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EVAPORATOR STRIPPER AND FRACTIONATOR

Filed Jan. 31, 1963

FIG. 1

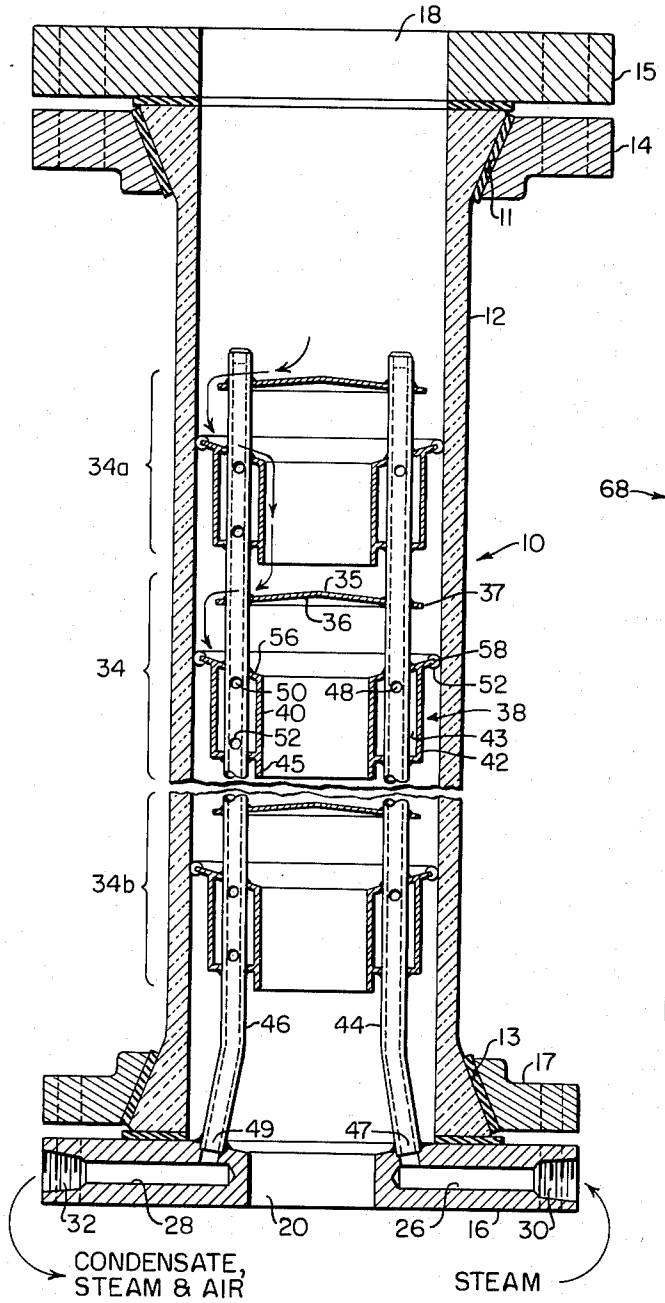
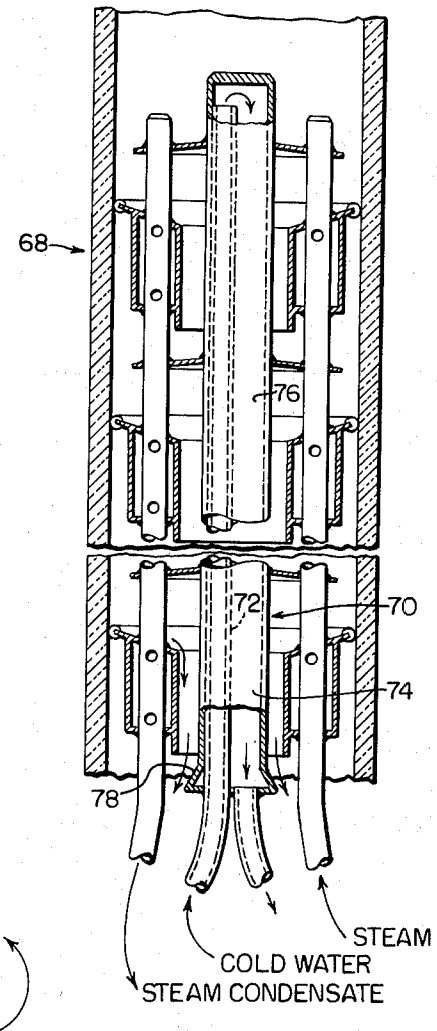


