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[54] **MEANS FOR THE TREATMENT OF LIQUID TO
 EFFECT COOLING, WARMING, VAPORIZATION,
 SEPARATION, PURIFICATION AND THE LIKE**
7 Claims, 11 Drawing Figs.

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 159/6
 [51] Int. Cl. B04b 15/02
 [50] Field of Search 233/11, 46,
 12, 13, 16, 19, 21, 22; 159/6; 202/236, 238

ABSTRACT: A device for the treatment of liquids comprising a drum mounted for rotational movement at a rate sufficient to generate centrifugal force greater than that of gravity, whereby the liquid adheres as layer on the outer periphery of the drum and means communicating the outer peripheral portion of the drum with an outlet whereby the layer of liquid on the peripheral surface of the drum separates in response to gravity during rotational movement of the drum with the heavier and colder liquid adjacent the outer peripheral surface, with the lighter and warmer liquid at the interior surface of the liquid layer to enable separation or fractionation thereof.

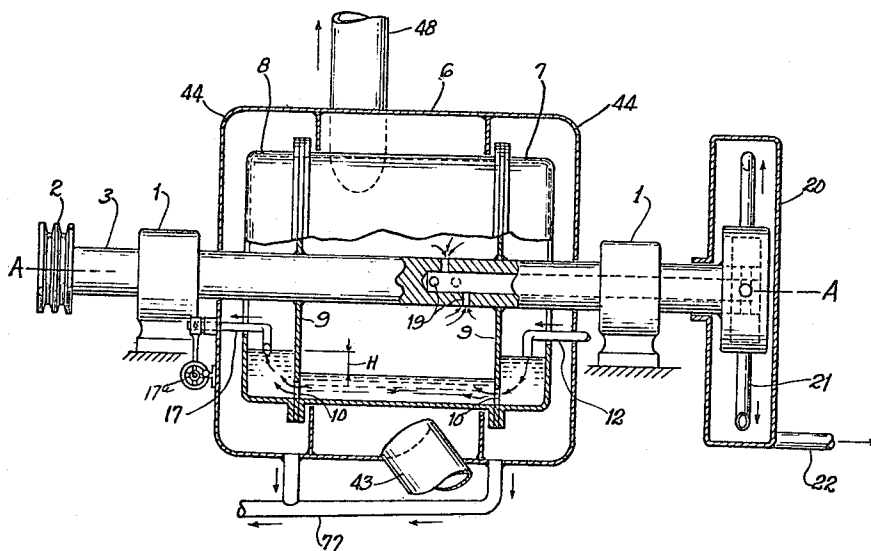
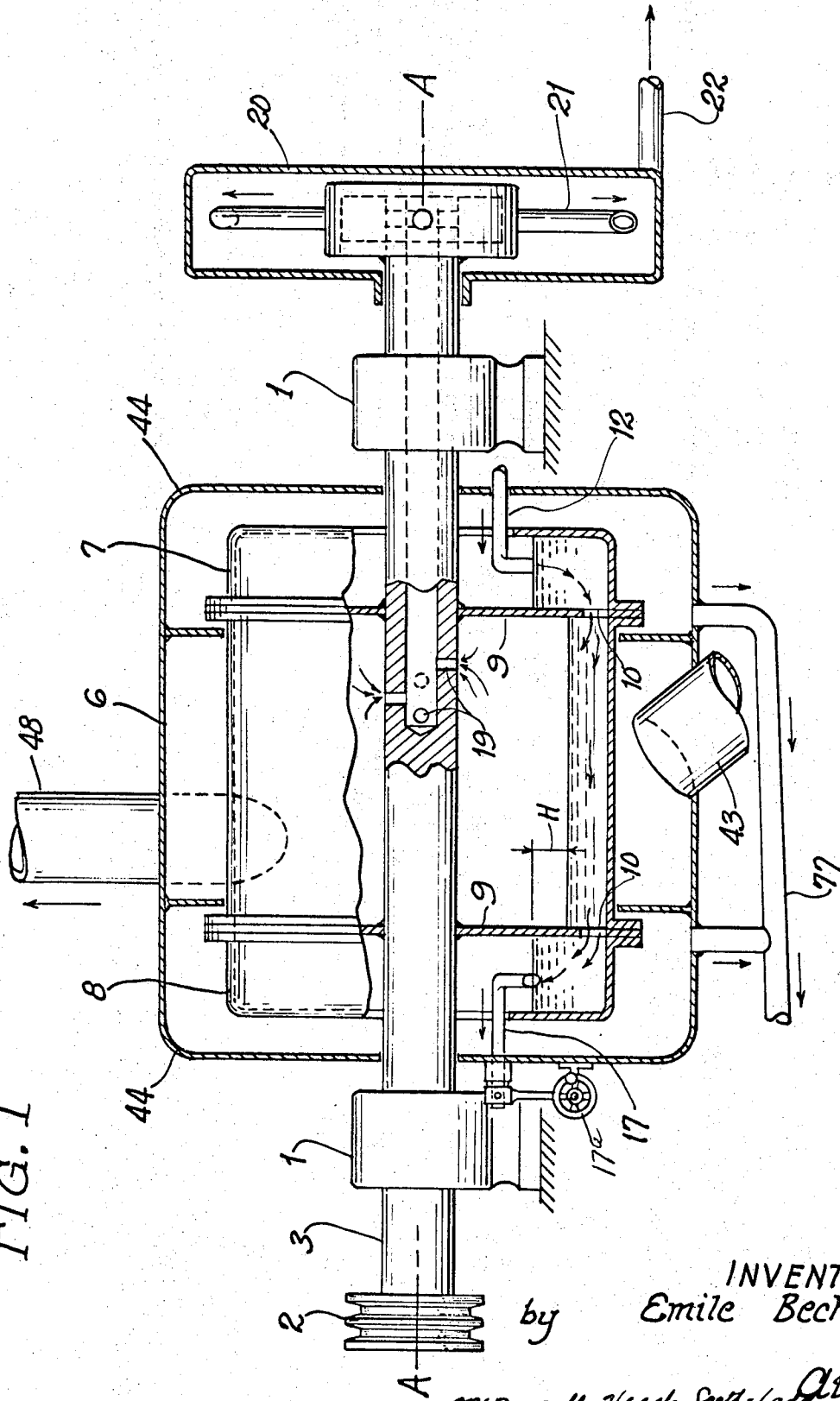


