ABSTRACT: For a vertically disposed liquid-liquid contact column using spaced perforated trays of the "rain deck" type, an improved tray construction that has weir means on each deck to provide a liquid coverage at each deck and, in turn, insure uniform droplet flow from all the holes through each deck, as well as curtain means on the opposing side of each tray to preclude the countercurrently flowing liquid stream from immediately sweeping droplets from the downstream face of each perforated deck and causing an undesirable back-mixing effect. A preferred design also uses specially located nonperforated areas on each tray section to permit a solvent liquid, or other contact liquid, a chance to settle and minimize entrainment.
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1 LIQUID-LIQUID CONTACTING TRAY SYSTEM

The present invention relates to an improved perforate type of liquid-liquid contacting tray system. More particularly the invention is directed to modifications in sieves tray or rain deck designs for a liquid-liquid contactor so as to provide a simplified and economical system that is effective in minimizing back-mixing problems.

Liquid-liquid contacting is, of course, carried out for solvent extraction operations as well as for scrubbing, absorption and fractionation-type functions, so that the present tray construction may well be used in many and various types of operations. Also, the presently used forms of liquid-liquid contact columns are of many types and varieties. It is known that the majority of nonmechanical types use embody a sieve tray or rain deck form of liquid dispersing device whereby a continuous liquid phase flow passes through a discontinuous or dispersed phase. With respect to the use of mechanically operated mixing and settling types of contactor units, there are also various forms and modifications in commercial use. For example, there is a "rotating disc" column where rotating disc portions are spaced vertically along the length of a shaft and the shaft rotated in a special contactor column adapted to accommodate countercurrently flowing liquid streams.

In connection with the perforated plate columns or contactor, the designs have progressed from the simple to the complex and now, after much experience, revert back to the simple. With respect to special types of contactor columns using perforate plates, the tray designs disclosed in U.S. Pat. Nos. 2,872,295; 2,895,809; 2,647,855 and 2,647,856 are typical of sieve plates or rain deck systems which have been or may be used in extraction functions. However, it is realized that the decks of complex construction or which have special downspout-riser means give rise to high initial costs and perhaps should not be justified unless there are unusually good operating efficiencies resulting from their usage. Similarly, the initial cost and operating and maintenance costs of the power-operated contactors should not be justified unless there can be exceptional resulting efficiencies. As a result, although at the present time, the power-operated contactors and the fixed special tray designs in vertical columns are giving good efficiencies, it appears that the use of other less expensive contactor means, such as provided by this invention might well be used to advantage, particularly where the cost aspects will permit a larger number of decks and stages and still have less initial cost than certain of the prior art types.

It is therefore a principal object of the present invention to provide a contactor deck or tray system which is both economical and of simple design so as to minimize first cost, as well as maintenance or replacement costs or both.

It may be considered a further object of the present invention to provide a perforate type sieve deck or rain deck system which can be closely spaced in a vertically oriented column, as well as economically fabricated, so that there may be used a large number of contactor decks in any one column to result an overall high efficiency for a low first cost.

Broadly, the present invention provides an improved simplified form of vertically disposed contacting column for the countercurrent flow of substantially immiscible liquid phases through a multiplicity of contact stages utilizing transverse perforate plates, with such improved construction comprising in combination, a first plurality of spaced perforated decks each of which has at least one unblocked area for a liquid to flow vertically in a non-dispersed manner, a second plurality of perforated decks spaced vertically away from and in between the first said decks, with each of said second plurality of decks having an unblocked area with respect to adjacent decks which is out of alignment with and laterally to one side of the unblocked areas of the latter to thereby provide a non-dispersed tortuous path for flow of one liquid through said column, weir means on each deck adjacent the unblocked areas therein to further provide a level on each deck for a liquid to be dispersed, and curtain wall means from the opposing face of each deck which extend codirectionally with said weir means to be adjacent the unblocked areas through said tray whereby a crosscurrent flow of liquid will not directly sweep away droplets of the other liquid as they result from the dispersed flow through the multiplicity of perforations in each deck.

Generally, the operation of the contacting column and the spaced perforate decks therein will provide for a downward flow of the heavier more dense phase through the perforate plates so that it becomes a dispersed phase which thereof droplets down through a continuous upflowing less dense phase. Thus, with this operation, the more dense phase will be held on the top of each perforate tray by the weir means on each tray whereby such dense phase will then pass as droplets through the multiplicity of small holes provided across the main body portions of each deck or sieve tray. At the same time, a short dense phase will be passed from each deck at the edge of each tray riser opening so that the upflowing less dense material will be prevented from sweeping directly across the lower surface of each deck and interfering with the formation of droplets which in turn is desired to provide the dispersed phase downward flow to a next lower contact tray.

