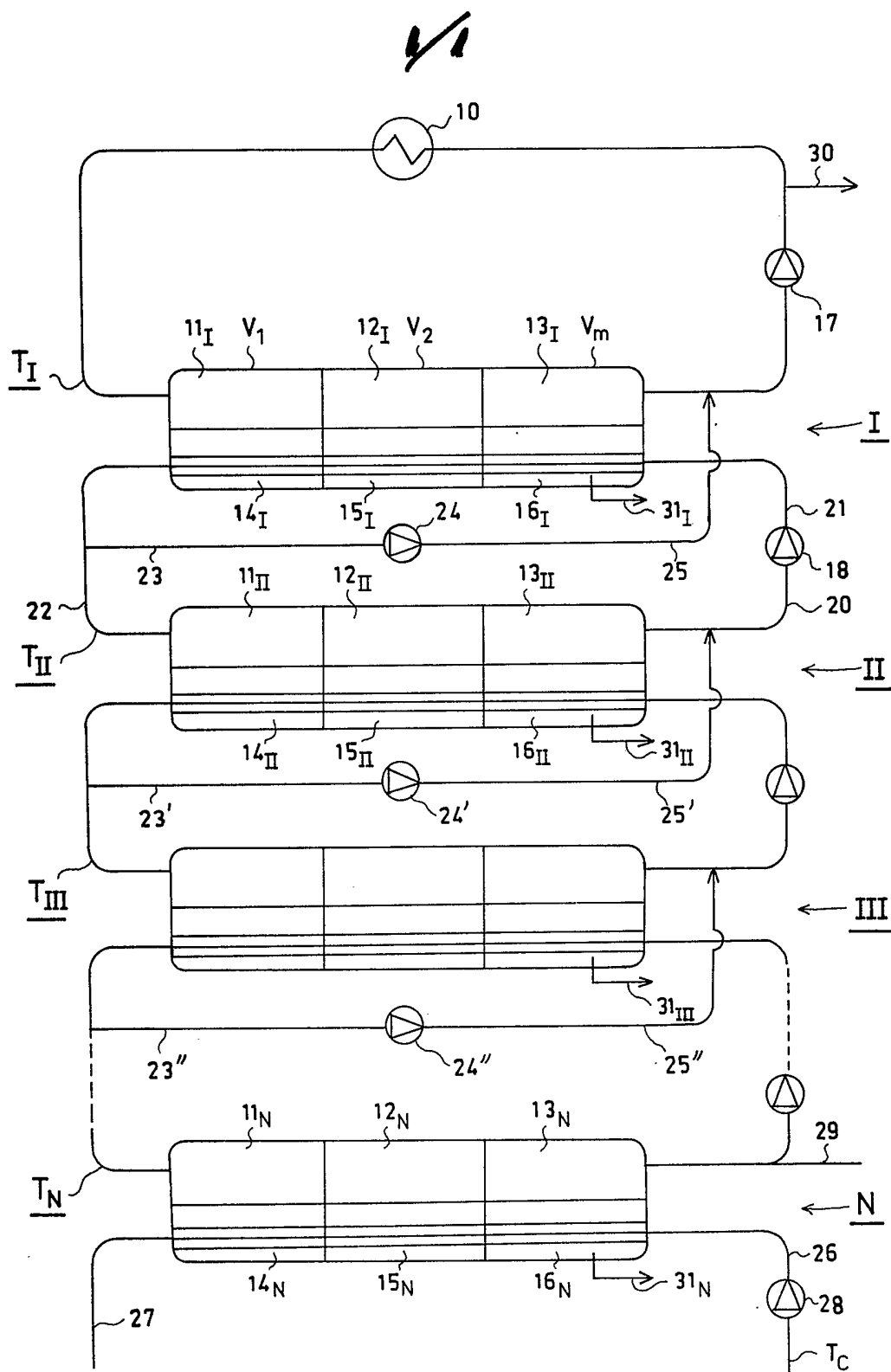
Hans & Danielsson

(54) Method and apparatus for distilling liquids

(57) In a method and apparatus for distilling liquid the latter is repeatedly vapourised and condensed in respective successive distillation units I-II--N at descending temperature levels T_I — T_{II} — T_N , the liquid also being vapourised and condensed in two or more stages V_1 — V_2 — V_m in at least one of said units I-II--N. The liquid passes from the evaporator 11_I of one distilling stage V_1 of a distilling unit I to the evaporator 12_I of the succeeding distillation stage V_2 , in which prevails a lower pressure than in the preceding evaporator 11_I and the liquid flowing in the evaporators 11_{II} , 12_{II} , 13_{II} of the succeeding distillation unit II, operating at a lower temperature level T_{II} , is conducted as a cooling

