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ENTRAINMENT SEPARATOR FOR WIPED THIN FILM PROCESSOR

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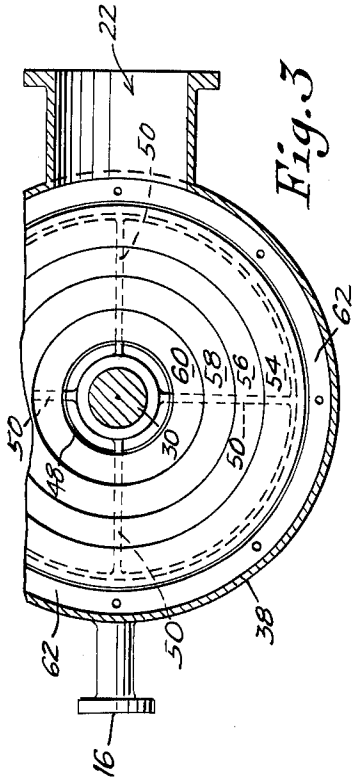


Fig. 3

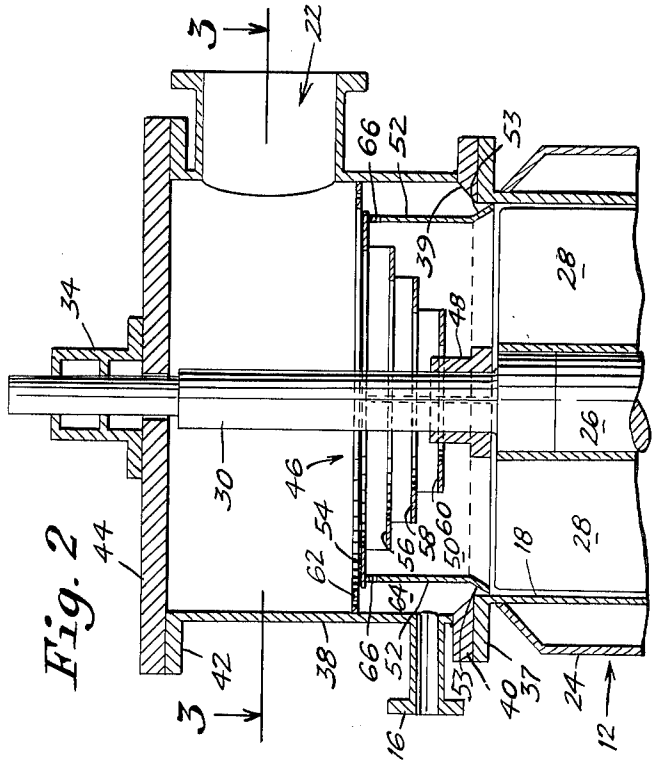


Fig. 2

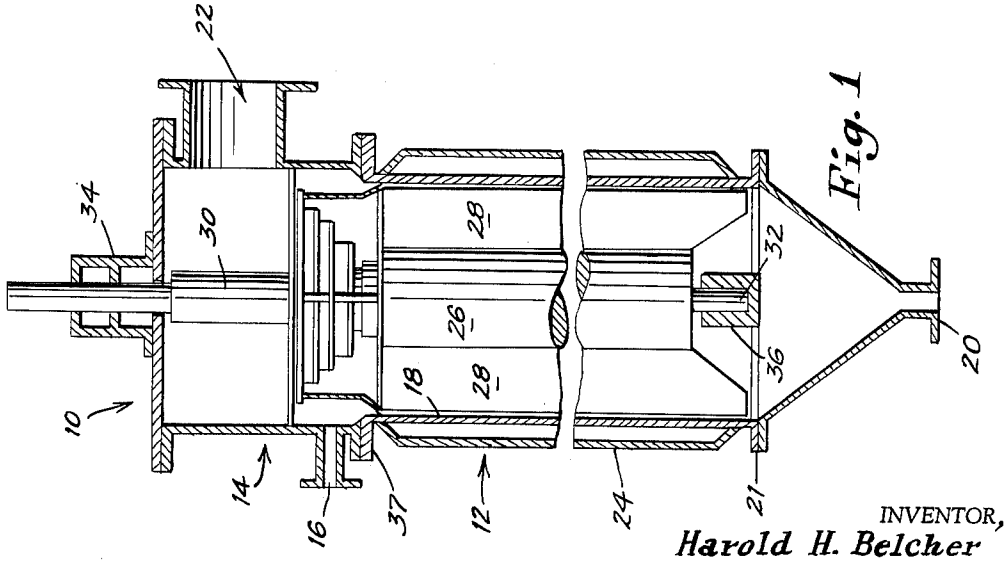


Fig. 1

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ENTRAINMENT SEPARATOR FOR WIPED THIN FILM PROCESSOR

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This invention relates to a thin film processor and more particularly to an improved entrainment separator for such a processor which will prevent the undesired carry-over of fine droplets of liquid in the discharge vapor stream.

The apparatus of the present invention is of the general type known as a thin film evaporator. Equipment of this type is commonly used for processes of evaporation or distillation, but may be used for other heat or mass transfer processes. In such processes, a liquid feed material is introduced at the top of an externally heated hollow cylinder, flows down the inside wall of the cylinder by gravity as a thin film, and is agitated or fanned by a concentric rotor. Vapors generated rise to the top of the unit, usually through a mist or entrainment separator, and discharge from a vapor discharge pipe.

Separators commonly used at present are of three general types. They are gravity settling, packed bed and centrifugal throw-out. All of these types have certain disadvantages.

The gravity settling type requires large chambers wherein vapor velocities become low enough to permit gravity to settle out the heavier droplets of entrained liquid. These large chambers are usually so large that they cannot readily be accommodated in the processor structure but must be built as separate units. Costs are high and piping inlets and outlets losses make the pressure drop undesirably high.

Packed bed systems filter the vapors through a compact mass of fibers, wire or ceramic shapes. These beds may be made quite compact but pressure drops are undesirably high and tend to become even higher as the bed clogs up with separated liquid.