FIG. 1



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FIG. 2

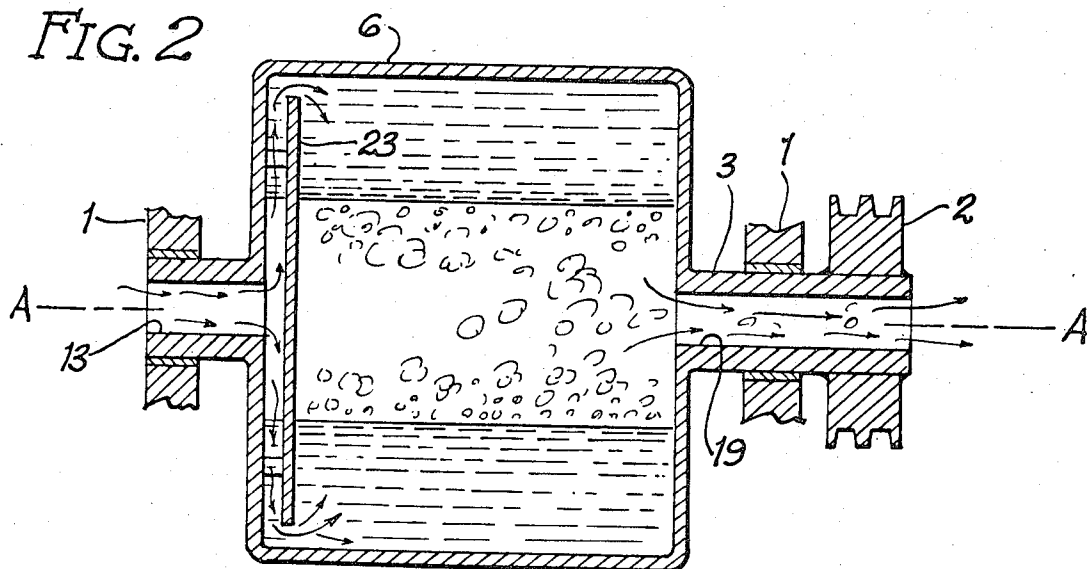


FIG. 3

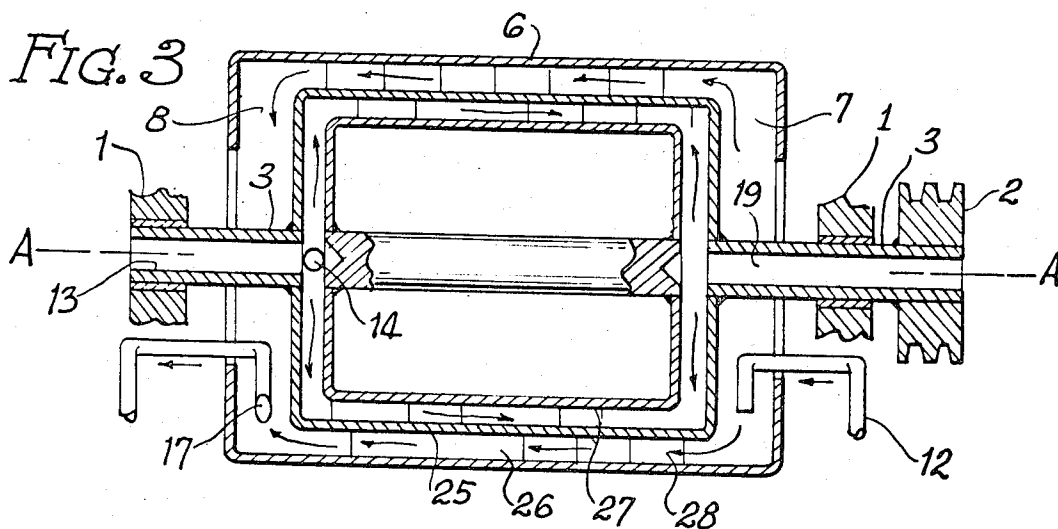


FIG. 4

