# United States Patent

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[54] **FALLING FILM EVAPORATOR STRIPPER**
**9 Claims, 4 Drawing Figs.**


[52] **U.S. Cl.** ..... **159/13 A,** 202/236, 203/89
[51] **Int. Cl.** ..... **B01d 1/22,** B01d 3/08, B01d 3/00
[50] **Field of Search** ..... 159/13 A, 15, 18, 13; 202/236; 203/89



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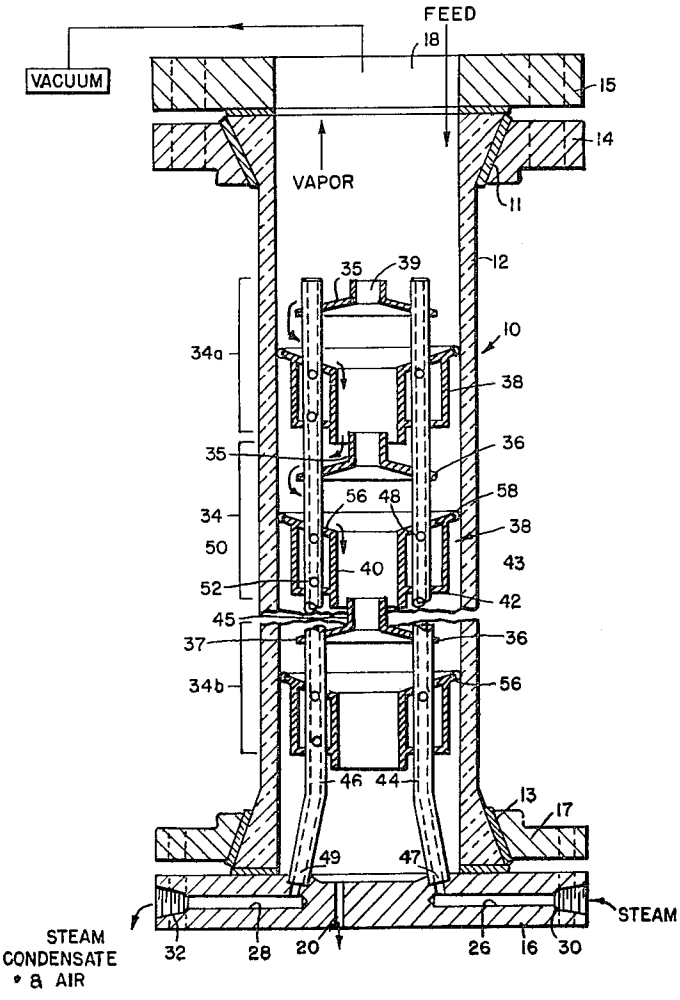
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**ABSTRACT:** A falling film evaporator which includes an alternating series of tubular heat jackets and discs, which units are vertically and spatially separated within the column. The discs are characterized by a central flow passage therein. The inner circumference of the heated tubular jacket is less than the diameter of the disc directly below it. The upper portion of the tubular jacket has an inwardly and downwardly dished flange the outer circumference of which is greater than the peripheral edge of the disc directly above it.