Centrifugal throw-out separators exist in many forms. In the common form, the rising column of vapor swirling around at the rotor speed is forced to move outward toward an expanded diameter section and then is forced inward again. The entrained droplets, swirling with the vapor column, are thrown out to the wall of the expanded diameter section by centrifugal force. Since vapor volume in thin film processors is often very high, the flow cross-section out to the expanded section, up through this separator section, and back into the processor body must be quite large, resulting in separators of greatly expanded diameters and heights ranging up to 2 or 3 times the diameter of the main processor body. This type of separator adds greatly to the cost, overall height and overall diameter of the processor.

According to the present invention, it has been found that these difficulties may be overcome by using a novel centrifugal separator. This separator assembly is so constructed as to require the vapor and any droplets that might be contained therein to move against a centrifugal force before emerging from the assembly. This movement against the centrifugal force causes substantially all of the droplets to be retained within the assembly with only the desired vapor being withdrawn.

Accordingly, the primary object of this invention is to provide a method and apparatus for evaporating or concentrating liquids in which losses are held at a minimum.

Another object of this invention is to provide a method and apparatus in which droplets are prevented from escaping the evaporating assembly.

Yet another object of the present invention is to obtain an improved separator which has a minimum pressure loss.

Still another object of this invention is to provide a separator with minimum space requirements of both diameter and height.

These and further objects and advantages of the invention will be more apparent upon reference to the following description and claims, and the appended drawings, wherein:

FIGURE 1 is a broken side elevation and sectional view of a thin film evaporator having a separator constructed in accordance with this invention;

FIGURE 2 is a more detailed section of the novel separator shown in FIGURE 1; and

FIGURE 3 is a horizontal sectional view in the plane 3—3 of FIGURE 2.

The same reference numerals denote the same parts throughout the several views of the drawings.

