June 21, 1938. L. P. EVANS 2,121,318

COUNTERFLOW APPARATUS

Filed April 28, 1937

FIG. 1.

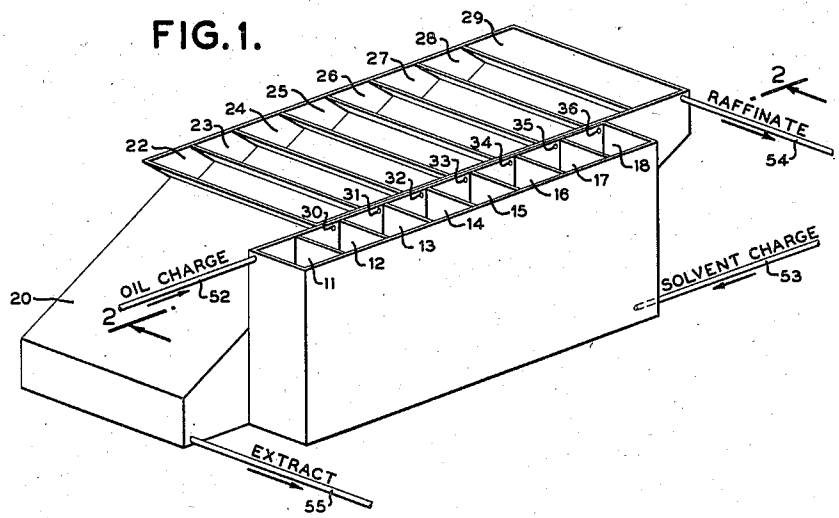
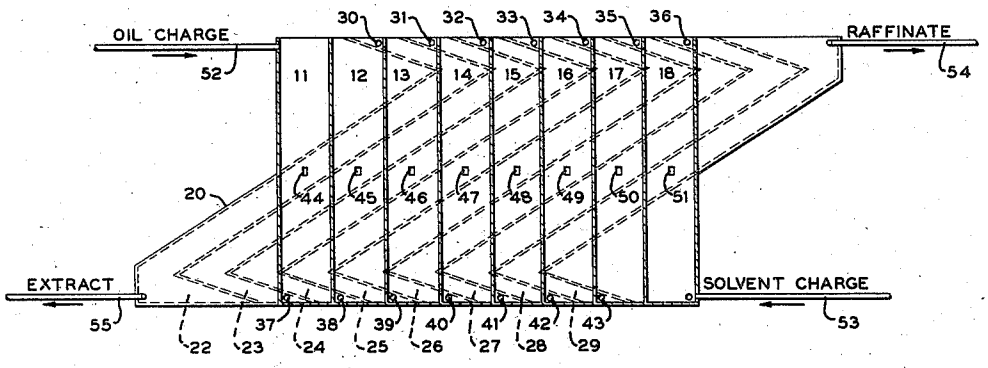


FIG. 2.



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COUNTERFLOW APPARATUS

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11 Claims. (Cl. 196—46)

This invention relates to counterflow apparatus and more particularly to such an apparatus which is applicable for use in the solvent refining of mineral oil.

In solvent refining practice it is common to admit the oil charge near the upper end of a vessel or tower and the solvent charge near the lower end, this being on the assumption, of course, that the oil charge is heavier than the solvent so that the oil will flow downwardly through the solvent which is rising through the oil. The clean oil or raffinate is drawn off at the top of the vessel while the extract is drawn off near the bottom.

The principal object of the invention is to provide a box type of counterflow apparatus having a compact arrangement of vertical mixing chambers and inclined settling chambers designed so as to obtain an increased capacity and more efficient separation of the liquids while keeping the overall size of the equipment at a minimum. The settling chambers are rectangular rather than circular in cross-section thus providing an unusually compact horizontal arrangement.

In accordance with the invention, a plurality of vertical mixing chambers are provided, as well as a corresponding number of settling chambers. Each of the settling chambers is inclined with respect to the mixing chambers so as to secure a rapid and more efficient separation than would be possible were the settling chambers arranged vertically or horizontally and of comparable size. Connections or ports between the settling and mixing chambers are so arranged that the raffinate from, for instance, No. 1 settler, will overflow while the extract from an alternate or No. 3 settler will underflow into the same vertical mixing chamber. The mixture will then flow from the center of that mixing chamber into the No. 2 settling chamber disposed between Nos. 1 and 3. This same operation takes place with the other chambers, i. e., each mixing chamber receiving the overflow and the underflow from alternate settling chambers and supplying the mixture to the settling chamber disposed between said alternate chambers.

For a better understanding of the invention, reference may be had to the accompanying drawing in which

Figure 1 is a somewhat diagrammatic isometric view of an apparatus embodying the invention, while

Figure 2 is a vertical section taken through the mixing chambers and looking rearwardly or toward the settling chambers.