medium through the condensers 16_I , 15_I , 14_I of the distillation stages V_m , V_2 , V_1 of the first distillation unit I. The said units I-II--N comprise condensers 14 , 15 , 16 with horizontal tubes. Pipes 22 , 23 , 25 , 26 , 27 and pumps 17 , 18 , 24 , 28 serve for transfer of cooling and other fluids, pipes 31 serve for discharge of distillate if required. The liquid to be distilled enters through pipe 29 , and final concentrate leaves through pipe 30 . A heater 10 heats liquid passing via the pump 17 from the evaporation 13_I to the evaporator 11_I .





SPECIFICATION

Method and apparatus for distilling liquids

5 The object of the invention is to provide a method for distilling liquids in at least two successive distillation units operating at different temperature levels. The liquid to be distilled is vapourized in each distillation unit and
 10 the formed vapour is condensed into distillate in heat exchange with the liquid which flows in the following distillation unit operating at the lower temperature level. Another object of the invention is to provide an apparatus for realizing the method.

The distillation methods generally used nowadays, especially for distilling sea water, are so called vertical tube multi effect evaporation (VTE) and multi stage flash distillation (MSF). Both of these methods have their own advantages and disadvantages. The disadvantages of these known methods come clearly out when trying to use distillation for concentration of different industrial waste waters.

25 At vertical tube evaporation the liquid vapourizes on the inner surface of heat exchanger tubes. As a consequence of this scale is formed at heat exchanger surfaces, which is the main disadvantage of this method.

30 When the MSF-distillation is used for concentrating liquid the inconvenience is the fact that the same concentrated liquid has to be circulated within the whole temperature range of the distillation plant. So the boiling point elevation of the concentrated liquid as well as the increase in viscosity reduce essentially the efficiency of the distillation plant. When applying this method the distillation plant is forced to be provided with very many stages if
 40 one tries to keep the size of the most expensive component, the condenser, of the distillation plant reasonable. This is caused by the fact that the smaller the flashing temperature drop of vapourizing liquid per one distillation stage is, the larger is the temperature difference between vapour and cooling water.

One object of the invention is to provide a method for distilling liquids which eliminates these disadvantages of the earlier known
 50 methods. A more detailed object of the invention is to provide a method for distilling liquids in which one can influence, within certain limits, on flashing temperature drop in a distillation stage without being forced to
 55 increase the number of distillation stages. A further object of the invention is to provide a method for distilling liquids by which one can process liquids of different concentrations at different temperatures, and thus boiling point elevation and increase in viscosity do not have
 60 influence on the whole temperature range. It is also an object of the invention to provide a method for distilling liquid in which the liquid can be vapourized by flashing off in a free
 65 liquid space and so the heat exchange sur-

faces can be prevented from scaling.

The objects of the invention will be achieved by a method characterized by the fact that in at least one of the distillation units
 70 the liquid is vapourized and correspondingly condensed in at least two distillation stages.

One more object of the invention is to provide an apparatus for realizing the method in accordance with the invention. The main
 75 characteristics of the apparatus are defined in patent claims 6-9.

The invention is described in more detail by referring to the schematic illustration of one method and apparatus according to the invention presented on the enclosed drawing. The invention is not, however, meant to be limited only to this embodiment.

The distillation process presented on the figure of the enclosed drawing consists of
 85 many successive distillation units or modules I, II, III . . . N. In accordance with the invention in each module there are several distillation stages $V_1, V_2 \dots V_m$. Each distillation stage consists of an evaporator and a condenser which communicate with each other so that the vapour evaporated in the evaporator can flow to the condenser and condense there into distillate. Thus for instance the evaporator
 90 11_1 of module I and the condenser 14_1 belong to the first distillation stage V_1 , the evaporator 12_1 and the condenser 15_1 to the second distillation stage V_{12} as well as the evaporator
 95 13_1 and the condenser 16_1 to the last distillation stage V_m . The evaporators $11_1, 12_1$ and
 100 13_1 are in connection with each other so that the liquid to be distilled can flow from the evaporator 11_1 to the evaporator 12_1 and further to following evaporators, but vapour flow from one evaporator to another is prevented.
 105

The liquid to be distilled flows in the module I to the evaporator 11_1 , in which part of the liquid flashes into vapour and the vapour condenses in the condenser 14_1 . The liquid to
 110 be distilled flows further to the evaporator 12_1 , where there is a lower pressure than in the evaporator 11_1 , and again part of the liquid to be distilled vapourizes. When vapourizing the liquid cools down and the cooled liquid discharges from the last evaporator 13_1 via pump
 115 17 to the heater 10, where the liquid is heated up by outer heating energy, and from where it returns to the evaporator 11_1 .