Referring particularly to FIGURE 1, the thin film type processor, shown generally at **10**, is tubularly constructed and is normally operated in a vertical position. The lower section, indicated generally at **12**, is the evaporator portion while the upper section, indicated generally at **14**, is the separator portion of the apparatus. Material to be processed enters through an inlet pipe or fitting **16**, which is generally located between the evaporator **12** and the separator **14**, and flows down the inner wall of the vertical cylinder **18** under the influence of gravity. The concentrated liquid is withdrawn or discharged through a conical collector or fitting **20** which is secured to the bottom of the evaporator **12** by a flange arrangement **21**. The vapor produced by the evaporator is discharged through a pipe or conduit **22** located above the separator **14**.

The wall **18** of the evaporator portion is generally cylindrical throughout substantially the entire length of the evaporator chamber. This wall may, however, be formed of other shapes such as, for example, a frusto-conical. Thus, while a cylindrical chamber is preferred, it is to be understood that the term "cylindrical" when applied to the evaporator **12** includes also other shapes that may be found desirable.

Surrounding the vertical cylinder wall **18** of the evaporator is a steam jacket **24** provided with suitable inlet and outlet ports (not shown) which are in turn connected to a source of steam and a drain, respectively. The flow of steam within the jacket **24** causes the wall **18** to be heated to a desired temperature, thereby evaporating the material flowing down the inner wall **18** in a manner well known in the processor art.

Located within the evaporating chamber is a concentric rotor body **26** which extends throughout substantially the full length of the chamber. The rotor **26** is smaller than the evaporating chamber formed by the wall **18** and is provided with a plurality of blades or vanes **28** which extend outward from the rotor into close proximity with wall **18**. Ordinarily, these vanes or blades **28** are flat strips of metal or the like and are designed to pass in close proximity with the wall **18** throughout their longitudinal length. The clearance between the vanes **28** and the wall **18** is kept as small as possible within reasonable mechanical limitations with the blade tip preferably contacting or just clearing the film of material on the wall.

The rotor body **26** has top and bottom shafts **30** and **32**, respectively, carried in suitable bearings **34** and **36**, respectively. The bearing **36** may be supported by a conventional spider support arrangement. These bearings may be of any suitable type which will prevent the escaping of, and will not contaminate, the material undergoing processing.

As better seen in FIGURE 2, the evaporating or processing chamber **18** terminates at its top with a flange **37**. The casing of the entrainment separator section **14** consists of a vertical cylindrical section **38** which is slightly larger in diameter than the wall **18** of the evaporator **12**. The section **38** is fitted at its lower end with a flange **40** which bolts to the flange **37** of the evaporator. The upper end of the section **38** is also provided with flange **42** which bolts to a top closure plate **44** which in turn carries at its center the upper bearing **34**. The vapor outlet **22** is also shown connected to the upper part of the section **38**.

As can be seen in FIGURE 2, the rotor body **26** and blades **28** do not extend into the entrainment separator section but stop slightly below the top of cylinder **18**. The shaft **30**, which is of smaller diameter than rotor body **26**, extends upward through the entrainment separator section and carries a novel separator assembly indicated generally at **46**.

This novel separator **46** consists of a hub **48**, which is slidable on shaft **30** and is secured to the shaft by set screws or other locking devices, a number of evenly spaced vertical plate spokes or separator blades **50**, a feed distributor cylinder **52** and a number of concentrical baffle rings **54–60**, assembled as shown. The separator blades **50** are secured to and extend radially outward from the hub **48**, as seen in FIGURE 3. The upper edges of the separator blades **50** are stepped as shown in FIGURE 2 to locate and receive the series of concentric baffle rings **54–60**. These rings are secured to the blades **50** by any suitable method such as welding.

The inside diameter of the lower ring **60** is approximately equal to the outside diameter of the rotor body **26** and the outside diameter of the upper ring **54** is approximately equal to the outside diameter of the flared lower end of feed distributor cylinder **52**. The number and exact position of the baffle rings **54–60** may be varied but, in general, the inside diameter of each ring should be approximately equal to the outside diameter of the next ring below it in the assembly.

The feed distributor cylinder **52**, which is located around and secured to the blades **50**, has an outside diameter which is slightly less than the inside diameter of cylinder **18**. The lower edge **53** of the feed distributor cylinder **52** is flared outward as shown with the diameter of the lower edge of the flare being a small fraction less than the inside diameter of the cylinder **18**. The cylinder **52** is also secured to the larger of the concentric baffle rings **54** by any appropriate method such as welding.