FIG. 2



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EVAPORATOR STRIPPER AND FRACTIONATOR

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The present invention relates to an apparatus adapted to and a method for removing relatively volatile materials from a relatively non-volatile fluid. In particular, the instant invention relates to an improved liquid-vapor evaporator-stripper in which a heat exchange fluid is placed in a heat exchange relationship with a falling thin film liquid surface.

Evaporators in which a relatively volatile material, such as a relatively volatile or low boiling liquid are removed from relatively non-volatile fluids such as a relatively high boiling liquid include both the falling film and the climbing film types. In evaporators known as the vertical tube and disc type, fluid material is introduced into an upper inlet and allowed to cascade over a heated series of tubular jackets and horizontally disposed discs with the relatively non-volatile material removed from a lower outlet and the relatively volatile material, that is the vapors, removed at an upper level.

In this type of apparatus a thin film of a fluid material is continually formed and re-formed on the internal vertical surfaces of the tubular jacket, while a heat exchange fluid is placed in heat exchange relationship with the disc the jacket and the intervening space between these components. Commonly these tube and disc vertical evaporators comprise a convoluted series of tubes and discs axially arranged in vertical fashion, so that the fluid material may be introduced at the top, and the heat exchange fluid at the bottom. However, these devices are not entirely satisfactory for many purposes. In particular these convoluted heat insulated tube and disc jacketed devices are difficult to disassemble for cleaning and inspection purposes. This is especially true wherein the insulating jacket or the heat exchange fluid containing jacket follows the convolutions of the multitude of tubes and discs incorporated in the unit. Additionally, in many of these devices the entire evaporator is placed in a heat exchange relationship with the heat exchange fluid.

In those areas where there is no uniform continuous liquid film formed such as on the disc on which the fluid material from vertical walls of the next higher tube jacket is dropping this arrangement frequently gives rise to hot spots or dry spots which are particularly disadvantageous for heat sensitive materials, such as in the concentration of pharmaceutical or food products.

It is therefore an object of this invention to provide an improved apparatus for the efficient heat exchange treatment of thin film fluid materials. Another object is to provide an evaporator which is adapted to be easily removed for cleaning and inspection purposes. A further object of this invention is to provide an improved evaporator for the treatment of heat-sensitive materials. A still further object is to provide an evaporator wherein the heat exchange fluid is placed in a direct heat exchange relationship with the vertical falling thin film layer. Yet another object is to provide an improved continuous process of concentrating liquids wherein heat is applied only to a relatively uniform continuous vertical-falling thin film.

An additional object is to provide an improved apparatus and process wherein fluid material may be fractionated with a low pressure drop.

Still further objects of this invention will be apparent to those skilled in the art from the foregoing description of the invention and the accompanying drawing.

There has now been discovered an apparatus and a method wherein a fluid material is cascaded over a series of tubes and discs yielding a continual disruption of the vertical liquid film on the internal surface of the tube jacket in the vertical fall path after relatively short vertical distances, and in which heat is supplied only to the continuous vertical relatively-thin liquid film phase. In this manner heat is conserved, hot and dry spots on the disc surface are prevented, and the ease and efficiency of handling heat-sensitive material is enhanced. The placing of the heat exchange fluid in a heat exchange relationship primarily with the thin film phase on the internal side of the tube permits the more efficient concentration and evaporation of materials. This improvement permits the thin film phase to be continuously disrupted by a relatively cool surface, the disc, and to be continuously reformed on a relatively hot surface, the internal surface wall of the tube jacket. Further, it has been found that the incorporation of a central cooling unit in the above-described apparatus and method promotes rapid evaporation, stripping and distillation in a single operation and apparatus without excessive pressure drop thereby effecting rapid and efficient fractionation of the inflowing fluid feed material.