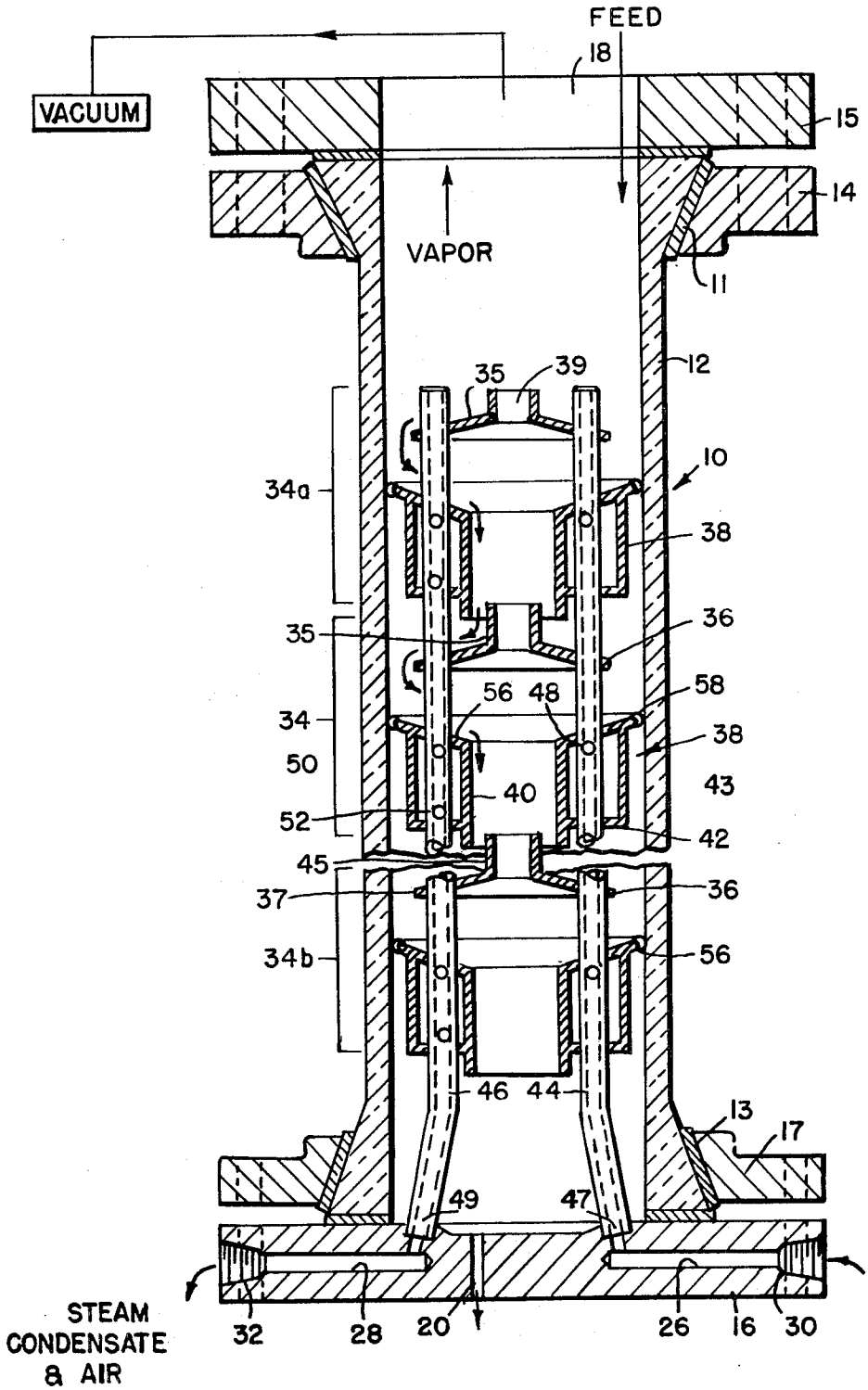



FIG. 1

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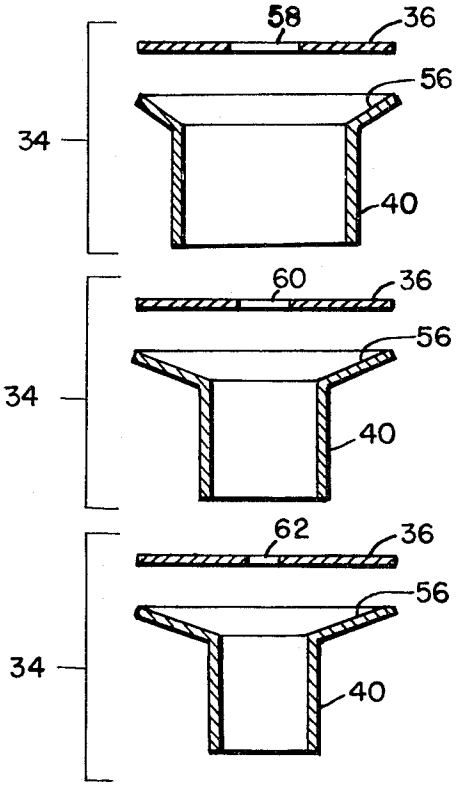



