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 [21] Appl. No. **733,851**
 [22] Filed **June 3, 1968**
 [45] Patented **Sept. 29, 1970**
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[54] EVAPORATOR TUBES

4 Claims, 6 Drawing Figs.

[52] U.S. Cl. 159/13,

159/28, 138/177, 165/146

[51] Int. Cl. B01d 1/100,

F16i 9/100, F28f 13/08

[50] Field of Search..... 159/270,

28VHS, 28, 27; 122/367C; 165/146, 147, 172;

138/177; 165/177; 159/13A; 202/236; 203/89

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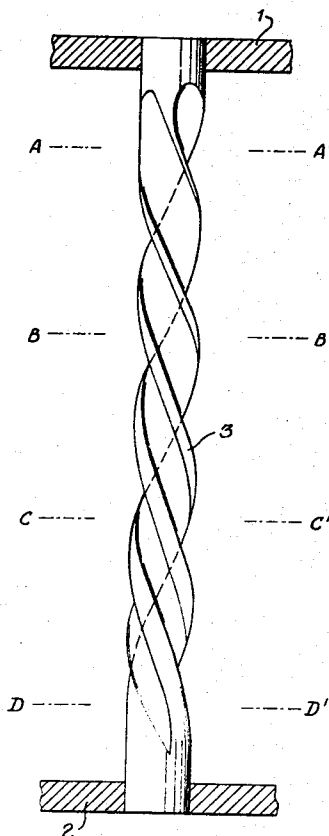
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ABSTRACT: An evaporator tube is helically creased to form channels within the tube which increase in cross section from one end of the tube to the other. This produces a swirl in the liquid flowing through the tube and the centrifugal force of which presses the liquid into good heat exchange with the tube wall. The vaporized liquid has a uniform velocity through the tube.



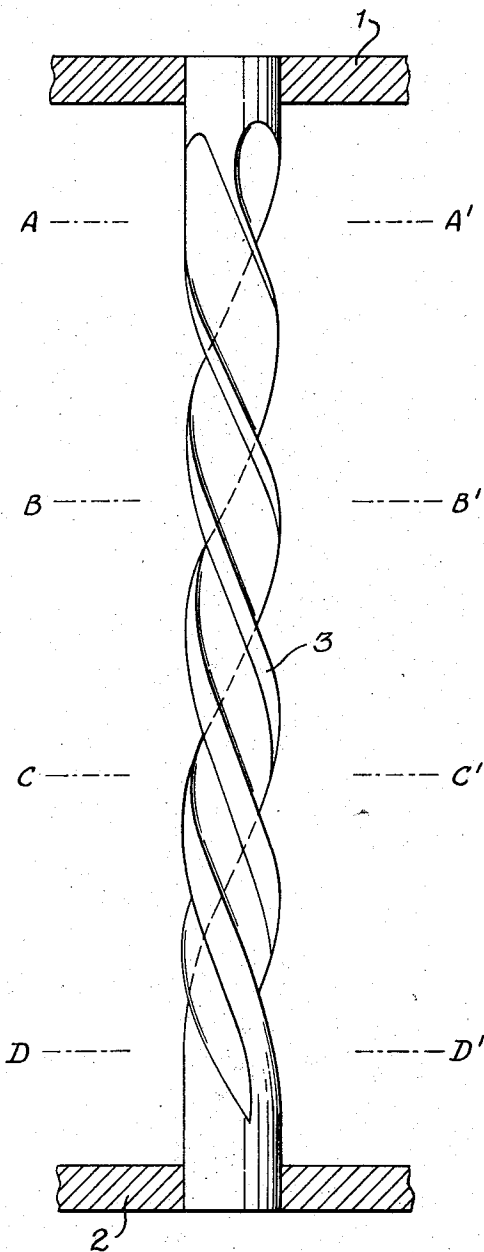


Fig. 1

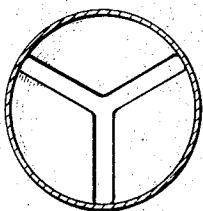


Fig. 2

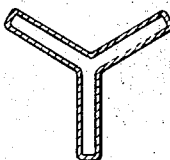


Fig. 3

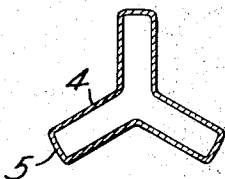


Fig. 4

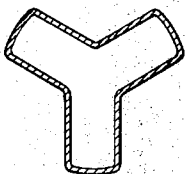


Fig. 5

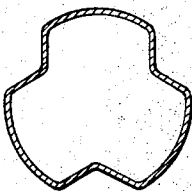


Fig. 6

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EVAPORATOR TUBES

In evaporators, the heating surfaces are preferably the walls of tubes which are usually pressed in or welded to tube header plates. The header plates are contained in a housing so that the outside surfaces of the tubes can be heated by steam, for example, while the liquid being vaporized is flowing through the tubes.