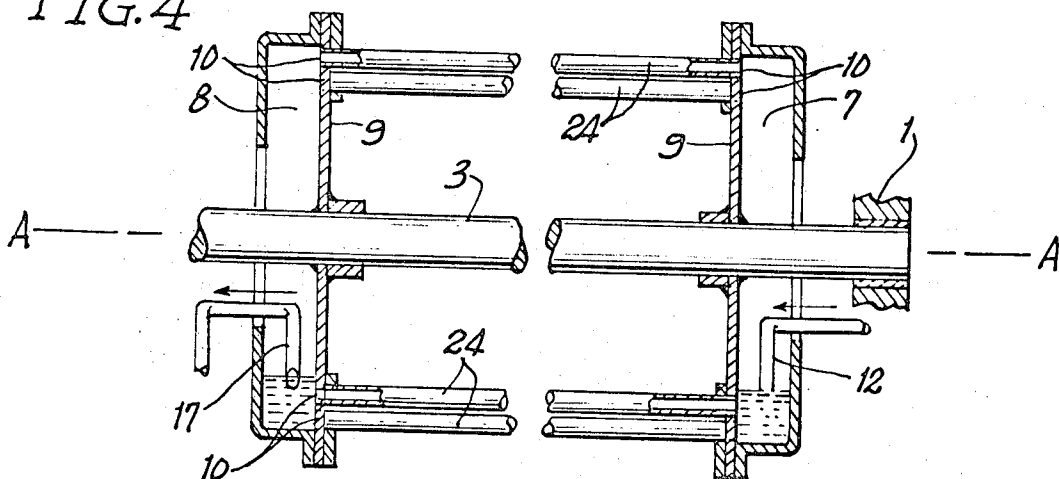


FIG. 5

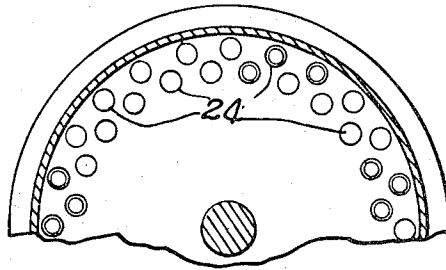


FIG. 6

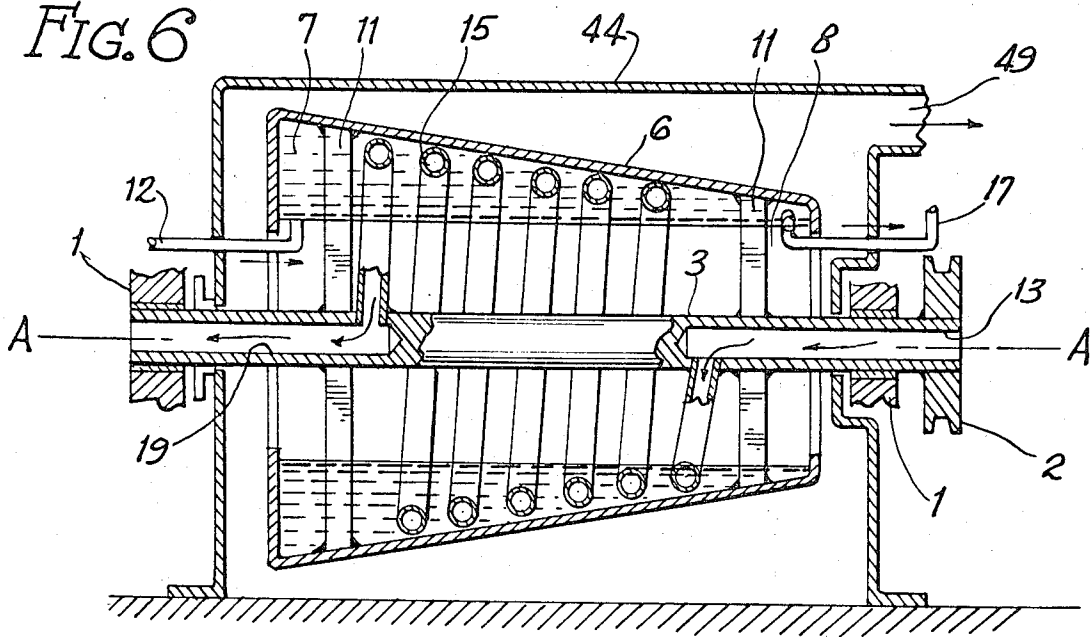


FIG. 7

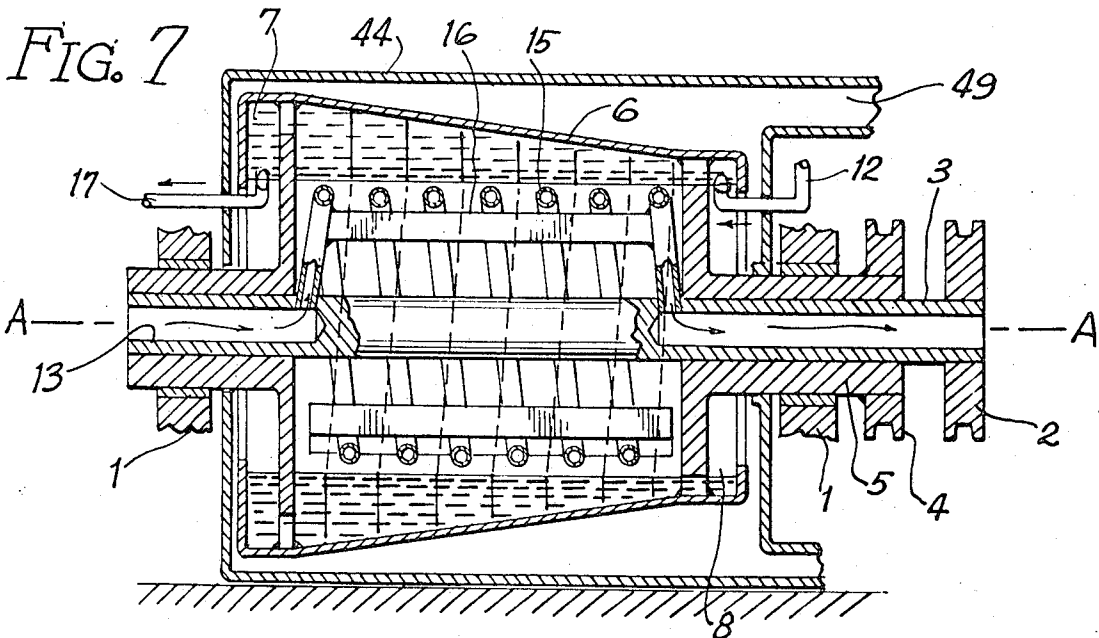


FIG. 8