It is, however, not intended to limit the use of the present improved contactor column arrangement with the modified rain deck design to a down flow of the dispersed phase. In other words, by regulating the initial filling of the column and the flow rates therethrough the operation of the column may be such as to have the less dense liquid become the dispersed phase and, in effect, rain as rising droplets from the surface of each tray up through a descending continuous more dense phase liquid stream. Thus, in this latter operation, each sieve tray will have the weir member along the lower face thereof at each down comer opening so as to provide a "level" or distribution of the light phase over the lower face to insure a uniform rise of droplets from all of the multiplicity of openings in a tray. Also, conversely, a curtain wall will extend above the surface of each contact tray along the edge of each down comer for the down flow of liquid so that the continuous more dense phase flow will be carried away from or included from passing directly along the upper surface of each deck. This will thus preclude the direct sweeping away of droplets from the surface of the deck and insure that there will be an upward rain of droplets as a dispersed phase traveling through the continuous descending more dense phase.

In a preferred design or embodiment for each of the special sieve decks, there will be one or more sections of tray which are not perforated in order that there may be, in effect, "stilling zones" or quiet zones that provide a chance for the dispersed phase to settle out and become free of entrained liquid from the continuous phase stream. For example, in a solvent extraction operation, wherein a solvent stream is descending through the column countercurrently to an immiscible rising hydrocarbon stream, the descending dispersed phase or solvent droplets will have a chance to separate and become free of entrained hydrocarbons before again being dispersed by the next tray or before being permitted to pass over a weir. Also, with respect to the action occurring below a tray or deck, there is another advantage is having a nonperforate "stilling zone" in that there will be less "rain", or descending solvent droplets, adjacent the riser openings where the upflowing hydrocarbon stream will take a turn from its horizontal flow to the vertical. In other words, the providing of a lateral space or distance should lessen "back mixing" and the carrying up of solvent through the riser zones of each tray.

Reference to the accompanying drawing and the following description thereof will serve to illustrate one embodiment of the inventor as well as point out additional advantageous features which are obtainable through the use of the present improved simplified form of sieve deck systems.

DESCRIPTION OF THE DRAWING

FIG. 1 of the drawing is a partial sectional elevational view indicating the lower end of a contactor column using a plural-
ty of vertically spaced sieve decks of the present improved simplified design.

FIG. 2 of the drawing is a sectional plan view, as indicated by the line 2—2 in FIG. 1, showing the design of one type of tray for the system.

FIG. 3 of the drawing is also a sectional plan view, indicating the tray design for an alternating tray in the deck system, as indicated by the line 3—3 in FIG. 1.

FIGS. 4 and 5 show, in enlarged partial sections, the construction of one form of weir means and a depending curtain wall means.

FIG. 6 of the drawing is a diagrammatic partial sectional view through a sieve deck contactor tray system where one tray of the system may be supported from a next lower tray and still provide a perforate plate sieve deck arrangement which will embody the improved features of the present invention.

FIG. 7 of the drawing indicates in a partial elevational view the use of an open latticework type of support beam or truss for use in effecting the connection of one perforate tray to another, as indicated by the line 7—7 in FIG. 6 of the drawing.

Referring now particularly to FIGS. 1, 2 and 3 of the drawing, there is shown a portion of a vertically oriented contactor column 1 having a plurality of trays 2 that are spaced vertically and which, in turn, have perforate plate means 3. At each level for trays 2 there are relatively large unblocked zones or open areas 4 which provide for the continuous flow of one of the phases being contacted in the column. Generally, the less dense phase liquid will rise through the contacting column and be contacted by a descending more dense dispersed liquid phase, indicated by droplets 5. For example, there may be a light hydrocarbon phase entering the column through a lower inlet port 6 while a more dense phase solvent stream enters the top of the column, in a manner not shown. Such a dispersed flow from one level of the column by way of outlet port 7 as an extract stream.