The separator assembly **46** is now positioned on shaft **30** by sliding the hub **48** until the lower edge **53** of the feed distributor cylinder **52** is within cylinder **18** just above the upper end of the blades **28**. The hub is then securely connected to the shaft **30** by appropriate locking devices which are not shown.

A feed compartment ring **62**, which is located with its lower surface approximately in line with the upper surface of the baffle ring **54**, is welded to the separator section cylinder **38**. The inlet or feed pipe **16** is also welded to the wall **38** so that it empties into the annular feed compartment or area **64** formed by the wall **38**, ring **62** and feed distributor cylinder **52**.

In operation, the shaft **30** and separator assembly **46** are started rotating at a selected speed and the material or liquid which is to be processed enters the feed compartment **64** by way of feed pipe **16**. As the liquid hits the wall of the compartment **64**, it will begin to flow toward the bottom of the compartment where it will run out the conical wall **39** of cylinder **38** and come into contact with the outward flare portion **53** of the distributor cylinder **52**. This cylinder **52**, which is rotating with the rotor **26** and shaft **30**, imparts a rotating velocity to the liquid feed, forcing it down and out along the slope of the lower edge flare **53** and discharging it evenly and with a slight downward velocity component on the wall of the heated cylinder **18** of the evaporator chamber.

The liquid, as it progresses down the wall **18**, is acted on by the blades **28** and heated from the heat source in jacket **24**. Vapors which are thus formed will rise through the unit, through the separator assembly **46** and be discharged from the vapor discharge pipe **22**. Due to the mechanical action of the blades **28** on the film of liquid on the wall of cylinder **18**, or to the bursting of vapor bubbles formed in the liquid, fine droplets of liquid will become entrained in the rising vapor stream. Since these liquid droplets represent loss of product if the desired product is the liquid from the bottom of the processor, or contamination of product if the desired product is the subsequently condensed vapors, it is important that all entrained liquid droplets be separated from the vapor and returned to the processor wall. This complete separation is obtained by the novel separator assembly **46**.

As the vapor and entrained droplets rise through the unit between blades **28**, they necessarily move in a spiral path, the pitch of the spiral depending on the vertical velocity of the vapor and the speed of the rotor. The circular component of this spiral motion causes centrifugal forces which act more strongly on the dense or large liquid droplets than on the light vapors. Droplets are therefore thrown out toward the wall of the unit. Coarse droplets generated low in the unit are quickly thrown back into the film of cylinder **18**, before reaching the separator **14**. Fine droplets, however, do not throw out as easily and may reach the separator **14**.

To pass through the separator **14**, it is evident that the vapors are confronted with the series of baffle rings **54–60**. At each ring, the vapor stream divides, a portion moving inward to pass up through the inside diameter of the ring, the remainder passing upward outside the ring. The portion moving inward moves against the centrifugal force and since the force acts more strongly on the droplets, few of the droplets can make the sharp S-turn to follow this portion of the vapor. This separation is further aided by the fact that droplets continuing with the vapor stream outside one baffle ring, for example, **60**, will acquire additional outward velocity from the movement of blades **50**, thereby assisting the centrifugal force in driving entrainment outward, and making it more difficult for the droplets to follow the inward moving vapor stream at the next baffle ring.

Some droplets may start to make the turn but fail and collide with the under side of the rings **54–60**. Droplets impinging on the under side of rotating baffle rings **54–60** will coalesce with other droplets to form large drops which will then be thrown by centrifugal force to the inner surface of feed distributor cylinder **52**.

In passing through the nest of baffle rings **54–60** in the separator assembly **14**, most of the entrained liquid droplets are thrown out to the inner wall of feed distributor cylinder **52** where they will coalesce as a film. This liquid film will flow downward, out the lower flared portion **53** and be thrown into the wall of cylinder **18** along with the fresh feed liquid. If vapor velocities are very high, this film on the inside of the feed distributor cylinder **52** will rise toward the upper baffle ring **54** and be discharged through holes **66** back into the feed compartment where it will mix with fresh feed and be redisposed on the wall of the cylinder **18**.

