

Dec. 9, 1958

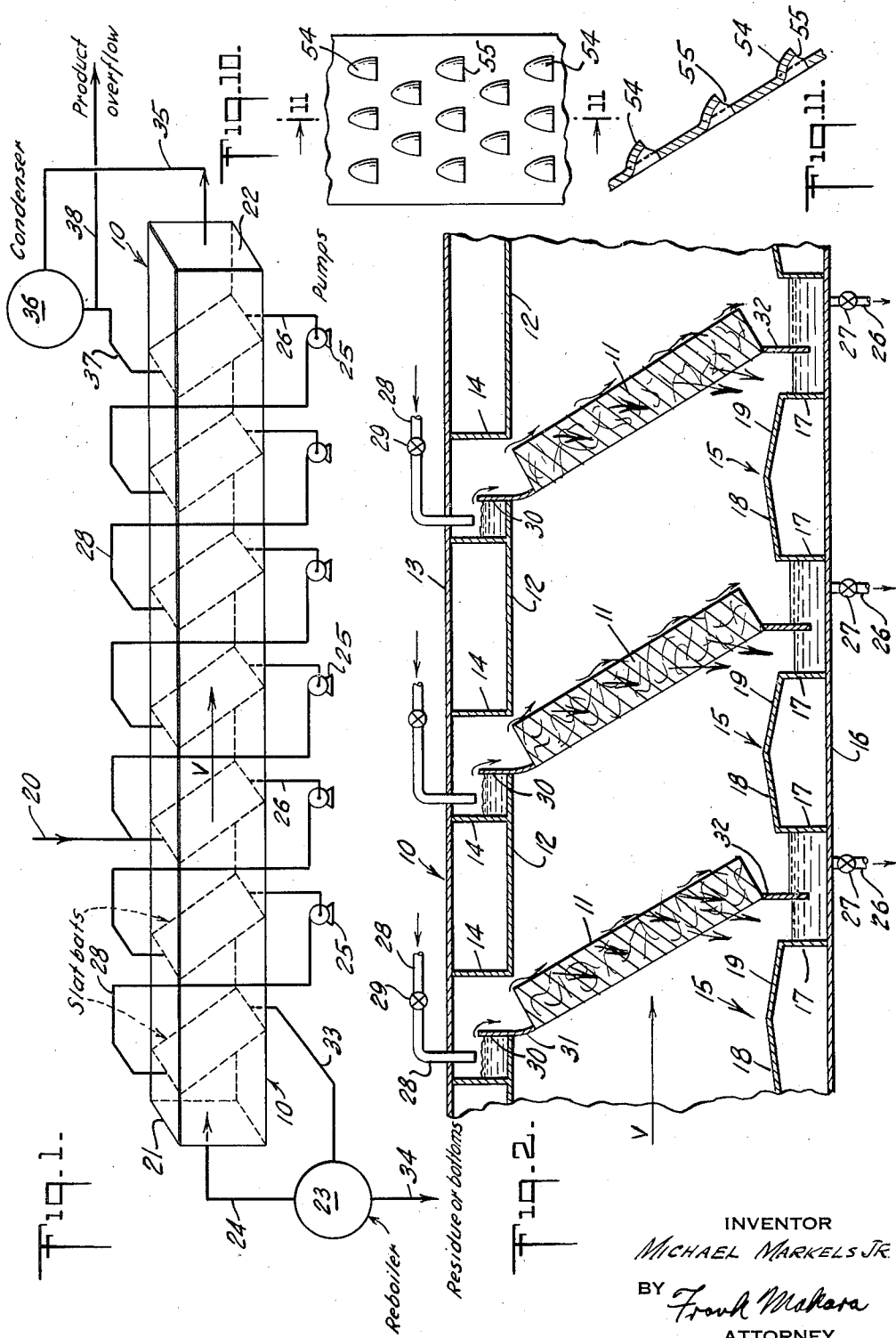
M. MARKELS, JR

2,863,808

APPARATUS FOR HORIZONTAL DISTILLATION

Filed May 21, 1956

2 Sheets-Sheet 1



Dec. 9, 1958

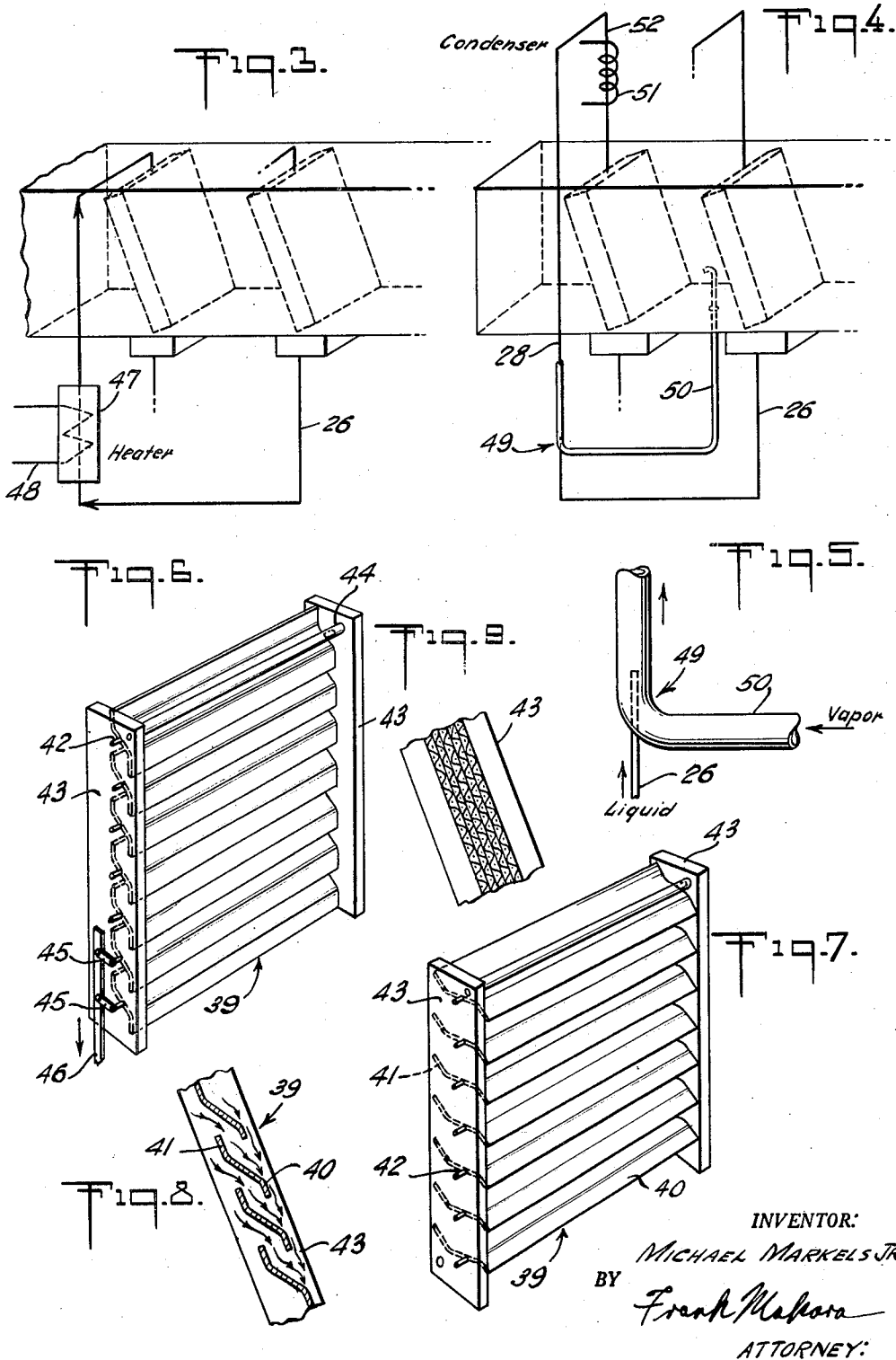
M. MARKELS, JR

2,863,808

APPARATUS FOR HORIZONTAL DISTILLATION

Filed May 21, 1956

2 Sheets-Sheet 2



1

2,863,808

APPARATUS FOR HORIZONTAL DISTILLATION

Michael Markels, Jr., New York, N. Y.