FIG. 2

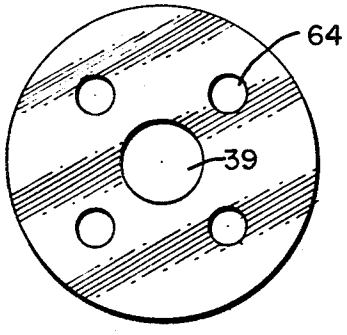



FIG. 3a

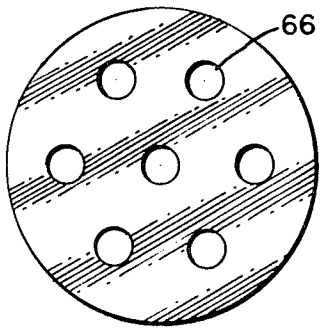



FIG. 3b

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# FALLING FILM EVAPORATOR STRIPPER

## BACKGROUND OF THE INVENTION

Evaporators in which a relatively volatile material, such as a relatively volatile or low-boiling liquid are removed from relatively nonvolatile 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 nonvolatile 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 reformed 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 tubes 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.

One patent which overcame many of the difficulties of prior art devices was U.S. Pat. No. 3,198,241 issued to James L. Baird. This patent is directed to an apparatus and method wherein liquid material to be distilled is cascaded over an alternating series of tubular jackets 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 primarily to the continuous moving vertically 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 materials is enhanced. The placing of the heat exchange fluid in a heat exchange relationship primarily with the thin-film phase of the internal side of the tube permits the more efficient concentration and evaporation of materials.

However, it has been found and although apparatus of this type are satisfactory for the processing of many types of material, particularly heat-sensitive materials, that for operation at low-pressure there occurs a pressure drop of a significant degree on the vaporous materials passing upwardly through the central portion of the cylinders and around the peripheral edge of the disc. This pressure drop limits the degree of recovery of the relatively volatile material from the relatively nonvolatile material.

## SUMMARY OF THE INVENTION

I have discovered a new and improved tube and disc falling film evaporator wherein the pressure drop through the unit is minimized to a significant degree by the use of discs having a central flow passage therein. This provides reduced pressure drop, increased efficiency, and the possibility to fabricate evaporators of smaller sizes than would be necessary if the concept of my invention were not employed in a conventional tube and disc evaporator. Depending on the cross-sectional area of the flow passages within the disc, the amount of vaporous material that may be bypassed and allowed to flow centrally through the evaporator will vary from about one-sixteenth of the total gas flow to about seven-sixteenths, reducing the pressure drop by a proportional amount. Further, the overall efficiency of the unit is increased as compared to a tube and disc unit since by providing flow passages in the center of the disc portion of the evaporator the loss in efficiency by passage of the limited portion or segment of the vapor stream which flows through the flow passage and not around the outer edges of the disc and the peripheral portion of the tube is more than offset by the increased efficiency of low-pressure operation. Typically with the disc and tube section the vapor must bend or turn four times before passing through one section. My invention, therefore, provides new and unexpected results in that the pressure drop through a disc and tube evaporator is minimized significantly, the size of the quipment can be reduced, and the overall operating efficiency is increased.



## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic partially sectional view of my invention.

FIGS. 2, 3*a* and 3*b* are alternative embodiments of my invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows my evaporator **10** 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 liquid discharging apparatus such as a vapor or liquid separator, slurry tank, vacuum pump, etc., (not shown). The evaporator has a liquid feed inlet opening **18** whereby the liquid feed material to be evaporated comprising for example a relatively nonvolatile and a relatively volatile material may be introduced into the apparatus.

The lower base plate **16** is characterized by an outlet opening **20** through which opening the liquid residue material or nonvolatile material is removed. Both the upper and the lower plates **15** and **16** are secured to the corresponding upper **17** and lower **14** collar plates surrounding the upper **11** and lower flanges **13** of the external jackets **12**. The lower base plates are further characterized by a horizontal radially disposed heat exchange inlet **26** and a heat exchange outlet **28** having threaded externally disposed ends **30** and **32** for steam and drain connections.