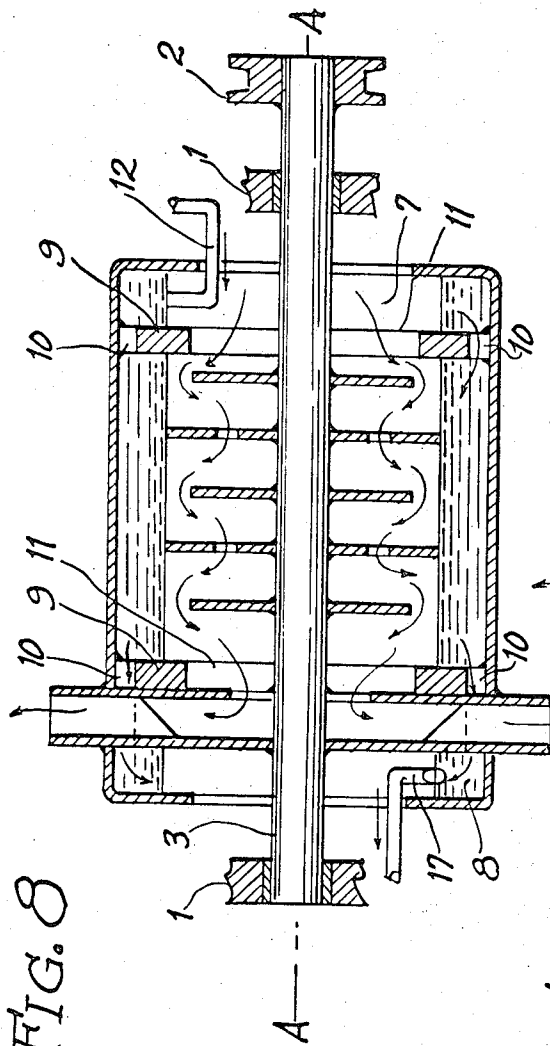


FIG. 9

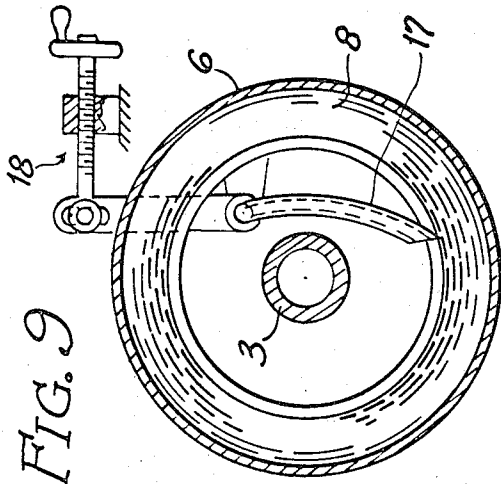


FIG. 10

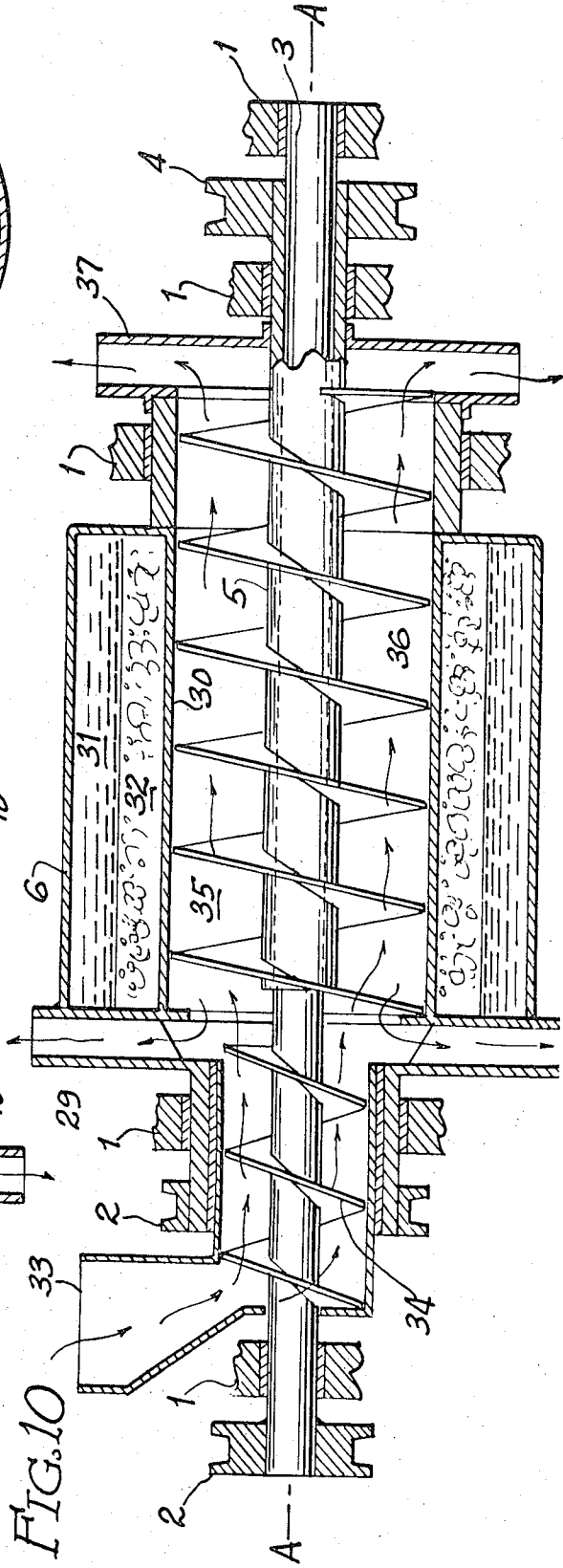
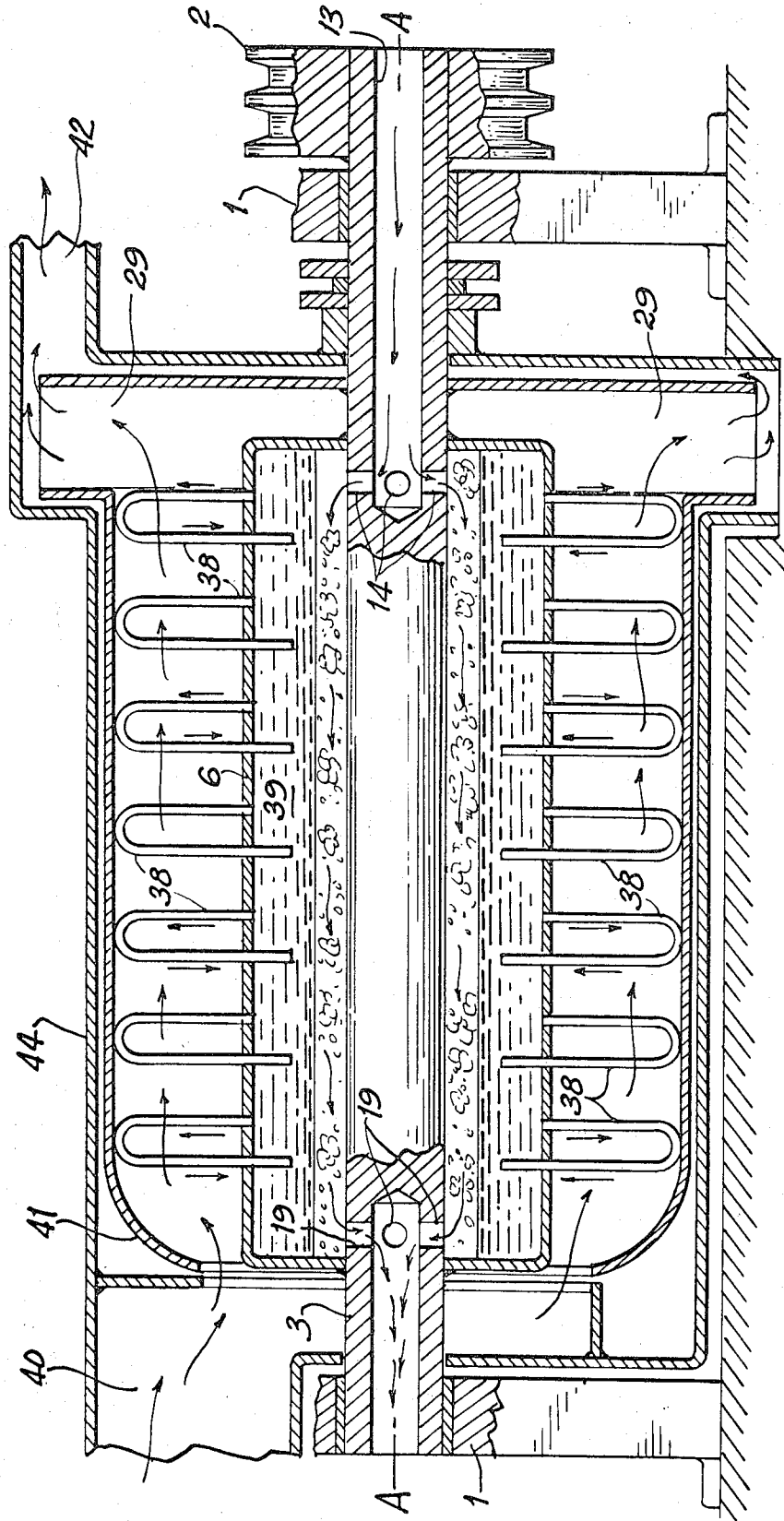