The process of this invention which is useful for the evaporation, fractionation and concentration of fluids in its broader aspects comprises: introducing a fluid feed stream into a heat exchange zone; permitting the feed material to fall through a series of relatively hot tube and relatively cool disc units vertically and spatially separated thereby creating a free falling thin film continuous surface on the internal surface of the tube, which film is continuously disturbed by the relatively cool lower disc surface and again reformed on the lower relatively hot tube surface; and placing the heat exchange fluid in a heat exchange non-contact relationship with the continuous vertical falling film surface; and thereafter upwardly and axially removing vapors from the top of the heat exchange zone while removing the concentrated fluid from the bottom of the heat exchange zone. The fluid material employed in the process may of course comprise a liquid-solid slurry, a liquid-gas mixture or a liquid mixture of miscible or non-miscible material.

The invention will be more readily understood from a description of the apparatus and the drawing wherein:

FIGURE 1 is a cross-sectional broken axial view of one embodiment of the inventive apparatus wherein a heat exchange fluid is placed in a non-contact heat exchange relationship with the vertical liquid falling film surface; and

FIGURE 2 is a partial cross-sectional axial view of another embodiment of the apparatus wherein a centrally located longitudinally disposed cooling tube is disposed within the inventive apparatus.

In FIGURE 1, there is shown a falling film evaporator apparatus 10 according to the invention which comprises in combination an external tubular container insulating jacket 12 composed for example of thermal shock resistant glass pipe which may be optionally heat insulated having a flanged upper 11 and lower 13 end adapted to fit and be

securely and firmly held by two opposing upper 14 and 15, and two opposing lower 16 and 17 base section flange plates. The upper base plates are securely bolted to the outlet of a fluid discharging apparatus such as a vapor-liquid separator, slurry tank etc. (not shown) and are characterized by a fluid feed inlet opening 18 in fluid communication with the outlet whereby the fluid feed material comprising a relatively non-volatile and a relatively volatile material may be introduced into the apparatus 10. The lower base plate 16 is characterized by a centrally located fluid outlet opening 20 through which opening the relatively non-volatile material or the concentrated material is gravity discharged from the evaporator apparatus 10 commonly to a fluid receiving apparatus, such as a liquid receiver vessel (not shown). Both the upper and lower plates 15 and 16 are secured by bolts or other fastening means to the corresponding upper 17 and lower 14 collar plates surrounding the upper 11 and lower flanges 13 of the external jacket 12. The lower base plate is further characterized by a horizontal radially disposed heat exchange inlet conduit 26 and a heat exchange outlet conduit 28 having threaded externally disposed ends 30 and 32.

Vertically disposed and axially aligned within the longitudinal external jacket 12 are a series of disc and tube evaporating units 34, 34*a*, 34*b* etc. which units are vertically positioned one above the other, the number of units being a matter of choice depending upon the particular processes in which the equipment is to be used and the complexity and extent of evaporation or concentration of the fluid feed material desired. These units are preferably so vertically and spatially separated so that the free flowing cascading fluid material gravity or pump fed to the inlet 18 is continuously formed and re-formed into a vertical, continuous relatively thin, uniform liquid film surface after a relatively short vertical distance such as about every two to six inches e.g. every 2 to 4 inches. In this manner of disposition the most efficient use is made of the vertical thin film surface, since the majority of heat transfer in thin film liquid evaporation takes place during the first one or two or so inches of the liquid film formation in gravity feed evaporators.

The tube and disc units such as shown by intermediate unit 34 each comprise in combination: a circular, convexed, horizontally disposed disc plate 36 having a centrally located relatively high portion or apex 35, which gradually slopes to the lower peripheral edge 37 of the plate, and a tubular jacketed chamber 38 having relatively vertical internal and external walls 40 and 42 respectively. The fluid confining portion or space 43 between the spatially separated internal and external walls forming a jacket of predetermined volume and design for the introduction, circulation and withdrawal of a fluid heat exchange medium.

