April 2, 1957 H. J. HIBSHMAN ET AL 2,787,453

FRACTIONATING TOWER UTILIZING DIRECTIONAL UPFLOW MEANS IN CONJUNCTION WITH SLANTED TRAYS

Filed Nov. 30, 1953 2 Sheets-Sheet 1

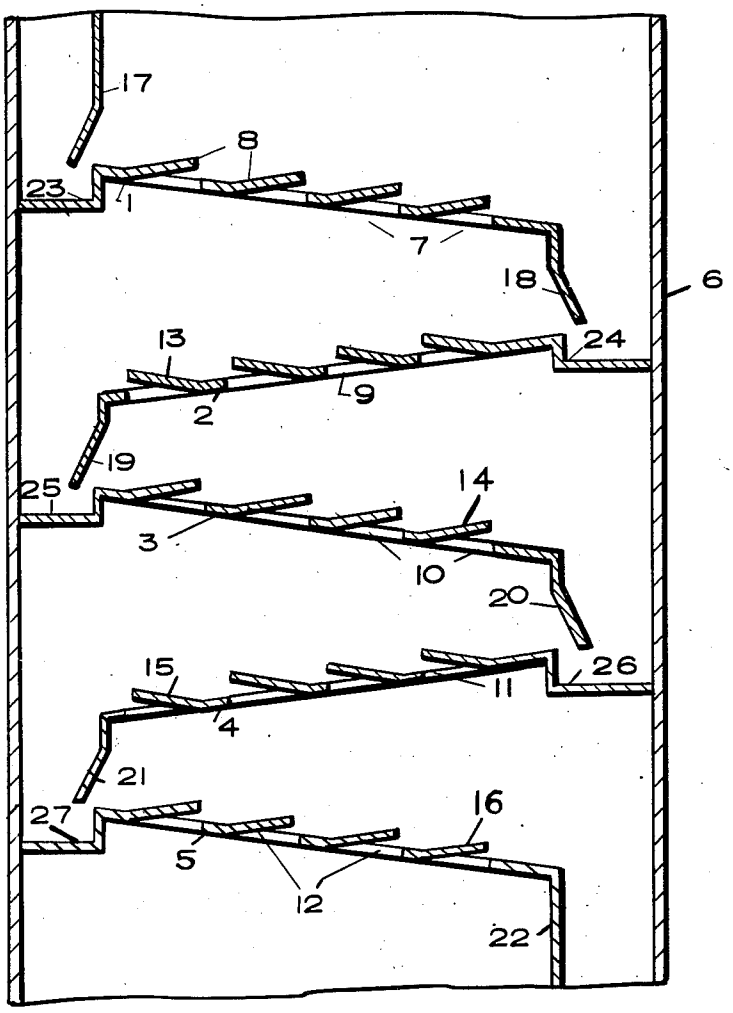


FIG.—1

HENRY J. HIBSHMAN INVENTORS
STEPHEN H. DOLE

BY W. O. Feilman ATTORNEY

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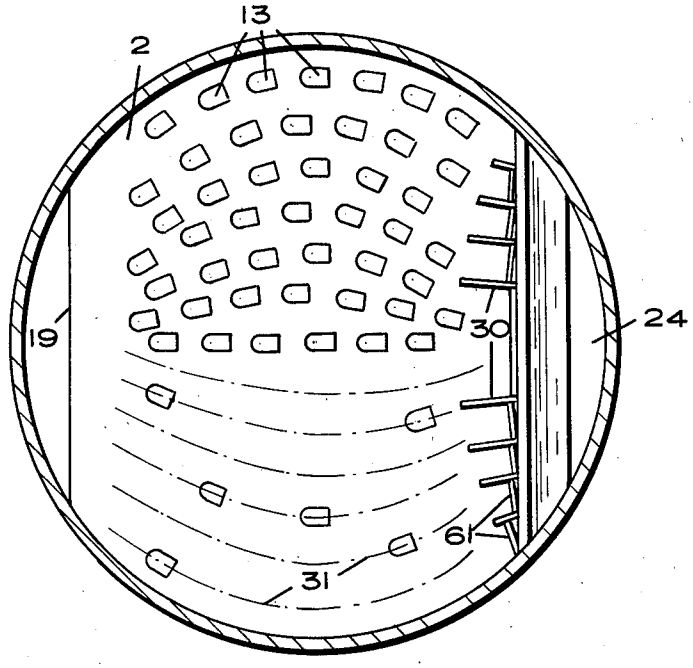