It will be obvious that the novel separator disclosed may take various other shapes adn forms without departing from the true spirit of the invention. For example, the baffles **54–60** may be constructed so that their inner edges are angled slightly downward toward the hub, thereby increasing the angle the vapor stream must make from that of an S to that approaching a Z configuration. Various other changes and configurations that may be used will be apparent to those skilled in the processing art.

It will be apparent from the foregoing that by dividing the spiral vertical flow of the vapor into a number of

separate streams by a succession of baffle rings, the height and diameter of the separator section are held to minimum proportions and that each increment of the vapor flow is subjected to an effective centrifugal action to remove a maximum of entrained liquid droplets.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. An entertainment separator for a thin film thermal processor comprising a housing, means for introducing a rising vapor stream into said housing, shaft means rotatably mounted in said housing, hub means mounted so as to rotate with said shaft, a plurality of stepped vanes spaced about the periphery of said hub and extending radially outward therefrom, and a plurality of spaced, horizontally disposed, vertically displaced and concentrically arranged baffle rings secured to the steps of said vanes for deflecting said rising vapor stream so as to remove entrained droplets therefrom and vapor outlet means connected to said housing downstream from said vanes and baffle rings.

2. An entrainment separator as defined in claim 1 wherein each of said rings except the lowermost has an inside diameter that is the same as the outside diameter of the next lower ring in said arrangement, said lowest ring having a diameter larger than the hub means.

3. An entrainment separator as defined in claim 1 wherein each of said rings except the lowermost has an inside diameter that is less than the outside diameter of the next lower ring in said arrangement, said lowest ring having a diameter larger than the hub means.

4. A thin film processor consisting of an evaporator and separator, said evaporator comprising a chamber having a substantially vertical cylindrical wall, means for heating said wall, rotor means rotatably mounted in said chamber substantially coaxially with said wall, a plurality of vanes spaced around the circumference of said rotor and extending radially outward therefrom into close proximity of said wall, means at the upper end of said chamber for securing said separator to said evaporator, said separator comprising a chamber having a substantially vertical cylindrical wall, a shaft rotatably mounted in said separator chamber and connected to said rotor of said evaporator, a plurality of vanes spaced around the circumference of said shaft and extending radially outward therefrom within the separator chamber, a feed distributor cylinder secured to and surrounding said vanes within the separator chamber, horizontally disposed annular baffle means carried by said vanes within the separator chamber, a feed compartment ring secured to the interior of said separator chamber just above said vanes within the separator chamber, thereby forming in part a feed compartment between said wall and said cylinder, said feed compartment communicating with said chamber of said evaporator, outlet means connected to said separator chamber, means for introducing liquid material to be vaporized into said feed compartment and said evaporator, said shaft and said rotor being rotatable whereby said vapor is subjected to centrifugal force in addition to deflection by said baffle means so as to free the vapor from entrained droplets.

5. A centrifugal throw-out separator comprising a chamber having substantially vertical cylindrical walls, shaft means rotatably mounted in said chamber, hub means mounted on said shaft, a plurality of vanes spaced around the circumference of said hub and extending radially outward therefrom, a plurality of vertically spaced, horizontally disposed baffle rings secured to said vanes in stacked assembly, the outside diameter of a lower ring being approximately equal to the inside diameter of the adjacent upper ring of said stacked assembly, a feed distributor cylinder having a flared-out lower edge secured to and surrounding the outer edges of said vanes, a feed compartment ring secured to the wall of said chamber just above said vanes thereby forming in part a feed compartment between said walls and said cylinder, inlet liquid feed means connected to said feed compartment, vapor outlet means located at the top of said chamber, and means for securing an evaporator assembly to the lower portion of said chamber whereby fluid material entering said feed compartment will gravitate into said evaporator assembly from said feed distributor cylinder, said evaporator assembly producing a rising vapor stream, and means for passing said vapor stream through said baffle rings and rotatable vanes so that said vapor is subjected to centrifugal force in addition to deflection by said baffle means freeing it from entrained droplets.

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