The internal wall has a peripheral lower lip 45 protruding slightly below heat exchange fluid space 43 in order to permit the free fall of a liquid film from the internal wall 40 surface to the next lower disc. Providing fluid communication and support between the axially disposed series of tubular jackets 38, are vertically disposed inlet and outlet tubular risers or conduits 44 and 46 respectively opposingly disposed and having lower inlet and outlet ends 47 and 49 connecting to conduits 26 and 28 respectively. These risers pass through and provide support and fluid communication between the axially disposed heat exchange fluid spaces of each successive tubular jacket. In the lowest or first tube and disc units 34*b*, the inlet and outlet risers provide fluid communication between the heat exchange inlet conduit 26 and the internal heat exchange fluid cavity of the first tubular jacket and between the heat exchange fluid outlet conduit 28 and the heat exchange fluid cavity of the tube. This permits the introduction of a heat exchange fluid into the heat exchange cavities and the withdrawal of that fluid from the outlet conduit. In the upper or last units 34*a* the risers are sealed at the upper ends. The fluid heat exchange medium employed to provide heat to the tubular jackets and thus in a direct non-contacting manner to the continuous vertical thin film formed on the internal wall surface may be a liquid, such as water, oil etc., or gases, such as air, hot combustion gases, steam, or the like.

The inlet riser 44 is characterized by an inlet opening 48 located in the upper wall portion of the tubular riser within the jacketed tube 38 thereby permitting the heat exchange fluid to be introduced from riser 44 into and circulate about the internal heat exchange fluid space 43. The outlet riser 46 is characterized by an upper and lower opening 50 and 52 in the wall portion of the tubular riser within the jacketed tube 38. The upper opening serves as a purge opening for non-condensible fluids such as air in steam, while the lower opening is located at a height slightly above the base of the jacketed space 43 to permit any condensible fluid such as the steam condensate to drain from the jacketed space and be withdrawn with the cooled heat exchange fluid through the outlet conduit 28. The number, size, type, frequency and location of the openings depend on the particular heat exchange fluid employed and the process requirements of the apparatus. The openings should have as a minimum an upper inlet opening in the inlet riser and lower drain outlet in the outlet riser. In some applications the diameter of the inlet opening within each tube may be varied, increasing with increasing vertical distance from the fluid inlet conduit 26, thereby in the case of steam permitting the more even distribution of the steam to each unit in the jacket. Of course the disposition of the openings within each tube jacket may be the same or different depending upon the particular problems at each level of the operation.

The upper portion of the tubular disc or jacket 34 is closed and circumferentially surrounded with a convexed, inwardly dished, open centered flange 56 so adapted and disposed to permit the gravity flow of a fluid from the relatively high peripheral edge of the flange toward the lower end of the dished central portion which meets and joins the internal wall of the tubular disc, thereby permitting fluid material falling on the outer edges of the dished flange to move toward the central portion and to form a thin downwardly moving vertical fluid film on the internal wall of the tube jacket 40. This flange 56 has a circumferential external protruding lip edge 58, which is provided with a tubular sealing gasket 52 to firmly seal each disc and tube unit within the external jacket 12, provides lateral support to each unit, and directs the flow of any condensed material to the internal walls of the jacket. This arrangement also permits the rapid slidable removal of the disc and tube units from the cylindrical jacket for cleaning purposes.

In between each tubular jacket 34, and preferably intermediately thereof, are located the convexed discs 36, etc., whose peripheral edges 37, etc., extend beyond the internal wall of the tube unit below so as to permit fluid material falling on the relative cool disc surface to flow by gravity feed to the outer edges and then fall to the inwardly dished flange of the next lower tube unit. The apparatus then in effect comprises a series of annular shaped tubular jackets the internal cavities thereof in fluid flow interconection by a series of two or more vertical tubular risers for the introduction and withdrawal of a heat exchange fluid with a series of one or more discs spatially inter-disposed between the tubes. This provides an apparatus whereby a heat exchange fluid may be introduced into the cavity of the jackets through the tubular risers to provide heat to the thin film liquid, vertically formed on the internal walls of the tubes and avoids directly heating the discs.

In the embodiment described the discs are dished, however, these discs which furnish a liquid reforming means on a relatively cool horizontal surface can be coned, flat, cupped or of other design.