FIG.- 2

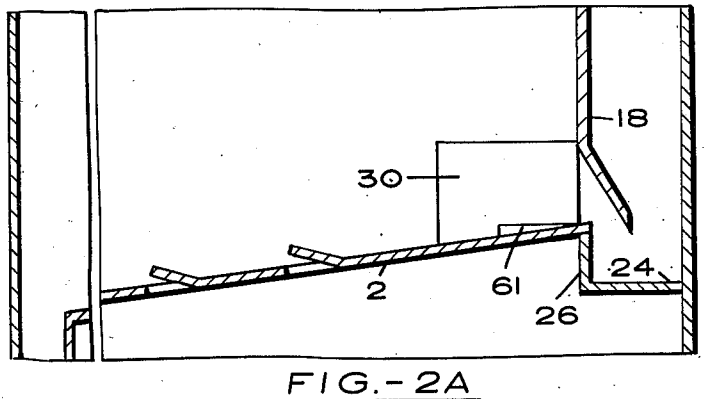


FIG.- 2A

HENRY J. HIBSHMAN
STEPHEN H. DOLE INVENTORS

BY W. O. Hilman ATTORNEY

United States Patent Office 2,787,453
Patented Apr. 2, 1957

2,787,453

FRACTIONATING TOWER UTILIZING DIRECTIONAL UPFLOW MEANS IN CONJUNCTION WITH SLANTED TRAYS

Henry J. Hibshman, Plainfield, and Stephen H. Dole, Westfield, N. J., assignors to Esso Research and Engineering Company, a corporation of Delaware

Application November 30, 1953, Serial No. 395,024

2 Claims. (Cl. 261—114)

The present invention relates to improved apparatus for operating a countercurrent-vapor-liquid treating zone. The invention is more particularly concerned with an improved fractionation zone and is especially directed to apparatus for contacting upflowing vapor and downflowing liquid utilizing improved contacting trays. In accordance with the present invention, the capacity of particular contacting trays and the entire treating zone is markedly increased by providing a means for efficiently and effectively contacting the countercurrently flowing phases. In accordance with the present invention, selected directional vapor and liquid streams are produced on the respective trays which facilitates the passage of the downflowing liquid across the tray, thus reducing liquid holdup on the tray. The directional stream is secured by a contacting tray which is characterized by containing directional openings, such as tab openings. A specific adaptation of the present invention is to utilize a slanted tray in conjunction with the directional upflow means. A particular adaptation of the present invention is to arrange the upflow means, such as the tabs in an elliptical pattern on the tray. When employing this latter modification, especially excellent uniform liquid distribution is secured by employing vertical vanes in conjunction with broad crested or sharp edged weirs at the inlet side of the tray.

It is well known in the art to carry out many chemical reactions and separations wherein vapor and liquid are contacted in a countercurrent zone, such as in a vapor liquid fractionation zone. Normally the liquid passes from one zone to a lower zone by means of downcomers or their equivalent while the vapors pass upwardly from zone to zone through chimneys in the tray, around various types of bell caps or their equivalent into the liquid phase disposed on top of the tray. The liquid phase flows across the tray and over weirs on the respective trays into downcomers and onto the tray in the zone below. The height of the liquid phase on the tray is determined by the height of the weir. The downcomer from the zone above must of necessity extend below the top of the liquid phase on the lower tray in order that vapor will not pass up through the downcomer instead of through the bubble caps. In liquid-gas contacting operations of this character, the capacity of the tray and consequently the tower is determined to a large extent by the degree of efficiency with which the downflowing liquid flows across the tray and into the downcomer. Thus, aside from limitations of auxiliary equipment, such as furnaces, feed pumps, and condensers, the capacity of a fractionation tower is determined by several factors. Basically, these are limitations to passage of liquid down and vapor up the tower in such a manner that efficient contacting is achieved.

The requirement of efficient contacting means that the limitation may be one of too rapid or free passage of one or more of the phases through the tower, as well as restrictions to flow of the phases. Tray dumping, liquid running down through bubble cap chimneys, is an example

of too free flow of liquid. Downcomer filling with backup of liquid on the tray is the opposite type of limitation, resulting in poor efficiency because of excessive entrainment and ultimately in tower flooding. A similar high entrainment result is produced by excessive vapor rates. In a typical bubble cap tower, each of these limitations predominates over a different vapor rate range.

One operating disadvantage comprises excessive liquid holdup which, in the absence of a downcomer limitation and obstructions on the tray, is determined by the linear velocity at which liquid is able to pass across the tray. For a given liquid velocity across the tray the liquid holdup is directly proportional to the volume of liquid flowing across the tray in a unit of time. Since the liquid on the tray is "aerated" by the vapor, the volume occupied by the liquid is a function of the velocity of the vapor in the tower and the amount of liquid holdup on the tray. At normal tray spacings a tower will ultimately be limited in capacity by the liquid flow approaching the tray above, resulting in excessive entrainment. Accordingly, higher capacities can be reached if the liquid holdup is reduced. Reduced holdup is accomplished by the present invention which directs the upflowing vapor stream through the trays in such a manner as to push liquid across the tray at a faster rate.