Vertically disposed and axially aligned with the longitudinal external jacket **12** are alternating series of disc **36** and tube **38** evaporating units **34**, **34***a*, **34***b*, etc., which units are vertically positioned one above the other. The number of disc and tube units is a matter of choice depending upon the particular process in which the equipment is to be used and the complexity and extent of the evaporation or concentration of the liquid feed material desired. These units are preferably vertically and spatially separated so that the free flowing cascading liquid material, gravity, pumped or vacuum fed to the inlet **18** is continuously formed and reformed into a vertically continuous relatively thin uniform liquid film surface after a relatively short vertical distance such as about every 2 to 6 inches, for example, every 2 to 4 inches. In this manner of disposition the most efficient use is made of a vertical thin-film surface since the majority of mass transfer in thin-film liquid evaporation takes place during the first one of two or so inches of the liquid film formation in gravity feed evaporators. The disc portions of the evaporating units **34**, **34***a*, and **34***b* are characterized by a central flow passage **39** therein to permit vaporous material to pass therethrough and to minimize the pressure drop in the evaporator.

About the flow passage **39** is a shield **35** the height of which would be sufficient to prevent liquid feed material cascading downwardly from splashing into the central flow passage of the disc. However, where the splashing of materials is not a problem during operation, the shield **35** would generally not be necessary. With a vertical distance of 1 to 9 inches between disc and tube units, vertical shield heights of 1 to 4 inches may typically be used. In some cases where splashing is a particular problem, it is desirable to extend the height of the inner shield **35** upwardly to or slightly above the lower portion of the next upper tubular jacket. Of course, the height of the shield **35** should not be such as to interfere with or come between the inner surface of the jacket **34** and the flow passage. The discs are convex and gradually slope downwardly to the lower peripheral edge **37** of the disc.

A tubular jacket **38** with vertical internal and external walls **40** and **42** respectively is provided on the tube portion **38** of the evaporating units **34**, **34***a*, and **34***b*. The fluid confining portion or space **43** between the spatially separate internal and external walls form 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 the 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 unit **34***b*, the inlet and outlet risers provide fluid communication between the heat exchange outlet **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 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 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 upper and lower openings **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 noncondensable fluids such as air in steam, while the lower opening is located at a height slightly above the base of the jacket space **43** to permit any condensable 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 or the operation.

The upper portion of the tube **38** is closed and circumferentially surrounded with a concave, 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 edge 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 or asbestos ringlike sealing gasket **51** to firmly seal each disc and tube unit within the external jacket **12**. The flange aids in providing 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 removal of the disc and tube units from the cylindrical jacket for cleaning purposes.

In between each tubular jacket and, preferably, intermediate thereof, are located the convexed discs **36**, whose peripheral edges **37**, 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 interconnection 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 interdisposed 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.

The flow passage **39** is shown as having a diameter of approximately three-fourths of the inside diameter of the tube. This may, of course, vary depending upon the particular application of the equipment; and the number, size, frequency, and location of flow passages in the disc may vary either within one disc or from disc to disc.

In the operation of the apparatus just described fluid feed material comprising a relatively volatile and a relatively nonvolatile material, for example, a fatty acid in the eight to 26 carbon range, say for example, stearic acid, as a volatile constituent and the dibasic acid of stearic acid, the nonvolatile constituent. This feed mixture is pumped, gravity fed or otherwise introduced into the top feed opening **18** of the evaporator apparatus **10**. At this time depending on the temperature desired and the material to be evaporated, 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 inlet riser **44** to the internal jacketed cavity of the first tube and disc unit and, hence, to succeeding disc and tube units through openings **48** 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 can be 1 to 9 inches to the disc flange **56** of the lower tube **38** where it drains by gravity to the internal wall **40** surface and forms a continuous vertically disposed liquid film over the internal wall of the tube. This film is thus placed in a noncontact heat exchange relationship with the steam within the internal tube jacket **43**.

The disc **36** characterized by the central flow passage **39** therein provides for the unimpeded passage of approximately 35 percent of the vapor generated by the removal of the more volatile components from the feed stream. The pressure drop from the top to the bottom of the unit is approximately 0.2 Torr., with an evaporation rate of 200 pounds per hour of vapor throughout and 12 evaporator sections each section comprising a tube and a disc with a throat diameter of 12 inches. If the orifice of the disc were 25 percent of the throat diameter of the evaporator, the unimpeded vapor passage would be approximately 7 percent of the total and if the orifice were 50 percent of the throat diameter, the vapor bypass would be approximately 20 percent of the total with pressure drops varying in proportion. Further, under the operating conditions described above, if a conventional unit were used to handle effectively the process requirements, the pressure drop from top to bottom would be 0.66 Torr., a throat diameter of 15 inches would be required in the conventional unit to give a pressure drop of 0.2 Torr. under the conditions described above. Also with the relatively smaller unit, the liquid flow rate per unit periphery is increased which increases the heat transfer coefficient. Most significant, however, is that the pressure drop is significantly reduced which increases boiling for enhanced efficiency in recovery of the fatty acid from the dibasic acid.