The liquid that flows through the condensers $16_1, 15_1$ and 14_1 of the module I becomes warmer when it receives the latent heat of evaporation from the vapour that condenses. The warmed liquid flows from the condenser 14_1 via pipe 22 to the first evaporator
 120 11_{II} of the module II where there is a lower pressure and temperature than in the first evaporator 11_1 of the module I. The liquid vapourizes in the evaporators $11_{II}, 12_{II}$ and
 125 13_{II} of the module II when the liquid cools down and flows via pipe 20, pump 18 and
 130

pipe 21 to the condensers 16_I, 15_I and 14_I of the module I, which thus operate as heaters of module II.

The distillation process proceeds correspondingly from one module to another until the heat energy first fed to the heater 10 is transferred to the cooling water flowing through the condensers 16_N, 15_N and 14_N of the last module N. This cooling water is fed by pump 28 via pipe 26 and discharges from the process via pipe 27.

The liquid to be distilled can be fed to the process for instance into the last module N via pipe 29. In module N part of the liquid to be distilled becomes distillate and part is fed further to the following modules. The feed pump 24'' feeds the liquid to be distilled via pipe 25'' to the liquid circulation of module III, from which again part of the liquid is transferred via pipe 23', pump 24' and pipe 25' to the liquid circulation of the module II. From the liquid circulation of module II part of the liquid to be distilled flows via pipe 23, pump 24 and pipe 25 to the liquid circulation of module I. The final concentrate is discharged from the liquid circulation of module I via pipe 30.

The original liquid to be distilled can, depending on the temperature, be fed to any module and the final concentrate can be discharged, depending on its characteristics from any other module. The distillate can be discharged from each module I, II ... N separately through the pipes 31_I, 31_{II} ... 31_N or from the module N operating at the lowest temperature by collecting all the distillate to the module N and discharging the distillate from there through the pipe 31_N.

By the method according to the invention the concentration of the flowing liquid can be adjusted in each module I, II ... N separately, which has a considerable advantage specially when concentrating liquids such as waste waters of industry. Thus the boiling point elevation of the liquid effects essentially only in part of the temperature range. In addition the corrosion and scaling inhibitors can be added to each module separately or they can concentrate automatically to the liquid circulations in which the concentration of liquid is the highest.

In applying the method and apparatus according to the invention the condensers can be built essentially below the free liquid surfaces of the evaporators by using horizontal tubes, when the liquid does not vapourize when flowing in the condensers. The whole distillation plant can be built of modules similar to each other, which has an influence on the planning and building costs of a distillation plant.

If the difference $T_1 - T_c$ of the highest and the lowest temperatures is called $\delta_0 T$, the boiling point elevation of the liquid $\delta' T$ and the flashing temperature drop of the liquid

when it flows through all the distillation stages of one module δT , so the average logarithmical temperature difference between vapour and cooling water flowing in the condenser can be written to:

$$\Delta T = \frac{T/m}{\ln \left(\frac{\delta_0 T - \sum_1^N \delta' T - \delta T}{\delta_0 T - \sum_1^N \delta' T - \delta T - N \frac{\delta T}{m}} \right)}$$

This temperature difference ΔT effects essentially on the size of the most expensive components, the condensers, of the distillation plant. From the above formula one can see that this temperature difference depends on the flashing temperature drop per distillation stage, the proportion $\delta T/m$ as in the MSF-distillation, too. The essential difference is that when $\delta_0 T$ in MSF-distillation is determined, one can effect on the proportion $\delta T/m$ only by increasing the number of distillation stages. In the method according to the invention one can on the contrary effect on the proportion $\delta T/m$ regardless of the total temperature difference $\delta_0 T$ by changing the liquid flow rate in each module I, II ... N and the dimensioning of condensers.