In accordance with the present invention, directional jet or tab-style fractionating trays are used in conjunction with slanted trays. While directional jet or tab-style fractionating trays have been shown in laboratory and plant scale operations to possess vapor handling capacities, up to and greater than 40% higher than conventional bubble cap plates, one disadvantage of these directional trays has been their tendency to dump or spill liquid through the tray at vapor rates below about 40 to 50% of the tray capacity. Thus, since the jet style tray dumps or spills more liquid than bubble cap trays at low liquid loadings, their usefulness has been somewhat limited.

In accordance with the present invention, it has been found that if these jet or tab trays are slanted from about 5 to 10 degrees from the horizontal toward the downcomer, this spilling of the liquid is substantially eliminated. It has also been found that if the pattern of the directional means is arranged in a family of ellipses, unexpected desirable results are secured with respect to the tray phase contacting efficiency. It is very desirable to use in conjunction with the slanted tray, vertical vanes in conjunction with broad crested or sharp edged weirs at the inlet side of the tray, the weirs being perpendicular to the elliptical flow lines.

The present invention may be readily understood by reference to the drawings illustrating embodiments of the same.

Figure 1 is a vertical cross-sectional view illustrating a plurality of tray elements disposed within a countercurrent treating zone.

Figure 2 is a top cross-sectional view of tray element 2.

Figure 2A is a detailed vertical cross-sectional view of tray element 2. Referring specifically to Figure 1, a plurality of tray elements 1, 2, 3, 4 and 5 are disposed within a countercurrent contacting zone 6. Plate element 1 contains openings 7 secured by punching tabs 8. In a similar manner trays 2, 3, 4 and 5 contain openings 9, 10, 11, and 12, respectively, secured by punching tabs 13, 14, 15 and 16, respectively. These openings permit communication from the area below the respective trays to the area above the respective trays. Downcomers are provided by means of baffle elements 17, 18, 19, 20, 21, and 22. These baffle elements extend into liquid seal reservoirs 23, 24, 25, 26 and 27, associated with plates 1, 2, 3, 4 and 5, respectively. It is to be understood that countercurrent contacting zone 6 is pro-

vided with a means for withdrawing vapor from the top of the zone, a means for withdrawing liquid from the bottom of the zone as well as other input and output means at selected portions of the zone.

In operation, liquid flows downwardly onto plate 1 through downcomer 17 into liquid seal reservoir 23. The liquid flows across the plate past tabs or equivalent means 8. Upflowing vapor passes through openings 7 in the direction of the cross flowing liquid and thereby intimately contacts the same. The liquid flows across the plate into downcomer 18 and passes to the liquid seal reservoir 24 associated with plate 2. In a similar manner the downflowing liquid passes over tray 2 into downcomer 19 and into well element 25. As the liquid flows across tray 2, it contacts upflowing vapor passing through the openings 9. Thus the liquid passes across tray 3 into well 26 across tray 4 into well 27 and across tray 5.

The character and particular dimensions of the plates illustrated in Figure 1 may vary appreciably. For instance, a typical 10-foot diameter tower would have trays having preferably a 7.5 degree slope with respect to the horizontal. The trays themselves would be about 7 feet in length and the average distance between the respective trays about 2½ feet. The height of the downcomer would be about 1.58 feet and the distance between the respective trays at the farthest point about 3.42 feet.

Figure 2 illustrates the preferred elliptical jet pattern on the slanted tray employed in conjunction with directional vertical vanes and broad crested weirs. Figure 2 is a top view of plate 2 with similar numerals designating similar elements.

In operation, liquid flows downwardly to tray 2 through downcomer inlet 24. The liquid is directed into elliptical paths by means of vertical vanes 30. The size and dimensions of these vanes will vary depending upon the size of the unit being utilized. In general, these vanes have heights in the range from about 2" to 6" and are about 4" to 18" long. The vanes at the center of the inlet section of the plate are relatively straight, while their curvature increases as they approach the shell wall.

Positioned between the respective vertical vanes as shown in Figure 2A are broad crested weirs 61, the length of which is in the range of 0" to 6".

In operation as illustrated above, the liquid flows across the tray and across the jets 13, the elliptical pattern of which is illustrated by lines 31. The liquid enters downcomer 19 and passes to the next succeeding zone.

An advantage of the present invention is that reduced tray inlet liquid heads are secured. In a normal bubble cap tray operation there is a tendency for liquid to build up to a higher level at the inlet side of the tray than anywhere else on the tray. It has been found that the use of tabs in place of bubble caps produces the opposite effect. In this case, the inlet head is lower than anywhere else on the tray.