In the operation of the apparatus just described fluid feed material comprising a relatively volatile and a relatively non-volatile material, for example, a miscible solution of a high boiling liquid having a boiling point of more than 212° F. and a low boiling liquid having a boiling point of less than 212° F. is pumped or gravity fed, or otherwise introduced into the top feed opening **18** of the evaporator apparatus **10**. At this time, depending upon the temperature desired and the material to be stripped, a heat exchange fluid such as steam, is introduced into the inlet conduit **26** where it flows upwardly in a countercurrent direction to the feed material through the tubular inlet riser **44** to the internal jacketed cavity of the first tube and disc unit and hence to succeeding tube and disc units through openings **48**, etc., while the steam that condenses during the heat exchange operation is allowed to drain out through drain openings **52**, etc., and the outlet conduits **46** and **28**. The feed material introduced will cascade over the multiple tube and disc units within the jacket. Falling initially on the upper disc **36** the liquid material then drains off the relatively cool disc falling through a vapor space or free fall zone of predetermined vertical distance which depends on the size of the unit but which can be 1 to 4 inches, to the dished flange **56** of the lower tube **38** from where it drains by gravity to the internal wall **40** surface and forms a continuous vertically-disposed thin liquid film over the internal wall of the tube. This film is thus placed in a non-contact heat exchange relationship with the steam within the internal tube jacket **43**. This arrangement permits the heat to be applied only to the vertically disposed thin film areas wherein the film is moving in a free falling vertical position.

This construction and method inhibits the application of direct heat to the relatively cooler disc surface containing a discontinuous and disturbed liquid surface or to the vapor or fall zone containing a mixture of vapor and fluid droplets, thereby preventing hot spots or overheating of any heat-sensitive material. From the internal wall surface **40** of the tube **38** the material drops to the next succeeding disc. In this arrangement the fluid feed material is continually formed and re-formed into a vertical continuous thin film on the relatively hot wall surface with the more concentrated fluid or liquid material removed from the bottom portion of the heat exchange unit through opening **20** and with the volatile vapors swept upwardly and axially through the evaporator, and removed through the feed inlet opening **18** into a vapor receiving apparatus such as a condenser.

The apparatus of this invention can be operated under atmospheric or reduced pressure by applying a vacuum pump or other source of reduced pressure at the vapor outlet **18**, or the apparatus can be operated under pressures such as from 1 to 100 atmospheres or even higher. All of part of the apparatus described can be composed of metal such as steel, or Pyrex glass or the usual materials of which falling film evaporators are constructed such as with the employment of heat conductive materials for the tubular jacket.

The apparatus will find particular utility in high vacuum stripping operations, since the apparatus permits a very low pressure drop, high efficiency, low hold up time, higher loading and flooding rates and combines both the stripping operation with an evaporation step. This evaporator is particularly useful for recovering chlorinated hydrocarbons from relatively non-volatile contaminates, for concentrating salt solutions, for removing inhibitors and volatiles from liquid organic polymer solutions, for the concentrating hydrocarbons, plasticizers, glycerines, fatty acids, for the treatment of heat sensitive material like vitamins, deodorizing, desolventizing and the like.

As described, the fluid heat exchange medium has been employed in a counter-current flow of circulation relationship with the incoming feed material, but of course it is recognized that the fluid heat exchange medium may be introduced co-current with the inlet feed material.

The apparatus of FIGURE 1 thereby differs particularly from conventional equipment in that the falling liquid film is continuously re-formed on both relatively hot and relativity cool surfaces, that is, on the heated vertically disposed surface and on the non-heated disc horizontally inclined surfaces. This arrangement permits the rapid concentration of the non-volatile mateerial.

In FIGURE 2 of the drawings there is shown a partial cross sectional view of a modified thin film evaporator apparatus as described in FIGURE 1 as a fractionating apparatus **68** with the addition of a centrally located longitudinally disposed bayonet type central cooling tube **70** comprising a center inlet **72** and an outlet **74** conduits for the introduction and withdrawal of a heat exchange fluid such as cold water. In this arrangement the circular central tube **70** provides an external relatively cool wall surface **76** parallel to and spatially separated from the internal wall surface of each tubular jacket unit, **43**, while the central tube also provides additional support and contact with each disc. This arrangement enhances the thermal or temperature differential between the relatively hot tube and relatively cool disc components by means of conductive heat transfer contact between the disc and the supporting central cooling tube. Thus where the disc is composed of a heat conductive material, such as a metal in contact with the central cooling tube, a predetermined greater discrepancy between the vertically disposed heated relatively high temperature internal wall surfaces of the internal walls of the tube and the horizontally inclined cooled relatively low temperature surface of the disc is provided. The lower portion of the center tube located at or near the outlet **20** is outwardly flanged at **78**. As shown both the center inlet and outlet conduits **72** and **74** are situated at the lower end of the apparatus. However, the outlet and inlet conduits of the central tube may be located at either or both ends of the apparatus. The relatively low temperature fluid can be introduced and withdrawn through conduits in the base plates as in FIGURE 1 or be separate from the apparatus for greater flexibility.

