

Sept. 23, 1958

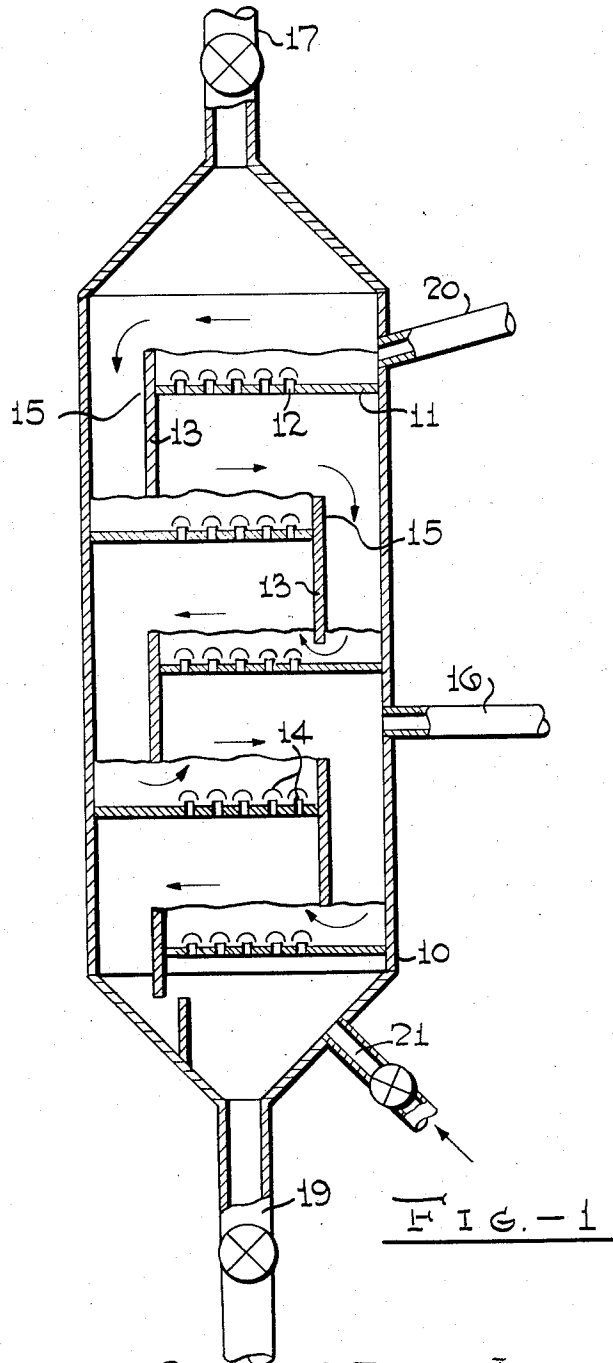
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FRACTIONATING TOWER