FIG. 2 is directed to an alternative embodiment of my invention wherein the central flow passages 58, 60, and 62 in the discs increases progressively in the cross-sectional area from the bottom to the top of the evaporator. FIGS. 3*a* and *b* represent a further alternative embodiment of my invention wherein various patterns of flow passages 64 and 66 are incorporated in the discs.

My invention will also find particular utility since it combines both a stripping operation with an evaporation step which stripping operation is enhanced by the improved flow passages of the axially aligned discs.

What I claim is:

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

a vertical elongated outer housing having at its upper end an inlet opening to introduce liquid material to be evaporated and an outlet to remove volatile material, and at the other end a discharge opening to remove nonvolatile material, the housing containing therein a plurality of alternating discs and vertically disposed, tubular, internally heated jackets axially disposed and separated within the housing;

the discs positioned transverse to the flow of material through the housing and convexly shaped to direct the flow of liquid material thereon toward the outer peripheral edge of each disc, each disc characterized by at least one generally axially located vapor flow passage therethrough surrounded by an upstanding collar to permit the flow of volatile materials upwardly therethrough the flow passages of the discs defining in serial combination a generally unobstructed axial flow passage for vapor from one to the other end of the housing;

the tubular jackets characterized by an enclosed annular tubular cavity, said jackets each having a substantially vertically disposed circumferential inner evaporating wall surface of sufficient vertical length that a majority of the heat transfer to to the mixture to be separated occurs on this surface and of less internal diameter than the disc directly below the tubular jacket and of greater diameter than the collar below the 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 evaporating 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 relatively volatile and nonvolatile materials by continuously forming and reforming said nonvolatile material on the relatively cool horizontal discs as films and directly heating the material only as a relatively thin downwardly moving film on the inner evaporating wall surface of the tubular jacket.

2. The apparatus of claim 1 wherein the disc is a circular convex plate characterized by a single flow passage therein, and further having a smooth gradual slope from the outer periphery of the flow passage 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 jacket 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, and further wherein the flow passage within the disc is centrally located.

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 said heat exchange fluid from the outlet conduit.

5. The apparatus of claim 1 wherein the collar extends upwardly from the surface of the disc to a distance of up to the bottom portion of the next higher tubular jacket surface.

6. The apparatus of claim 1 wherein the collar includes a cylindrical upwardly extending shield about a circular opening in each disc.

7. The evaporator of claim 1 wherein the cross-sectional area of the flow passages of the discs increases from the lower outlet end to the upper inlet end of the housing to handle the additional increase of vaporous material as evaporated from one to the other end of the housing.

8. The evaporator of claim 7 wherein the inner peripheries of the vapor flow passages lie in the surface of an inverted, axially disposed cone.

9. An evaporator which comprises in combination:

an elongated vertical cylindrical outer housing having at its upper end an inlet opening to introduce material to be evaporated and an outlet to remove volatile materials, and at the other end a discharge opening to remove nonvolatile material, the housing containing therein a plurality of alternating discs and vertically disposed, tubular, internally heated jackets axially disposed and separated within the housing;

the discs positioned transverse to the longitudinal axis of the housing and of a circular upwardly convex shape having a central generally axially located vapor flow passage therethrough surrounded by an upstanding collar, the flow passages of the discs defining in serial combination a generally unobstructed axial flow passage for vapor from one to the other end of the housing, and a gradual slope from the periphery of the central flow passage to the outer peripheral circumferential 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 annular tubular cavity, said jackets each having an axially aligned inner relatively long cylindrical wall surface and an outer cylindrical wall surface and a relatively short inwardly dished flange about the upper circumference of the cavity, the outer 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 and of greater diameter than the collar below the jacket whereby fluid material falling on the disc is directed to its outer edges, falls onto the flange of the tubular jacket below and forms a downwardly flowing 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, opposingly 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 of the conduit 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.

* * * * *