Application May 21, 1956, Serial No. 536,046

3 Claims. (Cl. 202—158)

This invention is an apparatus.

All distillation of a commercial nature is done in vertical distillation columns. So far as applicant can determine he is the first to have devised a horizontal distillation apparatus.

It is an object to provide a horizontal distillation apparatus.

These and other objects will become apparent upon reading the following disclosure taken in conjunction with the accompanying drawing in which:

Fig. 1 is a side elevation schematic view of the horizontal distillation apparatus,

Fig. 2 is a detailed view of a section of the distillation apparatus of Fig. 1,

Fig. 3 is a side elevation diagrammatic view showing one manner of moving the liquid being distilled,

Fig. 4 is a view similar to that of Fig. 3 but showing another manner of moving the liquid being distilled,

Fig. 5 is a schematic detailed view of the vapor pump manner of moving the liquid through the horizontal distillation column,

Fig. 6 is a perspective view of a louvered slat bat in partly closed position used in the horizontal distillation column,

Fig. 7 is a view of the slat bat of Fig. 6 in open position,

Fig. 8 is a detailed section view of a part of the slat bat of Fig. 6 disposed in a sloped position and showing the passage of water thereover (single arrows) and the passage of vapors (double arrows) between the slats and through the cascading water,

Fig. 9 is a detailed section view of a bat made from wire mesh,

Fig. 10 is a view of another bat provided with suction cups, and

Fig. 11 is a side view of the bat of Fig. 10.

Referring to the drawing and particularly to Figs. 1 and 2 a horizontally disposed rectangular column 10 is provided with a plurality of inclined bats 11.

The top wall of column 10 is provided with an inner top wall 12 (Fig. 2) spaced from an outer top wall 13 by spacer plates 14.

Similarly the bottom wall of column 10 is provided with an inner bottom wall 15 and an outer bottom wall 16. The inner bottom wall 15 is spaced apart from the outer bottom wall 16 by spacers 17. The inner bottom wall 15 consists of a plurality of sections as does also the inner top wall 12. However, the sections of inner bottom wall 15 are provided with an angle formed between two divergently sloping wall pieces 18 and 19 (Fig. 2).

Referring to Fig. 1, the inlet feed pipe 20 of the liquid mixture to be separated by distillation is lead to a bat feed disposed between the inlet face plate 21 of the column 10 and the outlet face plate 22 thereof, depending upon the composition of said liquid mixture.

A boiler 23 is provided with a conduit 24 which is

2

secured to inlet face plate 21. The high boiling fraction of the liquid mixture feed of feed pipe 20 is moved toward boiler 23 by means of a plurality of conventional fluid pumps 25.

Thus the high boiling molecules are pumped from the base of one bat to the top of the adjacent leftwardly disposed bat (Fig. 1) whence the material flows by gravity down through the inclined bat 11 (Fig. 2) whereupon it collects in a trough disposed at the base of bat 11.

In passing down through the bat 11 vapors from the boiler 23 transcending the bat 11 distill off the lower boiling molecules from the liquid mixture thus transforming them into the vapor state, which vapors move toward the outlet plate 22.

The non-vaporized liquid collected in any of the plurality of troughs formed by the sections 15 of the inner bottom wall are conveyed by conduit 26 provided with a control valve 27 (Fig. 2) to a pump 25. The liquid is then pumped by said pump 25 through a relatively tall conduit 28 to the top of the bat 11 disposed leftwardly of said pump 25 and toward said column inlet plate 21. The conduit 28 is preferably provided with a valve 29 (Fig. 2) for control of the liquid flow therethrough.

As shown in Fig. 2, conduit 29 passes through the top outer wall 13 and empties into a trough formed by a spacer plate 14 adjacent to conduit 28 and a weir wall 30 of suitable height. The weir wall 30 extends the full width of the column 10 and thus also of the width of the inner top wall 12. The weirs 30 are provided with an integral inclined and depending lip 31 against which a bat 11 rests at a pre-selected sloping angle. Bats 11 are of suitable rectangular cross-section to snugly fit into column 10.