Filed March 26, 1952

3 Sheets-Sheet 1.



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3 Sheets-Sheet 2

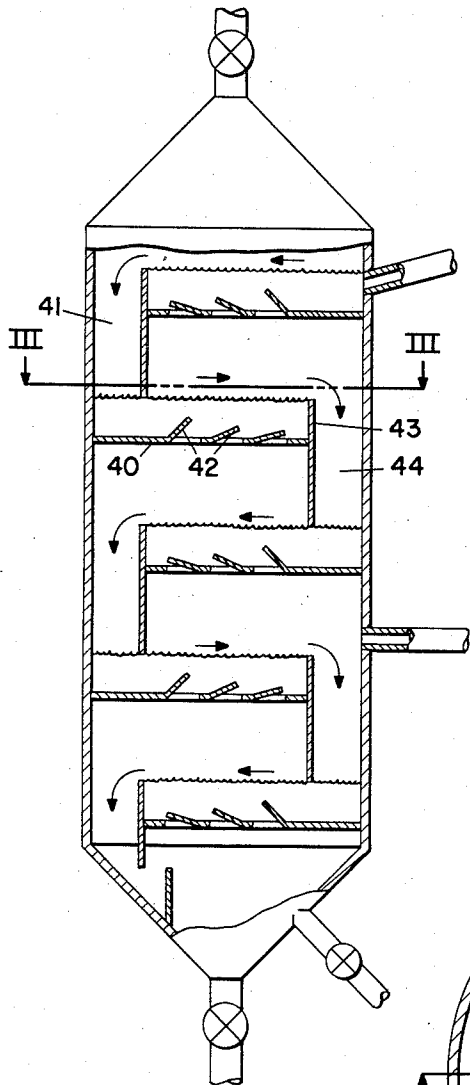


FIG. - 2

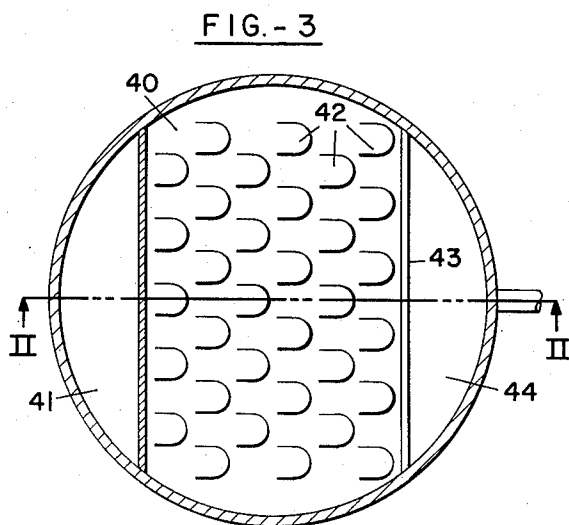


FIG. - 3

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3 Sheets-Sheet 3

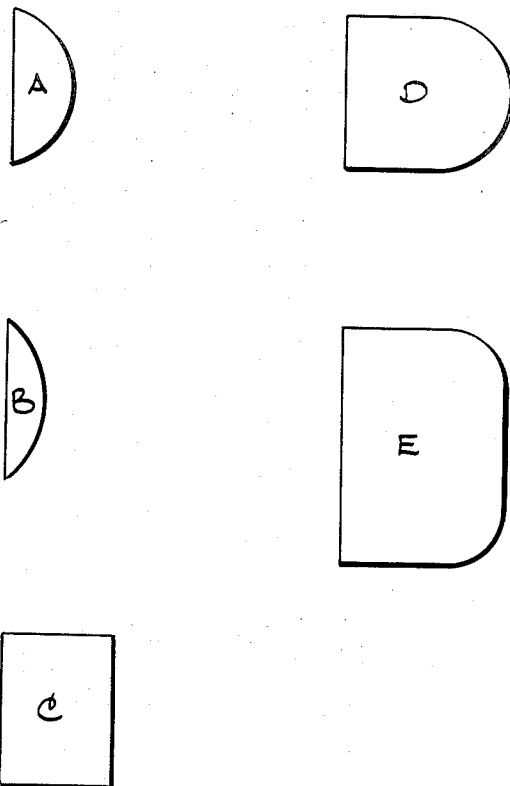


FIG. - 4

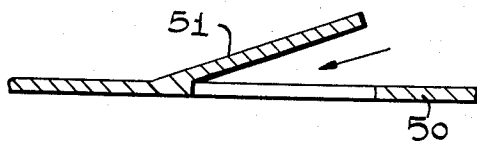


FIG. - 5

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2,853,281

## FRACTIONATING TOWER

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2 Claims. (Cl. 261-114)

The present invention is concerned with an 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 an apparatus for contacting upflowing vapor and downflowing liquid utilizing contacting vapor trays or their equivalent. In accordance with the present invention, the capacity of a tray and the entire treating zone is markedly increased by providing an apparatus for efficiently and readily contacting the countercurrent flowing phases. In accordance with the present invention, a directional vapor stream is 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 tab openings.

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

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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, liquid holdup on the respective trays is prevented by providing concurrent flow of upflowing vapor and liquid across the tray. In other words, a directional flow of vapors is provided in order to increase the velocity of the liquid flowing across the trays, thus minimizing liquid holdup. It is an important object of the invention to provide such directional flow by employing plates provided with a large number of punched tabs distributed over a substantial portion of their area, said tabs being punched so as to direct upflowing vapor in a direction toward the conduit associated with each plate, said tabs having tab angles which decrease progressively in the direction along the plate toward a conduit such as a downcomer.

The present invention may be readily understood by reference to the drawings illustrating embodiments of the same. Figure 1 illustrates a typical bubble cap tray fractionation zone, while Figure 2 illustrates a fractionation zone employing tabs of the present invention. Figure 3 is a top view of the tab tray of the present invention, while Figures 4A to 4E illustrate various types of tabs which may be utilized. Figure 5 is a side view of the tab and illustrates the tab angle.