In simple heating tubes through which the liquid flows, it is not possible to obtain a uniform and satisfactory heat transfer throughout the length of the tube. This is because, for example, in downflow evaporators the liquid flowing downwardly through vertical tubes contacts the interior walls of the tubes at first very slowly and irregularly as a result of which the upper portions of the tubes become covered with dirt and scale because they are over heated. After evaporation starts, the liquid in the tubes is pushed by the vapor formed into the center of the cross section of the tubes and flows toward the lower end of the tube so that a portion of the liquid no longer contacts the heating surface of the wall of the tube. This results in that the amount of liquid which has contacted the heating surface is partially overconcentrated and precipitates scale on the inner walls of the tubes.

In upflow evaporators in which the liquid being vaporized forms from the bottom to the top of the tubes, only a slight heat transfer occurs within the area of any liquid level because there is, as a rule, only a weak and laminar flow of liquid in the tubes. In the tube area where the liquid is transported upwardly by vapor bubbles, the heat transfer is substantially higher. The middle value of heat transfer is therefor limited in these tubes because of the unfavorable conditions at the intake sides of the tubes. Dirt and scale formation is also especially great in the lower portions of the tubes.

In an evaporator having horizontal tubes, it is almost completely impossible to achieve a uniform wetting of the interior walls of the tubes by the liquid being vaporized.

It is customary to keep the gases and vapors rotating in an evaporator by means of rotating inserts. Such inserts which are driven by an outside mechanical power source are too expensive for the purpose of this invention.

Attempts have been made to rotate the liquid and vapor in the tubes by means of rigidly fixed baffle elements within the tubes. However, the amount of liquid entering the tubes in a downflow evaporator and an upflow evaporator is very low and the velocity of the vapor is still so low that the desired rotating effect is not obtained and only to a small extent if it is. Because in an evaporator in which inserts are used at the intake of the heating tubes for producing a swirl 90 percent or more of solvent is evaporated behind the torque producing inserts, it is impossible to maintain a rotation of liquid and vapor which extends throughout the length of the tubes.

Inserts extending throughout the entire length of the tubes have been used and which force a rotation of the steam in the tube by means of screw-like spirals or coils. Such inserts have a larger wettable surface than the heating surface of the tubes. Since the inserts have no part in the heat exchange, a large portion of the liquid flowing through the tubes is used for wetting the surfaces of the inserts without having a chance to be vaporized. It is therefore necessary to concentrate to a higher degree that portion of the liquid which is conducted on the heating surface through the heating tubes so that the desired degree of concentration is obtained by the tube portion which has not been obstructed after the mixing takes place. This operation, however, leads to increased dirt and scaling of the heating surfaces and thus to a lower heat transfer value. Also, the cost for the inserts far exceeds the cost of the tubes alone.

The object of this invention is to avoid the above disadvantages. In this invention, the evaporator for liquids containing tubes heated from the outside is formed so that the liquid and steam flowing through the tubes is rotated. The tubes in this invention have helical creases which extend throughout the lengths of the tubes and form channels which increase in cross-sectional area along the tube.

In this invention, it has been found that the liquid and steam in the tubes is forced to rotate because of the channels formed by the creases. As the cross sectional area of the channels increases in the direction of the flow of the liquid and the mixture of liquid and steam, more favorable flow conditions are obtained at each point along the length of the tube and optimum heat transfer values are obtained when the increase in cross section is such that a constant steam velocity is maintained throughout the entire tube length. This achieves a completely uniform wetting by the liquid of the inner tube wall and damaging overheating of the liquid and formation of scale on the heating surface is avoided. Also, because of the favorable heat transfer values, it is possible to use smaller tubes than conventional tubes and still obtain the same evaporation capacity.

This invention starts with customary smooth tubes having an absolute uniform inner diameter and then to press them to form creases or other similar indentations in the tube walls along the longitudinal length of the tubes so that the cross section of each tube is enlarged in a longitudinal direction while for all practical purposes the tube has a uniform circumference. Usually it is preferred to form three or four helical creases around the tube. However, it is possible to use four or more creases. It is also possible that the tube can merely be crushed on two opposite sides so that a helical path is formed within the tube whose cross section increases in the longitudinal direction of the tube.

The torque, twist and/or velocity of rotation of the mixture of liquid and steam is determined by the pitch of the creases, grooves or other indentations which wind around the tube. Generally, it has been found that the creases which complete a 360° circle from one end of the tube to the other are usable. However, it is possible to make the creases so that they complete a 360° turn in one-fourth of the tube length.

The evaporator tubes of this invention can be used with good results in vertical, horizontal or even inclined tube arrangements and fitted into the tube header plates in a conventional manner. When the tubes are vertical or horizontal, it is possible to introduce the liquid to be vaporized either from the tops or the bottoms of the tubes, and in each case the liquid is introduced into the ends of the tubes having the smallest area cross section.