A cross-plate 32 is fixedly secured to the opposed side walls of column 10 and continually dips into the liquid in the troughs between the sections of bottom inner wall 15, there is thus provided a seal between the bat 11 and the liquid in the trough and causing all vapors from the boiler 23 to pass through the bat 11. The bat 11 may be and preferably is secured by conventional screw means (not shown) to weir lip 31 to prevent the bat 11 from being blown away from the said lip 31.

Referring now to Fig. 2, the bats 11 are inclined leftwardly and into the vapor stream coming from boiler 23. Accordingly the gas pressure to the left of the plate 32 and toward boiler 23 is greater than that on the right side of the respective bat 11 as shown by the difference in the level of the liquid on the two sides of any cross-plate 32.

The liquid material from the base of the bat 11 nearest the boiler 23 is conducted continuously through conduit 33 into the boiler 23. Also a residue from boiler 23 is continuously drawn off through conduit 34 from the boiler 23. Moreover, the vapor issuing from the bat 11 nearest the outlet plate 22 is conducted through conduit 35 to a conventional condenser 36. The condensed liquid from through pipe 37 from the condenser 36 is in part returned to the bat 11 nearest the outlet plate 22 and in part lead to storage as refined low boiling material through pipe 38.

The apexed wall formed by plates 18 and 19 of the bottom inner wall 15 serve to deflect the drippings from a respective bat to a common trough. Thus any liquid falling through a bat 11 falls on a plate 19 whereas any running off the top surface of a bat 11 falls upon a plate 18 adjacent the top surface of the bat 11. But in any event, the material which falls from a bat 11 or runs down through its center is collected in a respective trough.

In starting up the distillation column the boiler 23 containing a liquid mixture to be distilled is heated and

3

the column 10 filled with vapor, whereupon the feed from conduit 20 is turned on and the process as explained above becomes a continuous distillation process with the residue high boiling fraction being drawn off continuously at conduit 34 and the low boiling fraction being drawn off continuously at pipe 38.

The bats of this invention may be made from a variety of materials which can cause vapor to travel a tortuous path through the foraminous bat.

Thus the material may be a plurality of screens being in commercial construction 4 or more inches in thickness. Or the bats 11 may be made of expanded metal such as is used for metal laths. The material of the bat 11 may also be broken tile, conventional distillation rings or helices, etc. such as are used in vertical column distillation. Where small loose pieces are used the bat 11 is provided with suitable spaced-apart retainer screens to hold a full charge of separate pieces (Fig. 9).

On the other hand, the bats 11 may be made from rotatable slats rotatable as a unit (Figs. 6 to 8). Where the bats 11 are made from a plurality of slats, the slats 39 are preferably made with a forward downwardly sloping front plate 40 integral with a rear upwardly sloping back plate 41 (Fig. 7). The downward slop-

4

of the liquid in leg 52 produces the pumping action required.

The bats are disposed into the vapor stream and toward boiler 23 (Fig. 1). The angle varies depending on the characteristics of the column and the material being distilled but an angle of about 70° is preferred.

The bats may be circular for circular horizontally disposed columns, ovaloid, etc.

In optimum conditions of bat operation each cubic inch of bat will have the same quantity of liquid mixture therein as the fall from the weir 30 is uniform along the entire top wall of a bat 11.

Turning to Fig. 10 there is shown a modified form of bat or baffle plate having a plurality of dished punched out portions 54. These punched out sections are somewhat semi-cup shaped, each having a sloped surface over which the liquid mixture flows and then passes over the opening in the metal at the cup lip 55 where the liquid mixture being distilled comes in contact with the horizontal stream of vapor from boiler 23.

A series of runs of the horizontal distillation apparatus and process was conducted using air in lieu of vapor and water in lieu of a liquid mixture. The results are given in Table I here below.