Spaced in between each of the plurality of spaced trays 2 will be another plurality of trays 8 which shall be arranged to have unblocked riser openings, such as 9, out of alignment with the riser openings 4 in decks 2. Each of the decks 8 will also have a multiplicity of holes 10, which generally may be punched openings, so as to provide a "rain" of droplets 5 of solvent, or other contacting liquid. FIG. 2 of the drawing shows the multiplicity of holes 10 being distributed over a large area at each deck member 8 by the boundary lines 10'; however, in a preferred arrangement, there will also be a large nonperforate area 11 within the central zone of the deck so as to preclude the formation of droplets within an area or zone directly above the riser openings 4 in the next adjacent tray means 2.

FIG. 2 also indicates in plan view the upper weir plate means 12 which extend along the edges of the trays 8 at the open riser zones 9. At the same time, directly below the weir plate means 12, there are extensions thereof which provide curtain wall means 13, as best shown in FIGS. 1 and 4 of the drawing.

The weir or wall portions 12 extending above each of the perforate trays will serve to maintain a level or covering of the more dense phase descending stream over all of the multiplicity of holes 10 through each deck means 8. Generally, most of the descending dense phase will pass as droplets 5 through the deck means and become a dispersed phase moving through the continuous and laterally moving light phase stream however, at times a small portion of the dense stream may overflow the weir means 12 and pass downwardly through the riser opening 9. Thus, it may be desirable to have a plurality of notches 14 spaced along the top edge of each of the weir plates or walls 12 in order to permit a uniform distribution of liquid flow along each unblocked liquid riser opening.

Referring now particularly to perforate trays or sieve decks 2, as shown in FIGS. 1 and 3, it will be seen that each of the plate portions 3 have a multiplicity of holes 15 within areas indicated by the boundary lines 15' so that from each of the decks 8 there will be a multiplicity of descending droplets 5 to provide a dispersed phase and a rain droplike flow through the continuous phase liquid stream between each of the spaced decks. Again, a preferred arrangement provides that the holes 15 are in spaced portions of the deck only so as to provide nonperforate areas, such as 16, which generally will be opposite the riser zones 9 of the next adjacent decks 8. This arrangement, of course, provides that the upwardly moving continuous streamflow will follow a tortuous path in its rising flow to recross or move laterally with respect to a next higher or adjacent deck, whereby the continuous phase flow is repeatedly passed in successive stages through the descending droplets of the countercurrently moving phase.

As to each of the plurality of decks 2, each will have weir means or uniform height upper walls 12' that extend along riser openings 4 so that there will be insured a level of the more dense phase descending liquid from all of the multiplicity of openings 15 in each portion of the deck 2. As best shown in FIGS. 4 and 5 for the weir means 12, the weir 12' will also have spaced notch openings such as 14 to permit a uniform overflow of liquid in those operations where there may be a build up of the more dense phase liquid on each tray to the extent that a portion of the liquid will overflow and pass downwardly through a riser opening.

Also in a manner similar to the construction of trays 8, each tray 2 will have a depending curtain wall section 13' which will extend along surface of each tray surface under each tray opening 4 so as to provide a flow stream baffle or deflector on the underside of each tray. Each of the depending curtains or reflector means 13' will tend to prevent the lateral flow of the rising liquid phase from sweeping along the lower surfaces of each tray 2 and in turn preclude the sweeping away of droplets 5 as they are formed on the lower surface of the tray and leave the multiplicity of holes 15. As previously set forth, it is desirable to insure that there is the continuous running of droplets downwardly from one deck to another so that there is a uniform contacting of the nondispersed liquid phase as it moves from side to side in the contactor column and thence upwardly through the riser zones of successive trays to reach the top of the column. With the prevention of the immediate sweeping or entrainment of droplets from the bottom of the tray or sieve deck section, there will be a minimization of the recirculation of solvent back upwardly through a riser zone.

In connection with the multiplicity of holes 10 and 15 in each of the respective decks 8 and 2, it should be noted that the holes may be provided by machine "gang punching" or any other economical method of fabrication inasmuch as the present tray system does not require that each tray absolutely level or have entirely smooth opening perforate means. In other words, by the use of the weir walls 12 or 12' on each of the trays, there will be an insured covering of all of the multiplicity of holes and a resulting substantially uniform formation of droplets 5 from all of the trays so that the more dense phase liquid will carry in a rain drop manner downwardly through the entire height of the contactor column. Generally, the perforations will be rather small, of the order of approximately one-fourth inch diameter, so as to provide small droplets of the solvent or other descending liquid phase.