Referring to the drawing, an apparatus is illustrated which includes a unit 10 comprising a plurality of mixing chambers shown as eight in number and each being numbered consecutively from the left as 11 through 18. Each of these mixing chambers is shown as rectangular in cross-section and it will be seen that a compact group or mixing unit is thus provided. Each of the mixing chambers may have mounted within it any suitable agitator or mixer, not shown, and actuated from some suitable source of mechanical power.

Disposed adjacent the mixer unit 10 is the settling unit 20 shown as comprising eight settling chambers numbered consecutively from the left as 22 through 29. As will be observed with reference to Figure 2, each of the settling chambers is rectangular in horizontal cross-section and of a Z-shape in vertical cross-section. A plurality of ports designated as 30 through 36 are provided at the upper ends of the mixing and settling chambers, these ports connecting mixing chambers 12, 13, 14, 15, 16, 17 and 18 respectively with settling chambers 22, 23, 24, 25, 26, 27 and 28. Likewise a plurality of similar ports numbered 37 through 43 are provided near the lower ends of the mixing and settling chambers, these ports connecting mixing chambers 11, 12, 13, 14, 15, 16 and 17 respectively with settling chambers 23, 24, 25, 26, 27, 28 and 29.

An additional set of ports are provided numbered 44 through 51, these ports connecting respectively the midpoints of each of the mixing chambers 11 through 18 with settling chambers 22 through 29.

The oil charge enters the upper end of mixing chamber 11 through pipe 52 and the solvent charge enters the lower end of mixing chamber 18 through the pipe 53. The clean oil or raffinate leaves the apparatus from the upper end of settling chamber 29 through the pipe 54 while the extract flows out from the lower end of settling chamber 22 through the pipe 55. As has been mentioned hereinbefore, it is assumed that the solvent charge is lighter than the oil charge and, therefore, the solvent will rise through the oil or mixture while the oil will tend to settle downwardly through the solvent mixture. Thus, in Figure 1 the raffinate will overflow from No. 22 settler into the upper end of No. 12 mixer and the extract will underflow from No. 24 settler into the lower end of No. 12 mixer. In mixer No. 12, as is the case with all of the mixing

chambers, the mixture may be stirred or agitated and in the example given will flow through the center opening 45 into the mid-portion of No. 23 settling chamber. Considering the right hand end of the apparatus, the solvent charge entering mixing chamber 18 at 53 will rise therein mixing with the overflow which has entered chamber 18 at 36 from settling chamber 28, the mixture then passing through port 51 into the mid-portion of settling chamber 29. The raffinate will then rise in settling chamber 29 and will be drawn off at 54. The extract having passed from right to left as is viewed in the drawing will settle finally in the lower portion of the settling chamber 22 to be drawn off at 55.

It will thus be seen that the separation of the two mixed phases is unique. For, instead of having to settle through a vertical column of liquid from the settler inlet to its corresponding outlet, each phase merely gravitates a fraction of that distance until it reaches the inclined surface of its settling chamber whereupon it flows along the latter to its outlet into the proper mixing chamber. The raffinate moves upwardly along the left surface of each settling chamber to form a continuous phase, then proceeds farther upwardly allowing the remaining traces of the heavier extract mixture to settle out onto the opposite right hand surface, the raffinate finally passing through the overflow port into the upper end of the following mixing chamber. The extract settles or moves downwardly in an analogous manner.

Of course, the sharp angular turns in the settling chambers could be omitted by arranging the mixing chambers as a separate battery with tube connections for each overflow and underflow into the proper settling chambers. The construction might be simplified in this manner although in all probability compactness would be sacrificed.

There are two distinct advantages inherent in this principle of settling in an inclined chamber. First, there is the considerable decrease in settling time and hence in the size of the equipment required to effect a given rate of separation of two mixed phases. This is illustrated by the following data obtained by shaking furfural-water mixtures in a glass cylinder which was held at various angles during the settling period.

Angle of settling chamber	*Settling time in seconds*
90° (vertical)	126
60°	64
45°	52
30°	46
0°	39

It is thus evident that there is a rapid decrease in settling time of the order of about 50% as the settling chamber is tilted about 40 to 50° from the vertical position with comparatively slight decrease beyond this point. The minimum settling time obtained in the horizontal position is, in this particular test, of the order of 30% of that in the vertical position. In applying this effect of inclined settling to the apparatus disclosed, the clearance between the two parallel sides of the settling chambers will be the important factor for a given degree of inclination, and this will govern the settling distance. The time allowed for settling will then depend upon the relation between the charge rates and the capacity of the settling chambers, the time being considerably reduced in contrast to that required for vertical settling chambers.