TABLE I

Run	Velocity, ft./sec.	Pressure drop, inches of water	Liquid flow, gal./min./ft.	Entrainment in percent	E _L , Liquid Efficiency, fraction	E _G , Gas Efficiency, fraction	Bat Angle, Degrees	Bat Material
1-----	11	1.2	11	0.1	.90	.93	55	2
2-----	8	0.8	11	0	.85	.89	55	2
3-----	5	0.2	11	0	.53	.47	55	2
4-----	9	1.6	40	6.0	.90	.94	55	2
5-----	7	1.4	40	1.0	.94	.95	55	2
6-----	4	1.0	40	0	.84	.97	55	2
7-----	8	1.3	20	0	.91	.95	55	2
8-----	8	0.9	20	0	.94	.91	67	2
9-----	8	0.6	20	0.7	.87	.89	79	2
10-----	4	0.4	11	0	.87	.89	67	4
11-----	7	0.6	11	0.3	.93	.84	67	4
12-----	10	0.7	11	2.6	.91	.87	67	4

ing front plate 40 facilitates easy movement of liquid thereover whereas the rear upwardly sloping slat plate 41 prevents undue fall through or passage of the liquid through the slat.

To obtain maximum efficiency of distillation in any one bat 11, the bat should entirely confine the moving liquid mixture therein. Fig. 8 shows by means of single barbed arrows the path of travel of liquid mixture over the slats and by means of double barbed arrows the path of travel of vapor from boiler 23 through a slat bat.

The individual slats 39 are provided with a journal 42 on each end which fit into suitable apertures in the end plates 43. Cross bars 44 are provided to hold end plates 43 in place.

As shown in Fig. 6 the journals 42 may be fixedly secured to links 45 and these links in turn are pivotally secured to an actuating bar 46. Thus operation of bar 46 will selectively open or close all the passage ways between the slats an equal distance.

Turning to Fig. 3 there is shown a heat pump 47, heated by steam in a coil conduit 48, or by other means. This pump 47 heats the collected liquid from the base of a bat 11 thereby causing the liquid to vaporize in part and thus pump the liquid to the adjacent bat disposed toward the boiler 23. This heat pump 47 is used to replace motor 25.

Moreover, as shown in Figs. 4 and 5 a vapor pump 49 may be made by confining some of the vapor stream in pitot conduit 50 from the vapor exit side of a bat 11. The lifting effect of the vapor results from applying a condenser coil 51 to the down leg 52 of conduit 28, thereby condensing the vapor to liquid. The difference in density of the vapor-liquid in conduit 28 and that

E_L and E_G in the above Table I are the conventional Murphree film efficiencies.

The Murphree efficiency is a measure of the approach to equilibrium achieved by the stage or bat. E_L was calculated from the change in oxygen concentration which took place in the water as it flowed through the bat when the experiment was made with all the resistance to mass transfer in the liquid phase. This was done by stripping oxygen from the water with air. Similarly, E_G was calculated from the change in water vapor concentration which took place in the air as it flowed through the bat when the experiment was made with all the resistance to mass transfer in the vapor phase. These data for runs 1 and 2 of Table I are shown below. The oxygen concentrations are given in parts per million oxygen in water while the water vapor concentrations commonly called the humidity, are given in pounds of water vapor per pound of dry air.

Run 1

Gas phase concentrations:	Lb./lb.
In -----	0.01652
Out -----	0.02016
Equilibrium -----	0.02044

The Murphree efficiency is the actual change in concentration divided by the change which would have occurred had equilibrium been achieved as the gas passed through the stage.

$$E_G = \frac{0.02016 - 0.01652}{0.02044 - 0.01652} = 0.93$$

showing that 93% of equilibrium was achieved in the experiment.

5

Liquid phase concentrations:		P. p. m.
In	-----	16.0
Out	-----	8.3
Equilibrium	-----	7.5

The Murphree efficiency is again the actual change in concentration divided by the change which would have occurred had equilibrium been achieved as the liquid passed through the stage.

$$E_L = \frac{16.0 - 8.3}{16.0 - 7.5} = 0.90$$

showing that 90% of equilibrium was achieved in the experiment.

Run 2

Gas phase concentrations:		Lb./lb.
In	-----	0.01416
Out	-----	0.01820
Equilibrium	-----	0.01868

The vapor phase Murphree efficiency is calculated as before:

$$E_G = \frac{0.01820 - 0.01416}{0.01868 - 0.01416} = 0.89$$

showing that 89% of equilibrium was achieved in the experiment.