As best shown in FIG. 1, it will be noted that by having certain nonperforate areas such as 11 on trays 8, and areas 16 on trays 2, there will be substantially aligned flow of droplets down through the plurality of spaced trays for the entire height of the contactor column 1. This arrangement will, in effect, provide wide "walls" of droplets through which the rising liquid phase will pass in order to effect the desired multiple stage contacting between the immiscible liquid phases and a minimum of back mixing between such phases. At the same time, by the use of a uniform distribution of narrow nonperforate zones adjacent each riser openings, in accordance with a preferred embodiment, there will be still further minimization of back mixing between the rising liquid phase and the descending dispersed phase. More specifically, by provision of long narrow zones such as A on trays 8 and narrow zones B on trays 2 adjacent,
respectively, the weir means 12 and 12", there will be quiet zones or "stilling zones" whereby there is a chance for the descending droplet phase to become collected and partially made free of light phase liquid. At the same time, with respect to the lower face of each deck or tray, there will be a zone adjacent each riser zone or passageway 4 and 9 that will be free of descending droplets 5 so as to minimize collection and back mixing of fluids.

The present embodiments for decks 2 and 8 show straight, chordlike edges for each of the decks for in turn defining the riser openings 4 and 9; however, it is not intended to limit the present invention to the use of any one shape for each of the perforate trays or to the use of straight wall designs for the riser openings, inasmuch as numerous types of sides to side deck arrangements or disc and doughnut arrangements may well used to effect the lateral recrossing flows and the multistage contacting between the two liquid streams. Thus, where there may be a disc and doughnut tray arrangement, then the weir and curtain wall means around each riser opening for each spaced sieve deck or tray will be of a circular nature in order to provide corresponding curved wall sections for the riser openings.

In any modified perforated hole arrangement, a preferred design will still utilize certain nonperforate areas at each tray so that there will be the preclusion of descending droplets at zones directly opposing a riser area from a next adjacent tray. Also, modified designs in a preferred embodiment will utilize nonperforated areas within a particular section and the depending curtain wall sections so that there will be the preclusion of droplet formations at zones or areas next adjacent the riser openings through a particular tray.

It is recognized that various means may be utilized in connection with the present improved tray system to effect the supporting of the various trays from the inside wall of the contactor. For example, each tray may have supporting rings or clips on the inside of the contactor wall so that each tray and its supporting beam means for plates will carry the load of each tray to the particular supporting rings or clips. However, in one economical fabrication system or tray supporting means, there will be an arrangement where one deck is supported from a next lower deck in a manner to provide an entire column system where with each pair of sieve trays, the particular trays are interconnected or, in effect, supported one from another.

By way of example, in FIG. 6 of the drawing, there is indicated one embodiment where a lower tray such as 2' is in turn connected to and effects the support of an upper tray 9' through the elongated central area of a plurality of sections 18. Each beam section 18 is provided with a lower flange 19 and an upper flange 20 and these flanges, in turn, are interconnected by bar or rod means 21 in the manner of a latticed tray design. This openwork tray arrangement, of course, permits lateral liquid flow between tray sections without interference of flow as the continuous liquid phase moves gradually upwardly through the column in a recrossing flow. As one means of fabrication, the lower deck 2' may, for example, comprise respectively, plates 22, 23, 24 and 25 which have their longitudinal edges supported along the top face portions of the lower flanges 19 of each of the trays 18. The latter may, in turn, be supported from angle or clip means, such as 26, attached around the periphery of the inner wall of the contactor column 1'. The supported upper deck 8' may, in turn, comprise a series of sections 27, 28 and 29, each of which has its longitudinal edge portions supported on the top flanges 20 of truss sections 18. Thus, it will be seen that by using this method of fabrication the sections 23 and 27 may be of a similar size and configuration and may normally have similar patterns of punched holes such that one is replaceable with the other. Similarly, it will be noted that sections 24 and 28 are of a similar size and configuration and may have similar placement of punched openings so that as a result one section may be replaced by the other or fabricated in the same manner. This truss support arrangement, together with the fabrication of similar sections for adjacent decks, will result in an overall economical fabrication for all of the decks in the entire contactor column. FIG. 7 of the drawing is a partial sectional view through a pair of deck sections such as 2' and 8', as indicated by the line 7—7 in FIG. 6, and illustrates how the open latticework design for truss sections 18 will readily permit lateral liquid flow between deck sections. However, at the same time, the open truss design provides flange portions suitable to support upper and lower deck sections of interconnected adjacent decks in the perforate tray system. Obviously, other types of open trusses may be utilized and they need not be limited to the use of the diagonally laced rod means 21, such as indicated in FIG. 7. Still further, there may be variations in the shapes and/or configurations of deck sections, with respect to their plan views, or alternatively, with respect to the size and/or shape of riser openings so that a preferred rain deck system need not be limited to the particular placement of riser areas, as indicated in the present drawing. However, regardless of the particular deck configuration, a preferred embodiment will utilize the open truss arrangement in effecting an interconnection between at least two adjacent decks to provide a vertically spaced deck system where at least one deck is supported from another adjacent deck section.