FIG. 11



MEANS FOR THE TREATMENT OF LIQUID TO EFFECT COOLING, WARMING, VAPORIZATION, SEPARATION, PURIFICATION AND THE LIKE

This is a division of my copending application Ser. No. 356,434, filed Apr. 1, 1964, now U.S. Pat. No. 3,396,088 and entitled "Rotary Multi-Compartment Distillation Drum Having Radially Adjustable Outlet to Vary Thickness of Liquid Layer."

This invention relates to the treatment of water in such processes as concentration, distillation, condensation and refrigeration, and it relates more particularly to methods and equipment for use in the practice of same.

Whether it is a question of heat exchangers or distillation apparatus, such equipment is usually very large, heavy and cumbersome. In the majority of cases, distillation apparatus requires heating, as by steam made available from a boiler.

If the efficiency of each machine is considered, the total efficiency is poor. For example, an efficiency of 0.70 at the boiler and 0.80 at the concentrator, would give a total efficiency of 0.7×0.8 , or 0.56.

In accordance with the present invention, all of the elements are grouped as one whereby a higher efficiency can be achieved. The use of centrifugal force to enhance heat transfer allows for considerable output per unit surface area.

The aggregate of these elements allows for the satisfaction of the various requirements with a minimum amount of floor space and with costs reduced to a minimum insofar as investments and exploitation are concerned.

It is an object of this invention to provide an improved method and means for carrying out such water treatment processes and to provide more efficient and better equipment and method for effecting the same.

These and other objects and advantages of this invention will hereinafter appear, and for purposes of illustration, but not of limitation, an embodiment of the invention is shown in the accompanying drawings, in which:

FIG. 1 is a schematic sectional view taken crosswise through the center of apparatus embodying features of this invention showing the operating principles of a centrifugal concentrator, a regulator and control for the filling operation;

FIG. 2 is a schematic sectional view of a portion of the apparatus used for large volumes of liquid and vapor, as needed when substantial supplies thereof are alternately required;

FIG. 3 is a schematic sectional view showing a lamellar exchanger adapted to be heated or cooled by an auxiliary liquid;

FIG. 4 is a schematic sectional view of a portion of the equipment shown in FIG. 1 but in which the annular body is replaced by a group of pipes;

FIG. 5 is a sectional view taken crosswise through a half section of the apparatus shown in FIG. 4;

FIG. 6 is a schematic sectional view showing a heat exchanger with a spiral group of pipes positioned adjacent the inner surface of the apparatus and immersed in the liquid;

FIG. 7 is a sectional elevational view similar to that of FIG. 6 but showing a modification thereof with spiral pipes mounted tangential to the liquid to be heated or cooled;

FIG. 8 is a schematic sectional view of an exchanger in which one of the fluids is a vapor, air or gas adapted to circulate freely on the surfaces of the liquid to be heated, cooled or evaporated;

FIG. 9 is a schematic sectional view showing the use of a syphon or ladle to extract the treated or surplus liquids while in motion;

FIG. 10 is a schematic section view which, in the upper portion, shows the principle of an exchanger with a padding or thermal insulation to exclude the risks of localized heat, especially in concentrating viscous materials which are sensitive to temperature variations and which, in the lower portion, shows a conical bowl containing a reserve of material to be treated;

FIG. 11 is a schematic sectional view showing an embodiment of the invention in methodic circulation of the heating and cooling gases and the circulation of the liquids to be heated, vaporized or cooled;

These FIGS. are not restrictive, especially not as to dimensions, and in certain cases they may be combined. For example, one device will produce a fluid, another will use it and a third will make an inverse thermal exchange, by condensing a vapor or by cooling a liquid.

In the same way, all materials, metals or compatible substances, with the pressures, temperatures, the aggressivity of the products or the mechanical resistances, may be used.

Finally, the communicating gear may be any of the known methods, mechanical, thermal or electrical, by belts, chains or grooved pulleys.

DESCRIPTION

To obtain the centrifugal force used to accelerate the thermal exchanges or to localize them, all these embodiments revolve about an axis A-A, supported by ball or roller bearings, or pads 1.

They are activated by pulleys 2 mounted on the central shafts 3 for the single rotation machines, and the pulleys 4 mounted on the encased shafts 5 for the machines with two concentric rotations.

All these machines include a bowl, drum or rotor 6 rotated by the shaft 3 or by the sockets 5 according to the requirements of the procedure used.

This principle element 6 is often supplemented by the annular chamber 7 on the intake side for the product to be treated and a chamber 8 on the outlet side for the products of liquids that have been treated.