This particular embodiment of the invention permits the conversion of the evaporator to a more efficient fractionator. In the operation of the fractionator apparatus **68** a heat exchange fluid e.g. steam at a relatively high temperature is supplied to the internal cavity of the tubular jacket cavity **43**, thereby providing a relatively high temperature relatively hot internal wall surface peripherally surrounding a center tube unit **70**. The center tube unit **70** is provided with a heat exchange fluid having a relatively low temperature, e.g. cold water thereby providing a relatively low temperature relatively cool parallel external wall surface **76**. The quantitative thermal difference in temperature between these vertical wall surfaces as well as what wall surface has the higher temperature depends upon the type and operation of distillation and fractionation being accomplished and which vertical surface is to be used for condensation.

In the operation of this apparatus the feed material, for example, a fluid or a liquid solution to be fractionated is introduced into the feed inlet **18** of the apparatus where it cascades down in a free falling manner through the apparatus as described in the evaporator **10** of FIGURE 1. However, in this embodiment the temperature of the fluid heat exchange medium such as steam supplied to the tubular jacket is regulated to provide evaporation from the heated internal vertically disposed surface of the jackets, while the fluid heat exchange medium temperature, such as cold water, is selected in the central internal cooling tube **70** to provide condensation on that tube surface **76**

of some of the volatile material evaporated from the tubular jacket surface 43 thereby affecting a separation of some of the lower boiling volatile materials. The non-condensed vapors of the relatively volatile material removed upwardly as in the evaporator of FIGURE 1. This process accomplishes fractionation with an extremely small pressure drop and will therefore find particular usage where high vacuums are used and low pressure drops are desired.

There has thus been described an improved evaporator so constructed to provide heat to the vertical thin film surface and to refuse heat to the horizontal surface thereby creating a reformation of gravity flow material on both relatively cool and hot surfaces and also avoid difficulties associated with conventional evaporators. Further there has been described a means to convert the improved evaporator of my invention or a conventional evaporator into a more efficient fractionator through the use of a longitudinal cooling surface. This surface thereby creates within an evaporator horizontal and vertical surfaces in each disc and tube unit having an enhanced thermal differential. This improvement permits the fractionation of liquids with a small pressure drop in the process.

What is claimed is:

1. An evaporator for the separation of a relatively volatile material from a relatively non-volatile material which evaporator comprises in combination:

an elongated outer housing having at the one end an inlet opening to introduce fluid material to be evaporated and to remove volatile material, and at the other end a discharge opening to remove non-volatile material, the housing containing therein a plurality of alternating discs and tubular jackets axially disposed and spatially separated within the housing;

the discs positioned transverse to the flow of material through the housing and shaped to direct the flow of fluid material thereon toward the outer peripheral edge of each disc;

the tubular jackets characterized by an enclosed tubular cavity having a substantially vertically disposed circumferential inner wall surface of sufficient vertical length that a majority of the heat transfer to the mixture to be separated occurs on this surface and of less internal diameter than the disc directly below the tubular jacket, the jacket having an inwardly dished relatively short flange about its upper circumference, the outer peripheral lip of the flange extending beyond the peripheral edge of the disc directly above the flange, whereby fluid material from the upper disc is directed onto the flange and is rapidly formed into a thin downwardly moving film on the inner wall surface and then falls onto the lower disc; and

means to introduce into and means to withdraw from each tubular cavity a fluid heat exchange medium thereby permitting fluid material introduced into the evaporator to be separated into a relatively volatile and non-volatile material by continuously forming and reforming said non-volatile material on the relatively cool horizontal discs and directly heating the material only as a relatively thin downwardly moving film on the inner wall surface of the tubular jacket.