Liquid phase concentrations:		P. p. m.
In	-----	17.4
Out	-----	9.4
Equilibrium	-----	8.3

The liquid phase Murphree efficiency is calculated as before.

$$E_L = \frac{17.4 - 9.4}{17.4 - 8.3} = 0.88$$

showing that 88% of equilibrium was achieved in the experiment.

The efficiency results as well as the other pertinent data such as gas velocity, pressure drop, liquid flow rate, entrainment, bat angle and bat material designation are given in Table I. E_L is based on the changes in concentration which take place in the liquid, while E_G depends on the concentration changes in the gas. Taking E_G as an example, this efficiency is equal to the ratio of the actual change in gas concentration across the stage to the change in gas concentration which would have occurred, had the outlet gas reached equilibrium with the liquid on the stage. Since in a practice equilibrium cannot be achieved, the change in concentration is less than the equilibrium change, giving an E_L of less than 1.

Bat material number 2 (Table I) is made from multiple layers of knitted stainless steel, each layer being crimped in a herringbone pattern. The crimping of alternate layers lying at right angles gives the bat a high internal void fraction 4 x 16 x 24 inches in size.

Bat number 4 was made from 73 layers of flat uncrimped screen, each layer separated from the other by a pair of crimped screens. Both bats number 2 and 4 were 4 x 16 x 24 inches and fitted snugly into the horizontal distillation column.

Taking runs 1, 2 and 3 of bat number 2, the table shows that at 55° bat angle and 11 gallons per minute per foot (G. P. M./ft.) of weir, both Murphree efficiencies are highest at the highest air-rate (11 ft./sec). The reason is that this air velocity is needed to keep the liquid within the bat thereby preventing its draining out the front face. At 40 G. P. M./ft. of weir (runs 4, 5 and 6), the efficiencies are higher but now the maximum in liquid contacting efficiency occurs at 7 ft./sec. while the maximum gas efficiency occurs at the lowest air velocity. The high water rate makes the efficiencies less sensitive to variations in air rate. Runs 7, 8 and 9 show intermediate air-rate and water-rate with varying bat angles. For these runs, the pressure drop is highest at 55°, indicating that most

6

of the water is being held in the bat. This gives the high gas film efficiency measured. It seems, however, that the water is actually broken up and contacted to better effect at 67° giving the high liquid efficiency reported at that angle. In general, pressure drop tends to increase with both liquid and gas loading. The variations with bat angle depends on the balance on the moving liquid, the pressure drop tending to decrease with the liquid as it drains out of the front face (toward boiler 23) at low gas velocity or is blown clear of the back face (toward condenser 36) at high velocity. Indication of this is shown by the entrainment in run 9 which appears at 79°. Runs 10, 11 and 12 cover bat number 4 which was constructed so as to hold the liquid in the bat more than in bat number 2 discussed above. The result, as shown, is that higher efficiencies were obtained at low liquid rates but the pressure drop tended to be higher, especially at low air velocities. This illustrates the variation in design that is possible with these bats in order to meet given problems. It is most important to note the low pressure drop through the bat obtained for all the runs in the table, even at relative high liquid and vapor loadings.

The following example is given to show the separation of two fatty alcohols; n-decyl alcohol, B. P. 452° F. from lauryl alcohol, B. P. 498° F.

This separation takes thirty bats. Since the material is temperature sensitive, it is not heated above 400° F. This necessitates that the column be operated under a vacuum. The two factors of the 30 bats and the low operating pressure require a low pressure drop per stage. When a mixture of equal amounts of the alcohols is fed into the column on bat number 15 of the 30 bat column the distillation is carried out to produce a substantially pure decyl alcohol overhead at the condenser 36 and substantially pure lauryl alcohol in the bottoms at the boiler 23.

It is often desirable in a separation of this type to inject steam directly into the boiler so that the distillation temperature can be reduced. Should that be desirable it should be noted that the heaters shown, which boil a portion of the liquid in pumping it over to the next bat, do not have to be used. It would also be possible to inject steam directly into the liquid, giving the necessary change in average density and obtaining some stripping action at the same time. Superheated steam must be used for this purpose.