The rotors 8 and the annular chambers 7 and 8 are assembled by the discs 9 which make them integrated with the driving shaft. These discs are drilled with holes 10 for the communication between these elements. In certain cases, these discs are replaced by arms 11.

The arrival of the liquids to be treated is effected by a pipe 12 when the feed is natural, without pressure, or by a drilling 13 in the shaft 3 and by the interposition of a stuffing box for the feed of liquids under pressure. These drillings communicate with the intake chamber or thermal exchange chambers by the orifices 14.

In installations containing one or more coils 15, these drillings on the shaft communicate with the one or more coils. When this or these coils are not applied to the inner wall of the bowl, they are supported by squirrel cage bars 16.

The extraction of the heated, cooled or concentrated liquid is made by the syphons or ladles 17 fixed or adjustable by screws and steering wheels when under pressure 18, or by the drillings 19 and the interposition of a stuffing box for an outlet under pressure. If there is a need to produce a vapor at a pressure higher than that of the atmosphere, it may be received in a casing 20, and its outlet may be facilitated by extractor pipes 21, then directed to other utilizations or treatments by the pipe 22.

In the exchangers with large volumes of liquids and vapor, so as not to disturb the exchanges in course, the liquid to be treated is admitted in a circular sheet, formed by the interposition of a disc 23.

In the embodiments with groups of pipes parallel to the axis, or spiral, these pipes 24 are encased, dudgeoned, expanded or set onto the plate 9. In these embodiments, the flames or heated gases pass across the group of pipes, thus increasing the exchange surfaces.

In the lamellar embodiments, the arrangement includes an intermediate drum 25 forming a circular space 26 with 6, in which the heating or cooling liquid circulates. The surplus inside volume is filled by a drum 27 leaving between 25 a sheet of liquid 28 which will rapidly circulate, in any case with the least inertia that could come from a large volume.

The submerged pipes 15 tangential to the drum 6 allow the instantaneous heating of all the volume in the course of treatment, on the other hand, in the arrangements with the pipes tangential to the liquid, supported by the arms 16, only the inside surface of the top of the liquid is heated, thus bringing no

thermal modification to the mass of the liquid in the course of treatment.

In the equipments that use a vapor, a gas or air, these elements, after having fulfilled their functions, being saturated, are extracted by an aspirating device 29.

To create a thermal padding so as to avoid all local thermal charges, temperature excesses, etc., the liquid ring is contained between the bowl 6 and the bowl 30 on the inside at 6 and between the two is a predetermined quantity of liquid of easy evaporation, water for example, which will produce a vapor 32.

For semiliquid or viscous products, the inlet will be effected by a funnel 37. They will be regularly advanced by a screw 34 which will lead them into the treating chamber 35. In this chamber a screw 36 revolves slowly which advances the products in proportion as the liquid that they contained is vaporized, extracted by 29, whereas the products are extracted by 37.

To achieve rigorously methodic thermal exchange, that is to say, counter current, in which the heated fluid circulates in the opposite direction to the cold fluid, so as to maintain constant the maximum divergence between them, on the collector, rotor, bowl or drum, pipes are mounted, called hairpin pipes.

The arm on the inlet side of the liquid does not pass beyond the interior of the thickness of the collector 6. The other arm, that on the outlet side of the heated fluid, on the other hand, continues through to the interior of the liquid layer 39. The heated liquid or the formed vapor will escape by means of the passages 19, to be directed to its use, passing through the fixed piping by means of a conventional stuffing box.

As far as the flames or the heated gas are concerned, which are admitted at 40, they go through to the revolving chamber 41; this chamber revolving with the rotor 6 and the pipes 38 avoids whirls. Thus the gases circulate freely to leave at 42, aspirated by the ventilator 32.

This invention can use all known types of heating, solid (wood or coal) in a fire set under the bowl, rotor or drum, by gas or liquid fuels 43 from which the flames are directly projected onto the revolving sections, which run no risk of burning, on account of the continual movement in front of the flame.

To retain the hot gases around the exchange elements, the latter is enclosed in a casing or housing 44.

In the cases when electrical heating is being used, the electrical resistance 45 is submerged in the liquid to be heated, or supported by the squirrel cage bars when the heating should be made on the inside layer of the liquid 46.

If heating by infrared rays is used, the ramps 47 are mounted in segments or rings around the elements to be heated, which revolves in the center.

The residual heating gases, the saturated air or vapors are rejected into the open air through the chimney 48.

When it is a question of recuperating distillation gases and eventually condensing them, they leave by the tubulus 49 which can be connected to an apparatus "in vacuo" or a condenser 50.

The ribs with their developed surfaces, have the advantage, under an equal volume, of being able to increase the exchange surfaces between the metal and the gases or liquids.

The ribs parallel to the axis, or in appropriately oriented spirals, have the advantage of being able to facilitate a progressive advance in the direction of the methodic exchanges; the radial ribs, on the other hand, circular in shape, on the inside or the outside, would stabilize between each circle, forming as many circular rings, which in certain cases would be detrimental to the circulation of the liquids or gases, but which in other cases allows a selection of the produced vapor.

In nearly all these embodiments having the same aim, to concentrate, to distill, to condense or to cool, the most important part is in maintaining a constant level in the bowl, rotor or drum while assuring the distribution of the evaporated liquids, that is to say, assuring a supply as a function of the liquid given off in the form of vapors.

The centrifugal level or inside diameter of the liquid rim (crown) is controlled by a shoe or skis 52 revolving about an axis 53, which drives a lever 54 on which a spring acts 55 which keeps the shoe constantly in contact with the liquid rim (crown).

The lever 54 transmits its movement to a rod 56 which controls a slide valve, a tap or an electromagnetic circuit of gate valves.

To obtain an automatic operation at a determined concentration, it is necessary to extract the concentrate as soon as the maximum desired concentration is obtained, which corresponds to a variation in density, which will allow the control of an extractor 57 including a concentrate intake 58 and the outlet of the liquid 59 that has not attained the desired concentration.