The design of the tabs is not critical. Hemispherical baffles open on one side towards the downcomer, square or rectangular box-type baffles open towards the downcomer elbow-type baffles and similar devices may also be used.

In one preferred design of tab tray, which has a vapor handling capacity of about 10 feet per second, the superficial air velocity at which 5% dumping occurred, was reduced from 3.1 feet per second to 1.97 feet per second by changing the tray slope from 0 to 5 degrees and further reduced to 0.66 feet per second by slanting the tray 10 degrees. Thus, the operability range of the tray was increased from 69% to 80% and 93% by sloping the tray 5 degrees and 10 degrees respectively.

Although the specific reduction in dumping obtained by slanting a jet tray depends upon the design of the tray such as number of openings of unit area, opening size, opening shape, opening angle, and percent open area of the tray, nevertheless the preferred sloped angle remains from about 5 to 10 degrees. In general, with jet trays such as tab trays, dumping is most severe at low liquid loadings.

The invention may be more fully understood by the following example illustrating the same:

EXAMPLE

A number of operations were carried out wherein the air rate was varied as well as the tray angle. The percent dumping was also determined. The results of these tests are illustrated in the following table:

Table —Dumping data for tab tray having 50% tab area (tabs 2" x 2")

[Percent dumping at various air rates at 900 G. P. H./ft. water rate. Tray pressure drop-mm. H_2O in parentheses ( ).]

Tab Angle	15°				20°				25°			
Air Rate, Ft./Sec.	0	1	2	3	0	1	2	3	0	1	2	3
Tray Angle:												
0°	100(0)	64(9)	4.3(14)	0.2(14.5)	100	100	28	5.8	100(0)	100(1)	58(13)	26(18)
5°	67(0)	4.1(5)	0(9)	0(13)	79(0)	29(4)	4.7(7)	0.7(10)	100(0)	85(1)	34(4)	5(9)
10°	12(0)	0.6(3)	0	0(11)	31(0)	2.6(3)	0.6(7)	0.1(8.5)	51(0)	11(2.5)	5.6(4.5)	1.1(7)
15°	4	0.2	0	0	11.5(0)	0.7(3)	0.2(5.5)	0.1(8)	18.5(0)	2.8(2)	1.5(4)	0.8(5)
20°					4.2(0)	0.4(2)	0.08(4)	0.04(7.5)	7.4(0)	2.1(2)	0.5(3.5)	0.2(5)
Dry Tray	(0)	(1)	(4)	(8.5)					(0)	(1)	(2)	(3)

AIR RATE FOR 5% DUMPING

Tab Angle	15°	20°	25°
Tray Angle:			
0°	1.95	3.10	>4
5°	0.94	1.97	3.00
10°	0.30	0.66	2.11
15°	0	0.24	0.51
20°	0	0	0.38

It may be seen from this table that, in order to substantially reduce dumping, it is necessary to slope the tray only 5° or 10°. Slanting the tray more than this, say 15° or 20°, results in a tray more dump-free than is practically required in most commercial fractionating towers. Slanting a tray 5° to 10° increases its vapor handling capacity about 10% but slanting it more than 10° reduces the available downcomer height excessively and might reduce tower capacity by making the downcomer limiting. No important reduction in pressure drop accrues from slanting the tray more than 10°. Hence the preferred tray angle in this invention is 5° to 10°.

What is claimed is:

1. Apparatus adapted for contacting upflowing vapor and downflowing liquid comprising a vertical tower, a plurality of vertically spaced plates the plane of said plates being inclined at an angle of from 5 to 10 degrees with the horizontal, said plates extending substantially across said tower and intersecting vertically positioned conduits extending through each of said plates and terminating below each plate in spaced relation to successive plates, an array of vertically disposed liquid directing vanes extending from said conduits a short distance onto said plates, the end of said vanes nearer said conduit being arrayed along a chord subtending an arc of the circumference of said tower, the other end of said array describing an arcuate configuration, the said vanes being adapted to direct a liquid stream in an elliptical pattern, an array of vapor directing means carried

on said plates, each of said vapor directing means forming vapor ejecting orifices adapted to effect flow of vapor across said plate in a predetermined direction, said vapor directing means being disposed on said plates along the circumference of a plurality of concentric ellipses and oriented with said orifices ejecting vapor along said circumferences, whereby liquid flowing across said plate is directed to a pattern corresponding to the circumference of said concentric ellipses.

2. Apparatus according to claim 1 wherein said vanes are separated by individual weirs positioned perpendicular to the elliptical liquid flow lines across the plate.

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