Referring specifically to Figure 1, the numeral 10 designates a bubble cap tray column, contacting vessel. The vessel 10 is conventionally provided with a series of vertically spaced, transverse, perforated plate elements 11, forming a vertical series of superimposed, contact chambers or zones. These chambers or zones are in communication with one another by way of the passageways 12 formed by the plate perforations, and downcomers 13 disposed at alternate sides of the vessel from plate to plate. The downcomers extend from the surface of one plate downwardly into vertically spaced relation to the surface of the plate next below. As shown in Figure 1, the passageways 12 through the plate are each provided with bubble cap elements 14. In addition, each plate 11 is provided with a weir member 15, at the entrance to the downcomer 13, extending upwardly from the plate surface to a level above the lower end of the downcomer from the plate next above. The vessel is also

provided with a feed line 16. An outlet from the vessel for gaseous materials is provided as by conduit 17. At the lower end of the vessel is an outlet 19 for heavier materials. In operation, it is to be understood that any number of trays may be utilized. In accordance with the present invention, for the purpose of description, it is assumed that a vaporous feed is introduced at an intermediate point of fractionating zone 10 by means of line 16. Temperatures and pressures are adjusted so that vapors flow upwardly in zone 10 through the chimneys 12 and around bubble caps 14 into a liquid maintained on the top of the plate, the height of which is determined by weir 15. The liquid phase on the plate comprises dissolved or condensed constituents of the vaporous feed introduced by means of line 16. The liquid phase which flows down through zone 10 over each plate and weir in succession is known as reflux. The reflux is normally initiated by condensing a portion of the vapors withdrawn through line 17 and introducing the liquid condensate into the top of zone 10 through line 20. Vapors for the section of zone 10 below feed line 16 are obtained by vaporizing a portion of the heavy product withdrawn from line 19 and introducing the said vapors through line 21.

Figure 2 is identical to Figure 1 except that the bell caps 14 are replaced by tabs 42.

Referring specifically to Figure 3, liquid flows downwardly onto plate 40 through downcomer 41. The liquid flows across the tabs 42 on the plate through which up-flowing vapors pass and contact the cross-flowing liquid. The liquid passes across weir 43 into downcomer 44 in which the liquid passes to the zone below.

Figures 4A to 4E illustrate various types of tabs A, B, C, D and E, which may be utilized. Figure 5 shows a tray 50, a tab 51 and the tab angle.

Another 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 be used.

A simple and effective arrangement may be fabricated by punching plate trays to provide the required openings, leaving inclined flaps of metal adjacent each opening to direct vapors toward the downcomer.

The baffles may be equipped with slots on their open ends and they may have holes or clearance with the tray floor on the sides other than that facing the downcomer. However, they must produce a directional vapor stream leaving the tray in the direction of the downcomer.

In accordance with the present invention the tabs on the tray are punched or fabricated so that the tab angle is within a critical range. The tab angle is the angle between the plane of the tab and the plane of the tray. It has been found that the tab angle and distribution of tabs and tab angles across the tray are highly critical and that satisfactory operation can be achieved only if proper consideration is given to these factors. For instance, if a uniform tab angle is utilized with respect to the tabs across the tray, it is essential that the tab angle be between about 12° and 25°, preferably between 15° and 20°. At tab angles less than about 12°, the vapor handling capacity is no higher than with conventional bubble cap trays. At tab angles higher than about 25°, the trays dump excessively, thus limiting the range of operability. This is illustrated by the following example.

### Example I

Various operations were conducted using various tab angles, the results of which are shown in the following table<sup>1</sup>:

| Tab Angle            | Liquid Rate,<br>G. P. H./<br>Sq. Ft. | (A)<br>Vapor Rate<br>at Flood-<br>Point,<br>Ft./Sec. | (B)<br>Vapor Rate<br>at Incipient<br>Dumping,<br>Ft./Sec. | (A—B)<br>Operability<br>Range,<br>Ft./Sec. |
|----------------------|--------------------------------------|------------------------------------------------------|-----------------------------------------------------------|--------------------------------------------|
| 5.....               | 800                                  | 3.95                                                 | 2.37                                                      | 1.58                                       |
| 10.....              | 800                                  | 7.43                                                 | 4.33                                                      | 3.10                                       |
| 15.....              | 800                                  | 10.14                                                | 5.94                                                      | 4.20                                       |
| 16.5.....            | 800                                  | 10.65                                                | 6.36                                                      | 4.29                                       |
| 20.....              | 800                                  | 11.12                                                | 7.18                                                      | 3.94                                       |
| 25.....              | 800                                  | 10.90                                                | 8.02                                                      | 2.88                                       |
| 30.....              | 800                                  | 10.06                                                | 8.61                                                      | 1.45                                       |
| Bubble Cap Tray..... | 800                                  | 8.73                                                 | 4.66                                                      | 4.07                                       |
| 5.....               | 305                                  | 3.95                                                 | 2.25                                                      | 1.70                                       |
| 10.....              | 305                                  | 7.09                                                 | 4.07                                                      | 3.02                                       |
| 15.....              | 305                                  | 9.46                                                 | 5.56                                                      | 3.90                                       |
| 16.5.....            | 305                                  | 9.89                                                 | 5.94                                                      | 3.95                                       |
| 20.....              | 305                                  | 10.10                                                | 6.36                                                      | 3.74                                       |
| 25.....              | 305                                  | 9.16                                                 | 6.28                                                      | 2.88                                       |
| 30.....              | 305                                  | 6.79                                                 | 5.52                                                      | 1.27                                       |
| Bubble Cap Tray..... | 305                                  | 9.46                                                 | -----                                                     | -----                                      |

<sup>1</sup> Data taken from 10-ft. diameter experimental half tower using air and water. Tray had 344 2-in. tabs on 3.5-in. centers, staggered pattern.

From the above it is apparent that if a satisfactory operating range is to be secured, the tab angle should be between 12° and 25° when utilizing a uniform tab angle across the tray.

A preferred mode of operation is to employ tab angles of decreasing value across the tray in the direction of liquid flow. This is illustrated by the following example:

### Example II

A number of operations were carried out utilizing a 10-ft. diameter tower. With the conventional 20° angle directional jet tray having 344 tabs 2 inches wide arranged in staggered or triangular pitch with 3½ inch centers, the 10-ft. diameter tray would only handle 30,000 cubic feet of vapor per minute when 525 gallons per minute of liquid was flowing across the tray. When the tab angle was raised to 45° on the inlet ⅓ of the tray and decreased to 10° on the outlet side of the tray, the vapor handling capacity of the tray was increased to 35,000 cubic feet per minute. This is an increase of 17%.

Thus, when utilizing tabs having angles which decrease in the direction of liquid flow, the angles of the tabs are not within the 12° to 25° critical limit discussed heretofore. Under these conditions the first ⅓ of the tabs should have angles in the range from about 30° to 60°, the middle third of the tabs should preferably have angles in the range from about 12° to 24°, while the last ⅓ of the tabs in the direction of liquid flow should have angles in the range from about 5° to 15°. Thus, if all the tabs on a directional jet tray are bent to the same angle, the critical angle has been found to be between about 15° and 20°. Under these conditions, trays having angles greater than 25° or less than about 12° are significantly inferior.

However, the combination employing graduated tab angles produce better results with respect to operability range and maximum vapor handling capacity. Under these conditions the tab angles should be as specified above. It is of note that other combinations were tried but found to be inferior. For example, raising all the tabs to 90° but reducing vapor flow on the outlet ⅓ side of the tray by blanking every other row of tabs gave poor performance. Lowering of the inlet ⅓ of the tabs to 45° to affect an increase in the rate of liquid flow across the tray produced inferior results. Poor results were also secured when the center of the tray was blanked off. Other inferior results were secured when every other tab was lowered on the inlet side of the tray from 45° to 20°.

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What is claimed is:

1. Apparatus adapted for contacting upflowing vapor and downflowing liquid comprising a vertical tower containing a plurality of horizontally disposed vertically spaced plates extending substantially across the tower, a vertically positioned conduit extending through each of said plates terminating above and below each plate in spaced relation to successive plates, in which said plates are provided with a large number of punched tabs distributed over a substantial portion of their area, said tabs being punched so as to direct upflowing vapor in a direction toward the conduit associated with each plate, said tabs having tab angles which progressively decrease in the direction along said plate toward said conduit.

2. Apparatus as defined by claim 1 wherein said tabs furthest away from said conduits have tab angles in the range from about 30° to 60° wherein said tabs in the

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central area of said plate have angles in the range from about 12° to 24° and wherein said tabs nearest said conduits have angles in the range from about 5° to 15°.

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