The liquid having attained the maximum concentration desired, or not to be passed, is evacuated by the base of the clack valve 60. The clack valve 61 having the shape of a pipe 62 is integral with the float 63. This pipe is carefully guided by two stars 63, which are similarly used to avoid whirls and giratory outflow which could disturb and distort the working of the float. The pipe 63 has a diameter which permits the placing of a salt gauge, acids, milk or a thermometer for the controls or adjustments. It is surmounted by a tray 65 allowing the placing of the weights necessary to calibrate the float. The whole unit is shut by a lid 66.

In an automatic installation for sterilizing water, producing vapor from salt water, the water to be treated arrives by 67 into a reservoir 68 or feed tank of which the level is regulated by a float 69. This water, aspirated by a pump 70 is driven back towards the feed regulator 71 whose opening and shutting are controlled by the skis 52. The pump is equipped with a pressure limiter to avoid any abnormal load on the slide valve regulator. The same motor 72 may drive the generator 6 by the chain gear 73, and the pump 70 by the gear 74. By turning the tap 75, the vapor is directed to another treatment or to the coolant 50.

In certain cases, it may be necessary to release under pressure a heated liquid free of vapor which is obtained by fixing the radial plunging pipes 76, fixed in the borings 19.

During the operation, large quantity of liquid constitutes the rims (crowns) formed by centrifugal force.

The volume of the segment being smaller than that of the rims (crowns), there is an overflow, which is taken up by the pipe 77 which will lead this liquid off to the tank 68 where it will be taken up again by the pump 70 as it is needed to compensate the vaporization.

OPERATION

It is known and has been demonstrated that the density of a liquid, vapor or gas, varies with the temperature because of the increase or dilation of a given weight, or because of its contraction or reduction in volume.

If "D" is equal to the density of a liquid at rest, water for instance at 10 C or D equals 0.99907, and "d" the density at 110 C = 0.951, the density has diminished from D to d = 0.99907 to 0.951 = 0.4807.

If water at 10 C is placed in a rotor with a diameter of 0.5 meters, turning at 1,000 revolutions per minute, it will be subject to an acceleration of which the vapor B is given by the simplified formula $B = 1.2 \times 0.5 \times (1,000 / 100)^2$, that is 56, thus a weight of one kilogram on balance will effect a pull of 56 kilograms at its center of gravity, it it turns at a speed of 1,000 revolutions per minute, on a radius of 0.50 meters, that is at a distance of 0.5 meters from the axis.

By applying this coefficient 56 to the differences in density, they successively become $0.99907 \times 56 = 55.94792$, and $0.951 \times 56 = 53.256$, that is a difference of $55.94792 - 53.256 = 2.69192$.

It is easily understood and admitted, and experience has shown it to be so, that with a difference of centrifugal density of 2.69192, the water will separate itself in function of its density, the hottest at the center, and the coldest at the inside circumference of the rotor, bowl or drum.

If the heat does not act on the bowl, rotor or drum, the liquid has no relative radial movement between the inside layer and the inside of the casing.

If, on the other hand, the casing 6 is heated, whatever the source of heat, the water for example that is in contact with the outside casing will become lighter proportionally to the heat received, its density will diminish; this diminution multiplied by the coefficient B -56 in the above example will cause such a lightening that it will come rapidly nearer to the center, giving place to colder water, whence an accelerated convection. This accelerated convection allows the obtaining of very considerable thermal exchanges per surface unit.

Another phenomenon improves the production, the suppression of the film, called the contact which disturbs the exchanges, the liquids being bad conductors.

In the present invention the elements 6, 7 and 8 form an aggregate of three compartments revolving together, separated by the partitions 9 but communicating between themselves by the orifices 10 placed as near as possible to the outside.

The water taken into 12 will be distributed in the rim (crown) if the aggregate revolves until the level is limited by the syphon or ladle 17. From that moment the level will be stable, regulated by the shoe 52 and the surplus extracted by 17.

As long as the heating does not intervene, there will be no change of movement in the liquid.

The lighting of the burner 43 will cause a rise in temperature of the water contained in the central body 6. The rise in temperature will cause a formation of vapor, which before escaping at 19 will be transformed by an elevation of pressure in the body 6; this pressure will be balanced by the centrifugal force, acting on the water contained in the bodies 7 and 8, which stay at atmospheric pressure.

The pressure of the vapor will cause a difference of level "H" in centrifugal value, that is under pressure $B \times H \times R \times d$, this being per square centimeter, the center of gravity of this column being H/a , the distance R being the radius of rotation of this liquid column, the density being expressed in kilograms per cubic centimeter.

This contribution of heat which will make the liquid lighter on contact with the heated wall, will force it closer to the center with a speed increased by the acceleration B, a colder liquid will take its place, whence the accelerated convection.

The effects of centrifugal force on the thermal exchanges may be strictly and rigorously controlled locally by the use of pipes 15 or concentric drums 60, 25, 27, which bring liquids to different temperatures causing the exchanges.

The terminal compartments 7 and 8 being in relation with the atmospheric pressure, this type of exchanger is strictly explosion-proof. In fact a sudden or abnormal excess of pressure in compartment 6 will force the liquids from compartments 7 and 8, thanks to the free passages 10.

In the case of the slowing down of the speed of rotation, the centrifugal force diminishes and at the same time so does the pressure in compartment 6.

In the case of the machine stopping, at least half of the passages 10 are immediately in contact with the atmosphere.

In the case of stoppage of the supply of the liquid to be heated or evaporated, the pressure diminishes at the same time as the thickness of the liquid rim (crown) to be eliminated when the passages 10 are opened.

Heating without a liquid presents no danger on account of the rotation which assures distribution by avoiding burnouts.

When the principle is used to concentrate, to distill or to dry liquids containing solid elements, that may be centrifuged, it is necessary to remove and to extract these elements before they can form a layer or crust stuck to the inside of the bowl 6, isolating and risking burnouts; this removal is assured by the screws 34 and 35, to be evacuated, concentrated or dried by the centrifugal extractor 37 when the evaporated liquid is extracted by the ventilator 29.

For products that are fragile and sensitive to heat, the liquid padding 31 is used, whose vapor 32 heats the cylinder 30.

As the vapor 32 cools, giving up its heat, it becomes heavier, even condenses and returns to a liquid state 31, thus forming a

cycle having a great regularity, hence the slight temperature variations.