Preferably, the ends of the tubes have a circular cross section in order to fit them into the tube header plates. Thus the ends of the tubes are not creased. This is accomplished by starting the creasings spaced from the ends of the tubes so that the ends of the tubes are of circular cross section, with the length of the tube therebetween being progressively creased.

The torque, swirl or rotating movement given the liquid and vapor flowing through the tubes and, at the same time, the volume of steam produced is taken into account by increasing the cross-sectional areas of the tubes in the longitudinal direction of the tubes. The turbulence of flow is enhanced by the rotary movement of the mixture of liquid and steam. The centrifugal force produced by the rotation throws the liquid droplets back onto the tube wall heating surface again and again which guarantees a satisfactory wetting of the tube wall and a continuous intimate mixing of the liquid being evaporated on the heating surface. Optimum operational conditions and heat transfer values are obtained when the cross-sectional area of the tubes is enlarged in the longitudinal direction in such a way that under predetermined operational conditions a uniform velocity of steam is produced throughout the entire tube length.

The means by which the objects of the invention are obtained are described more fully with reference to the accompanying drawings in which:

FIG. 1 is a front view of an evaporator tube having three creases;

FIG. 2 is a top plan view of FIG. 1; and

FIGS. 3 to 6, respectively, are cross-sectional views taken on the lines A-A', B-B', C-C' and D-D' in FIG. 1.

As shown in FIG. 1, the evaporator in a downflow apparatus has tube header plates 1 and 2 between which is the evaporator tube 3. Helical convolutions or creases 4 are formed substantially throughout the length of the tube of increasing depression. Lands 5 remain at a constant radial distance from the tube axis throughout the length of the tube following the formations of the convolutions. The liquid being vaporized enters tube 3 from the top and the tube is heated on its outer surface by a suitable heating medium. The circular upper end of the tube 3 is pressed into header plate 1. Below the header plate, the tube has three creases. These creases form the three-corner shape seen in FIG. 2 immediately beneath header plate 1. The creased tube has a circumference of the same size as the end of the tube. FIG. 3 shows the cross section on line A-A'. The cross-sectional area of the channels in the tube amounts to only a fraction of the original cross section of the tube. The creases extend helically around the tube in such a manner that the cross-sectional area of the interior of the tube increases from top to bottom. In FIG. 4, taken on line B-B', the cross sectional area of the channels in the tubes has increased to one-fourth of the original tube cross section. In FIG. 5, the section taken on the line C-C' has a cross-sectional area which is one-half of the original tube cross section. FIG. 6, taken on line D-D', has a cross-sectional area three-fourths of the original cross-sectional area of the tube. The creases fade out adjacent the lower end of the tube and the tube retains its original circular cross section. The lower end of tube 3 is pressed into the lower header plate 2.

In a downflow evaporator having three helical creases, a liquid having a 20 percent dry content is evaporated during a once-through passage through the tubes at a vaporizing temperature of 60°C and a heating steam temperature of 75°C to a 50 percent dry content. The throughput through a tube 4 m in length amounts to 36.7 kg per hour with a 20 percent dry content. The heat volume value is 2,000 kcal./m²h°C. The tube having an original diameter of 32 mm has the following cross-sectional areas after being creased:

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Cross-sectional area of tube at $\frac{1}{4}$ length of tube, approx. 200 mm.²

Cross-sectional area of tube at $\frac{1}{2}$ length of tube, approx. 400 mm.²

Cross-sectional area of tube at $\frac{3}{4}$ length of tube, approx. 600 mm.²

With a total evaporation per tube per hour of 21.8 kg at all points of the tube below the cross-sectional area of 200 mm², there is achieved a uniform steam velocity of 58 m/sec. Inasmuch as the creases have formed a 360° circle at a point one-fourth of the length of the tube, the vapor in the tube rotates at approximately 3.48 r.p.m. The liquid, because of the centrifugal force produced, is pushed onto the inner wall of the tube by a force which is 37 times that of its own weight.

I claim:

1. In an evaporator for evaporating liquids comprising header plates, evaporator tubes extending between said plates, and means for heating said tubes, the improvement in which each tube has a constant circumference and a plurality of continuous helical creases in the tube walls extending longitudinally around the tube and forming channels within the tube interior which increase in cross-sectional area from the feed end of the tube to the discharge end of the tube, the outermost surface of the channels having lands which are the original surface of the tube.

2. In an evaporator as in claim 1, said channels being increased in cross-sectional area by amounts to produce a uniform velocity in the vapors evaporated and flowing through the tube.

3. In an evaporator as in claim 2, further comprising uncreased ends on said tube.

4. In an evaporator as in claim 3, said tube having at least three creases.

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