Generally the decks or tray sections will be of carbon steel and of minimum thickness to meet structural requirements for the particular size of the tray and the pressure drops encountered; however, it is not intended to limit the tray or deck material to any one type of material inasmuch as they may be fabricated of one of the stainless steel materials or whatever material may be required to suitably accommodate the particular liquid phases to be encountered within the contactor column.

We claim as our invention:

1. In a vertically disposed contacting column having a multiplicity of contact stages using transverse horizontally disposed partially perforated sieve-type decks for accommodating countercurrent flow of substantially immiscible liquid phases, the improved construction which comprises, a first plurality of vertically spaced rain decks each having two elongated areas of multiple perforations, each of which has such deck having at least one central unblocked area for a liquid to flow vertically in a nondispersed manner and elongated side nonperforate areas, a second plurality of partially perforated rain decks spaced vertically away from and in between said first rain decks, each of said second plurality of decks having two elongated areas of multiple perforations, an elongated central area in each of said decks, and each of said decks having an elongated unblocked area of said first plurality of rain decks, and elongated unblocked area at its side thereof which are out of vertical alignment and laterally to one side of the unblocked area of said first decks and are in vertical alignment with the elongated side nonperforate areas of said first decks to thereby provide a nondispersed tortuous path for flow of one liquid through said column, each of said second plurality of rain decks having its multiple perforations in vertical alignment with said multiple perforations in said first plurality of rain decks, said perforations in said first plurality being out of alignment with the unblocked areas in said second plurality, said perforated areas of said second plurality being out of alignment with the unblocked areas of said first plurality, vertically disposed weir means on each rain deck adjacent the unblocked areas thereof to provide a level for a liquid to be dispersed therethrough, and curtain wall means from the opposing face of each rain deck which extend in a direction the same as said vertically disposed weir means, said curtain wall means being adjacent the unblocked areas of said rain decks said weir means and said curtain wall means being of a height substantially less than one-half the distance to the next adjacent deck, to provide that a crosscurrent flow of liquid will not directly sweep away droplets of the other liquid as they result from the flow through the multiplicity of perforations in each rain deck surface, and each rain deck having
narrow elongated nonperforate sections adjacent each weir means, whereby there will be precluded the formation of droplets of liquid from said nonperforate sections adjacent each weir means and a minimization of back mixing from the nondispersed liquid flow sweeping droplets over said weir means into the unblocked areas of said rain decks.

2. The contacting column of claim 1 further characterized in that said weir means on each rain deck is provided with spaced notches along its edge whereby to provide uniformly positioned spaced apart overflow zones for a liquid collected above each deck and said curtain wall means from the opposing face of each rain deck is an extension of said weir means to provide opposing weir and curtain wall means at the periphery of each unblocked area.

3. The contacting column of claim 1 further characterized in that at least one superposed partially perforate rain deck is supported from a next lower partially perforate rain deck in order to provide sets of interconnected partially perforated rain decks, with the support of an upper partially perforated rain deck being from the top flange portions of laterally disposed openwork truss sections positioned therebeneath whereby lateral liquid flow between deck sections is substantially unblocked and free to pass through droplets from a dispersed liquid phase.

4. The contacting column, with the partially perforated rain deck connection system of claim 3, still further characterized in that a plurality of laterally disposed truss sections are spaced and utilized in parallel arrangement between the interconnecting sets of rain decks and the lower rain deck is sectionalized so as to have separate sections of plate supported from the lower flanges of the spaced parallel truss means, while sections forming the upper rain decks are positioned to be resting on and supported from the top flanges of said parallel and laterally disposed truss members, and opposing sections of interconnected adjacent rain decks are of a similar size and shape whereby they may be similarly fabricated and substantially interchangeable one with another.

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