This invention is of generic scope. The horizontal column 10 may be modified so as to be fully packed with discrete packing material such as Rashig rings from inlet plate 21 to outlet plate 22 thereby avoiding the use of separate bats.

Moreover, bats of a wide variety of sizes and apertures may be used, so long as they are porous to a vapor stream and promote turbulence in the bat itself between the liquid stream flowing generally downwardly therein and the vapor stream flowing horizontally and therefor across the liquid flow in the bat. In a modified bat glass wool, or glass beads or glass balls may be used.

The column 10 need not be absolutely horizontal as columns at slight angles to the horizontal plane are operable.

The bats are disposed at an angle into the vapor steam toward boiler 23, said angle being such as to keep the optimum flow of liquid within the bat.

It is to be noted that the vapor steam in moving across a bat tends to drag the liquid flowing therein.

The low pressure drop in the bats is in part due to the fact that the vapors do not pass through a liquid seal such as is the conventional bubble cap vertically disposed distillation columns. Nor is the vapor accelerated through narrow openings as is the case for bubble caps and some packing material.

The principal advantage of this invention is that of high contacting efficiency and low pressure drop with high loading in large sizes, an advantage especially important when vacuum conditions are applied to this invention.

The bats of this invention are provided with a large fraction of voids for low pressure drop. Such bats provide a maximum of free volume for vapor-liquid contact. At the same time, the bats of this invention break up the liquid stream thereby producing optimum efficiency of contact between the vapor and the liquid. A range of voids of about 90 to about 99 percent is preferred.

Where the horizontally disposed distillation column is fully packed with discrete units such as Rashig rings the flow path of both the liquid and the vapor is that shown in Fig. 1. In other words, the plurality of bats of Fig. 1 is replaced by a continuous column of packing material, e. g. ceramic saddles, while the flow of vapor is maintained from left to right (Fig. 1) and while the flow of liquid is maintained transverse to the flow of vapor and moving generally from right to left all as previously described in the bat embodiment of Fig. 1.

I claim:

1. A distillation apparatus for separating a liquid mixture of liquids of low and of high boiling points comprising a horizontal longitudinal tube; an apertured vapor inlet closure secured in air-tight manner to one end of said tube; an apertured vapor outlet closure secured in air-tight manner to the other end of said tube; a plurality of spaced-apart foraminous bats completely and substantially transversely across the chamber of said horizontal tube; a plurality of pumps disposed between respective successive bats for conveying liquid toward said inlet closure and from the bottom of one bat to the top of the adjacent bat; boiler means connected to said inlet closure for conveying vapors of said liquid mixture into said tube, a condenser secured to said outlet closure for condensing vapors of the separated low boiling liquid, a liquid mixture feed inlet disposed intermediate said

closure ends, conduit means for returning a portion of the condensate to the tube and adjacent said outlet closure and conduit means for conveying the liquid in said tube adjacent the inlet closure to said boiler means.

2. The apparatus of claim 1 wherein the bats contain packing material and the pumps are thermal pumps.

3. The apparatus of claim 1 comprising top well means disposed adjacent the top of said bats for permitting flow of liquid onto the top of said bats and bottom well means disposed adjacent the bottom of said bats for collecting liquid draining from said bats whereby liquid is pumped from one bottom well means to the adjacent top well means of the successive bat closer to the inlet closure.

References Cited in the file of this patent

UNITED STATES PATENTS

489,147	Golding	Jan. 3, 1893
631,461	Guillaume	Aug. 22, 1899
651,190	Ilges	June 5, 1900
1,466,221	Foster	Aug. 28, 1923
1,874,849	Danforth	Aug. 30, 1932
1,983,058	Wait	Dec. 4, 1934
2,645,467	Rupp	July 14, 1953
2,671,053	Dannenberg	Mar. 2, 1954
2,698,287	Dowden et al.	Dec. 28, 1954

FOREIGN PATENTS

13,980	Germany	of 1881
456	Denmark	of 1896
328,074	France	Oct. 21, 1903
38,136	Norway	Nov. 18, 1918
891,464	France	Dec. 11, 1943
837,846	Germany	Mar. 27, 1952