Second, there is imparted a mild rotary motion (analogous to a convection current) to that heterogeneous zone between the two clear phases, that tends to break down any "rag" or persistent liquid foam which normally defies separation in the solvent extraction of certain stocks. This motion results from the combined "drag" exerted by the downward flow of the heavier phase along one surface of the narrow settling chamber and the upward flow of the lighter phase on the opposite parallel surface. In fact, this interesting phenomenon is so pronounced in positions near the vertical, say 10 to 20° inclination, that the upward current of the lighter phase, for instance, will actually carry droplets of the heavier phase for an appreciable distance before the "spray" meets a zone of relatively little turbulence and falls again. In the vertical, and especially in the horizontal positions of the settling chamber, this effect naturally does not occur, due to the diffuse nature of the settling action.

In view of the foregoing, it is thus obvious that by choosing a suitable angle of inclination (preferably 40 to 60°), and by properly designing the settlers with respect to clearance, volume, and charge rates, it is possible to obtain both increased capacity and more efficient separation for a given size of equipment.

Obviously many modifications and variations of the invention may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated by the appended claims.

I claim:

1. In a box counterflow apparatus for the solvent refining of mineral oil, a plurality of generally vertical mixing chambers arranged in a row, a plurality of inclined settling chambers arranged at one side of said row of mixing chambers in a parallel adjacent row, the inclination of a settling chamber being such as to overlap at least three adjacent mixing chambers, and ports providing communication between said settling chamber and said three mixing chambers respectively.

2. In a box counterflow apparatus for the solvent refining of mineral oil, a plurality of substantially vertical mixing chambers arranged in a row, a plurality of Z shaped settling chambers arranged in a row parallel and adjacent said row of mixing chambers, the Z shape of each settling chamber being such as to overlap at least three consecutively disposed mixing chambers, and ports providing communication between each of said settling chambers and three of said mixing chambers.

3. In a box counterflow apparatus for the solvent refining of mineral oil, a plurality of vertically inclined settling chambers, and a plurality of adjacent vertical mixing chambers, each settling chamber having an oppositely inclined portion at the upper end thereof for the separation of raffinate and an oppositely inclined portion at the lower end thereof for the separation of extract, and ports providing communication between adjacent mixing chambers and the central portion, the upper oppositely inclined portion, and the lower oppositely inclined portion respectively, of said settling chamber.

4. In an apparatus for the solvent refining of mineral oil, a receptacle having side walls inclined with respect to the vertical, said re-

ceptacle forming a settling chamber for an oil-solvent mixture, a vertically disposed mixing chamber, means for introducing oil-solvent mixture from the mid-portion of said mixing chamber, to the mid-portion of said settling chamber, a second mixing chamber, means for passing the overflow from said settling chamber into the upper portion of said second mixing chamber, a third mixing chamber, means for passing the underflow from said settling chamber into the bottom portion of said third mixing chamber, and additional settling chambers adapted to receive the oil-solvent mixture from said second and third mixing chambers.

5. In an apparatus for the solvent refining of mineral oil, a vertically elongated receptacle comprising a mixing chamber for the oil and solvent, a receptacle having side walls inclined with respect to the vertical, said last mentioned receptacle forming a settling chamber for the oil-solvent mixture, means for introducing oil-solvent mixture from the mid-portion of said mixing chamber into the mid-portion of said settling chamber, a second settling chamber, means for passing the overflow from said second settling chamber into the upper portion of said mixing chamber, a third settling chamber, means for passing the underflow from said third settling chamber into the bottom portion of said mixing chamber, and additional mixing chambers adapted to supply oil-solvent mixture to said second and third settling chambers.

6. In an apparatus for the solvent refining of mineral oil, a receptacle having side walls inclined with respect to the vertical, said receptacle forming a settling chamber for an oil-solvent mixture, a vertically disposed mixing chamber located at one end of said settling chamber, a port connecting the mid-portions of said mixing and settling chambers, a second mixing chamber disposed at one side of said first mixing chamber, means for passing the overflow from said settling chamber into the upper portion of said second mixing chamber, a third mixing chamber disposed at the side of the first mentioned mixing chamber opposite said second mixing chamber, and means for passing the underflow from said settling chamber into the bottom portion of said third mixing chamber.