The following comparison will demonstrate the advantages that will be achieved by the invention. If $\delta_0 T = 60^\circ \text{C}$, $\delta' T = 1^\circ \text{C}$ and the performance ratio of the MSF-distillation, (the proportion of the produced distillate to the quantity of the used heating steam) is 8, the logarithmic mean temperature difference will be 5.09°C . If the design temperature range is the same, the logarithmic mean temperature difference will be 5.61°C in a plant according to the invention, when $N = 8$, $m = 3$ and $\delta T = 3^\circ \text{C}$. The corresponding distillation capacity according to the invention can thus be built with 10 % smaller condenser and with all together 24 distillation stages only. This is to compare with the previous result in which was supposed 48 stages in conventional MSF-process.

From the formula of temperature difference one can also see that the boiling point elevation $\delta' T$ of liquid can be different in different distillation units and they effect on the average logarithmic temperature difference ΔT as a sum when the boiling point elevation caused by the largest concentration effects on only a distillation unit and not on the temperature range of the whole process.

The distillation units can be arranged for their inner structure and their mutual location so that in the closed liquid circulation the liquid to be distilled flowing in the condensers of a certain distillation unit is on a lower elevation than the free surface of the liquid flowing in the evaporators of the following distillation unit. All the distillation units of the distillation plant can be built in the way mentioned above. Thus one achieves the ad-

vantage that the liquid does not vapourize when flowing as cooling medium in the condensers, which essentially could cause scaling of the heat exchange surfaces and decrease in the heat exchange. This is known to be the

5 essential disadvantage of the conventional VTE-evaporation, especially when concentrating liquids, because in the VTE the vapourization takes place just on the surfaces of heat
10 exchanger tubes. By the method according to the invention on the contrary the inner surfaces of the heat exchanger tubes can continuously be kept clean for instance by placing a suitable quantity of sponge balls to each recirculation of the liquid.

It is advantageous to build a distillation plant of several similar distillation units which for its part reduces the capital costs of the plant.

20 It has been presented above only the basic principle of the invention and it is clear to a person skilled in the art that the details of the invention can vary very much within the limits presented in the patent claims.

CLAIMS

1. A method for distilling liquid in at least two successive distillation units (I, II . . . N) operating at different temperature levels (T_I ,
30 T_{II} . . . T_N), in which distillation units (I, II . . . N) the liquid to be distilled is vapourized and the produced vapour is condensed into distillate in heat exchange with liquid flowing in the following distillation unit operating at
35 lower temperature, and in at least one of the distillation units (I, II . . . N) the liquid to be distilled is vapourized and the vapour is correspondingly condensed in at least two distillation stages (V_1 , V_2 . . . V_m).

2. A method according to claim 1, in which the liquid to be distilled is conducted from the evaporator (11_I) of one distilling stage (V_1) of a distilling unit (I) to the evaporator (12_I) of the succeeding distillation stage
45 (V_2), in which prevails a lower pressure than in the preceeding evaporator (11_I) and the liquid flowing in the evaporators (11_{II}, 12_{II}, 13_{II}) of the succeeding distillation unit (II), operating at a lower temperature level (T_{II}), is
50 conducted at a cooling medium through the condensers (16_I, 15_I, 14_I) of the distillation stages (V_m , V_2 , V_1) of the first distillation unit (I).

3. A method according to claim 1 or 2, in which the liquid to be distilled is fed into one of the distillation units (I, II . . . N) from where the liquid is conducted further to the other distillation units, and that the concentrate is discharged from some other distillation unit
60 than that where the liquid was fed in.

4. A method according to one of the claims 1–3, in which the distillation is collected to the distillation unit (N) operating at the lowest temperature level and is discharged
65 from this distillation unit.

5. A method according to some of the patent claims 1–3, in which the distillate formed of the liquid to be distilled is discharged from each distillation unit (I, II . . . N) separately.

6. An apparatus to operate the method according to one of the claims 1–5, comprising at least two successive distillation units (I . . . N), at least one of which comprising at
75 least two distillation stages (V_1 . . . V_m).

7. An apparatus according to claim 6, in which the condensers of the distillation units (I, II . . . N) are made of horizontal tubes.

8. An apparatus according to claims 6 or 80 7, in which condenser of at least one distillation unit is on a lower level than the free liquid level in the evaporators of the succeeding distillation unit.

9. An apparatus according to some of the 85 patent claims 6–8, in which the distillation units (I, II . . . N) are structurally similar.

Printed for Her Majesty's Stationery Office
by Burgess & Son (Abingdon) Ltd.—1980.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.