2. The apparatus of claim 1, wherein the disc is a circular convex plate characterized by a central apex and having a smooth gradual slope from the apex to the peripheral edge of the plate.

3. The apparatus of claim 1 wherein the housing is an elongated cylinder and the diameter of the lip of the flange is slightly less than the internal diameter of the cylinder, the lip of the flange having a gasket whereby the lip is placed in sealing and supporting engagement with the internal wall of the housing.

4. The apparatus of claim 1 wherein the means to introduce into and withdraw from each tubular cavity a heat exchange medium includes: elongated inlet and outlet conduits within the housing which conduits pass through the cavity of each tubular jacket and support each disc, the inlet conduit characterized by a flow passage within each cavity to introduce a heat exchange fluid into the cavity, and the outlet conduit characterized by a flow passage within each cavity to withdraw a heat exchange fluid from each cavity; means to connect the inlet conduit with a source of a heat exchange fluid; and means to withdraw a heat exchange fluid from the outlet conduit.

5. The apparatus of claim 1 which includes an elongated tube axially positioned so that its external wall surface is substantially parallel to and spatially separated from the surrounding inner wall surface of at least one tubular jacket, said tube passing through at least one disc, and including means to introduce into and means to withdraw from the tube a fluid heat exchange medium.

6. An evaporator which comprises in combination:

an elongated cylindrical outer housing having at the one end an inlet opening to introduce material to be evaporated and to remove volatile materials, and at the other end a discharge opening to remove non-volatile material, the housing containing therein a plurality of alternating discs and tubular jackets axially disposed and spatially separated within the housing;

the discs positioned transverse to the longitudinal axis of the housing and of a circular convex shape with a central apex and a gradual slope from the apex to the outer circumferential peripheral edge of the disc whereby fluid material thereon is caused to flow toward the edge of the disc;

the tubular jackets characterized by an enclosed tubular cavity having an axially aligned inner relatively long wall surface and an outer wall surface and a relatively short inwardly dished flange about the upper circumference of the cavity, the lip of the flange having a diameter slightly less than the internal diameter of the housing and a gasket about the lip to place the lip in a sealing and support relationship with the internal wall of the housing, the inner wall surface of the jacket of sufficient vertical length that a majority of the heat transfer to the mixture to be separated occurs on this surface and having a diameter less than that of the disc below it whereby fluid material falling on the disc is directed to the outer edges, falls onto the flange of the tubular jacket below and forms a downwardly moving thin film of material on the inner wall surface of the jacket;

means to introduce into and means to withdraw from each jacket cavity a heat exchange fluid which means include elongated inlet and outlet conduits, oppositely mounted within the housing, each conduit passing through each jacket cavity, the inlet conduit characterized within each cavity by a flow passage in the upper portion thereof to introduce a heat exchange fluid into the jacket, and the outlet conduit characterized by an upper bleed passage and a lower condensate passage within each jacket, means to introduce a heat exchange fluid into the inlet conduit and means to withdraw a heat exchange fluid from the outlet conduit.

7. A method of separating a mixture containing a relatively volatile material from a relatively non-volatile material which method comprises:

flowing said mixture to be separated onto and over a relatively cool horizontally-disposed surface;

permitting said mixture to fall from the horizontal surface through a relatively short free fall distance onto a relatively hot surface;

reforming said mixture into a continuous downwardly-moving thin fluid film on a substantially vertical relatively hot surface;

placing this moving fluid film in a heat exchange relationship with a heat exchange fluid to vaporize at least a portion of the relatively volatile material in the film on this surface;

permitting the non-volatilized mixture from this vertical surface to fall onto a lower relatively cool horizontally disposed surface and repeating the sequence until the desired degree of separation is accomplished; and

thereafter recovering the relatively non-volatile material and the relatively volatile material.

8. The method of claim 7 which includes the steps of condensing on a spatially separated substantially parallel, relatively cool, vertical surface from the relatively hot vertical surface at least a portion of the relatively volatile material evaporated from the relatively hot vertical surface; and permitting said condensed material to flow onto a lower relatively cool horizontally-disposed surface.

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