7. In an apparatus for the solvent refining of mineral oil, a receptacle having parallel side walls inclined with respect to the vertical, said receptacle forming a settling chamber for an oil-solvent mixture, a vertically disposed mixing chamber located at one end of said settling chamber, a port connecting the mid-portions of said mixing and settling chambers, a second mixing chamber disposed at one side of said first mixing chamber, means for passing the overflow from said settling chamber into the upper portion of said second mixing chamber, a third mixing chamber disposed at the side of the first mentioned mixing chamber opposite said second mixing chamber, means for passing the underflow from said settling chamber into the bottom portion of said third mixing chamber, a second settling chamber disposed at one side of said first mentioned settling chamber, a port connecting the mid-portions of said second settling chamber and said second mixing chamber, a third settling chamber disposed at the side of the first mentioned settling chamber opposite said second settling chamber, and a port connecting the mid-portions of said third settling chamber and said third mixing chamber.

8. In an apparatus for the solvent refining of mineral oil, a receptacle having parallel side walls inclined with respect to the vertical, said receptacle forming a settling chamber for an oil-solvent mixture, a vertically disposed mixing chamber located at one end of said settling chamber, a port connecting the mid-portions of said mixing and settling chambers, a second mixing chamber disposed at one side of said first mixing chamber, means for passing the overflow from said settling chamber into the upper portions of said second mixing chamber, a third mixing chamber disposed at the side of the first mentioned mixing chamber opposite said second mixing chamber, means for passing the underflow from said settling chamber into the bottom portion of said third mixing chamber, a second settling chamber disposed at one side of said first mentioned settling chamber, a port connecting the mid-portions of said second settling chamber and said second mixing chamber, a third settling chamber disposed at the side of the first mentioned settling chamber opposite said second settling chamber, a port connecting the mid-portions of said third settling chamber and said third mixing chamber, means for introducing oil to be treated into the upper end of said third mixing chamber, means for introducing solvent into the lower end of said second mixing chamber, means for conducting the raffinate from the upper end of said second settling chamber and means for conducting the extract from the lower end of said third settling chamber.

9. In a box counterflow apparatus, a plurality of vertical mixing chambers disposed in a line, a corresponding number of settling chambers having walls inclined with respect to said mixing chambers and disposed in a line and parallel to and adjacent said mixing chambers, with the mid-point of each of said mixing chambers opposite the mid-point of an associated settling chamber, a center port connecting the mid-point of each mixing chamber with the mid-point of its associated settling chamber, means for admitting a liquid to be treated to the upper end of the mixing chamber at one end of said line, means for admitting a treating liquid to the lower end of the mixing chamber at the other end of said line, ports connecting the upper and lower ends of said mixing chambers respectively with the upper and lower ends of said settling chambers, the arrangement being such that each mixing chamber will receive through said upper and lower ports the overflow and underflow respectively from alternate settling chambers while supplying through its center port the liquid mixture to that settling chamber disposed between said alternate settling chambers.

10. In a box counterflow apparatus for the solvent refining of mineral oil, a plurality of vertical mixing chambers disposed in a series along a straight line, a corresponding number of settling chambers having parallel side walls inclined with respect to said mixing chambers and disposed in a line in parallel to and adjacent said mixing chambers, with the mid-point of each of said mixing chambers opposite the mid-point of an associated settling chamber, a center port connecting the mid-point of each mixing chamber with the mid-point of its associated settling chamber, means for admitting oil to be treated to the upper end of the mixing chamber at one end of said series, means for admitting solvent to the lower end of the mixing chamber at the

other end of said series, and ports connecting the upper and lower ends of said mixing chambers respectively with the upper and lower ends of said settling chambers, the arrangement being such that the oil-solvent mixture will enter the mid-section of each settling chamber from the mid-section of the associated mixing chamber whereupon the lighter and heavier constituents of said mixture will move respectively upwardly and downwardly along the inclined walls of said settling chambers and will enter the mixing chambers disposed at either side of said associated mixing chamber.

11. In a box counterflow apparatus for the solvent refining of mineral oil, a plurality of vertically elongated receptacles forming mixing chambers, a plurality of receptacles having parallel side walls inclined with respect to said mixing chambers and forming settling chambers, the mid-point of each of said settling chambers being disposed opposite and at substantially the same level as the mid-point of one of said mixing chambers, a port connecting the mid-point of each mixing chamber with the mid-point of a corresponding settling chamber, a port connecting the upper end of each mixing chamber with the upper end of one of said settling chambers, a port connecting the lower end of each of said mixing chambers with the lower end of one of said settling chambers, means for admitting oil to be treated to the upper end of one of said mixing chambers, and means for admitting solvent to the lower end of another of said mixing chambers, the arrangement being such that the oil-solvent mixture will flow through said ports at the mid-points of said mixing chamber into the middle of said settling chambers whereupon the lighter and heavier constituents will flow respectively upwardly and downwardly in said inclined settling chambers and through the ports in the ends of said chambers into mixing chambers disposed alternately adjacent to the mixing chambers which supplied the mixture to said settling chambers.

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