It will be understood that changes may be made in the details of construction, arrangement and operation without departing from the spirit of the invention, especially as defined in the following claims.

I claim:

1. A device for treatment of fluids and liquids comprising a drum mounted for rotational movement about an axis, means for rapidly rotating the drum about its axis at a rate sufficient to generate centrifugal force greater than that of gravity to cause liquid in the drum to adhere as a layer to the outer periphery of the drum during rotational movement, an axial inlet opening communicating the one end of the drum, an axial outlet opening communicating with the other end of the drum, a baffle plate fixed for rotational movement with the drum in closely spaced relation with the inlet end of the drum, said baffle plate having a diameter slightly less than the diameter of the drum thereby to provide a spaced relationship therebetween for the flow of liquid therethrough from the inlet opening into the drum whereby entrance of the liquid into the drum is confined to the outer peripheral portion of the drum and means for heating the liquid in the drum whereby, during rotational movement of the drum, the layer of liquid on the peripheral surface of the drum will separate in response to gravity with the heavier and colder liquid adjacent the outer periphery of the drum and the lighter and hotter liquid at the interior surface of the liquid layer.

2. A device for the treatment of openings in the inner walls of the drum and liquids comprising a pair of laterally spaced apart drums mounted for rotational movement about a common axis, means for rapidly rotating the drums about the axis at a rate sufficient to generate centrifugal force greater than that of gravity to cause liquid in the drum to adhere as a wall to the outer periphery of the drum during rotational movement, laterally spaced apart outer and inner openings in the peripheral end portion of the inner walls of the axially spaced apart drums, pipes extending axially between axially aligned openings in the inner walls of the drum with the outer pipes communicating the outermost openings and the inner pipes communicating the innermost openings, a stationary inlet extending into one of the drums for introduction of liquid into said drum, a stationary outlet extending into the other drum with means for radial adjustment of the inlet to said outlet means to a position inwardly of the innermost openings to maintain a layer of liquid against the peripheral wall of the drums having a thickness to extend beyond the innermost of said openings, a vapor outlet in communication with the interior of said drums, and means for passage of heat exchange fluid or gas in heat exchange relation with said pipes whereby, during rotational movement of the drum, the wall of liquid on the peripheral surface of the drum will separate in response to gravity with the colder and heavier liquid in the outer portion of the layer and the hotter and lighter liquid in the inner portion of the layer.

3. A device for the treatment of liquid comprising an outer drum mounted for rotational movement about its axis, means for rapidly rotating the drum about its axis at a rate sufficient to generate a centrifugal force greater than that of gravity, an inner drum spaced concentrically with the outer drum and mounted for movement with the outer drum, an intermediate drum concentrically arranged between the inner and outer drums and spaced therefrom to provide an outer annular space between the intermediate drum and the outer drum and an inner annular space between the intermediate drum and the inner drum, a stationary inlet extending into the outer annular space at one end of the drums, a stationary outlet extending into the outer annular space at the other end of the drums, an inlet in communication with the inner annular space at the other end of the drums, and an outlet in communication with the inner annular space at the one end of the drum for flow of liquid through the inner space countercurrent to the flow of liquid through the outer annular space, and means for

heating one of the liquids whereby, during rotational movement of the drums, the layer of liquid will separate in response to gravitational force with the colder and heavier liquid outermost in the layer and the lighter and hotter liquid innermost in the layer.

4. A device for the treatment of liquid comprising a drum of frustoconical shape mounted for rotational movement about an axis, means for rotating the drum about its axis at a rate sufficient to generate centrifugal force greater than that of gravity, axially spaced radially extending bars adjacent the opposite ends of the drum, a stationary inlet extending into the drum at the larger end thereof for introduction of liquid to be treated, a stationary outlet extending into the smaller end of the drum with means for radial adjustment of the inlet to said outlet means for adjusting the thickness of the layer of liquid adhering to the outer peripheral surface of the drum during rotational movement of the drum, coils about the inner periphery of the conically shaped drum within the thickness of the layer of liquid about the drum during rotational movement of the drum and rotatable with the drum, an inlet in communication with one end of the coils and an outlet in communication with the other end of the coils, means for circulating liquid from the inlet to the outlet of the coils for passage in indirect heat exchange with the liquid layer on the periphery of the drum during rotational movement, and means for maintaining the thickness of the layer of the liquid in the drum to submerge the coils in the liquid layer during rotational movement of the drum whereby, during rotational movement of the drum, the layer of liquid will separate in response to gravitational force with the heavier and colder liquid outermost in the layer and the lighter and hotter liquid innermost in the layer.

5. A device as claimed in claim 4 in which the coils are arranged within the drum concentric with the axis thereof and spaced inwardly from the wall by an amount greater than the wall of liquid on the outer surface of the drum during rotational movement of the drum whereby the coils are rotated within the space occupied by the vapor given off from the liquid.

6. A device for the treatment of fluids, a drum mounted for rotational movement about an axis, means for rapidly rotating

the drum about its axis at a rate sufficient to generate centrifugal force greater than that of gravity whereby liquid in the drum forms as a wall on the surface of the drum during rotational movement, a bowl within the drum mounted for rotational movement therewith about the same axis with the ends of the bowl joined to the end walls of the drum to subdivide the drum into an outer casing and an interior compartment open at the opposite axial ends, inlet means for feeding a viscous material into the interior compartment at one end thereof, outlet means at the other end of the compartment for removal of viscous material, vapor outlet means in communication with the one end of the interior compartment, a screw extending axially through the interior compartment for displacement of viscous material axially through the compartment from the inlet end to the outlet end in heat exchange relation with the surface of the rotating bowl and means for circulating heating fluid through the outer casing in heat exchange relationship with the bowl for heat transfer therebetween.

7. A device for the treatment of fluids comprising a drum mounted for rotational movement about an axis, means for rapidly rotating the drum at a rate sufficient to generate a centrifugal force greater than that of gravity, an outlet at one end of the drum for introduction of liquid to be treated, a vapor outlet in communication with a central portion of the drum for exhausting vapors given off by the liquid in the drum, a plurality of U-shaped tubular members each having an inlet end and an outlet end with the inlet ends in communication with the outer portion of the wall of liquid on the surface of the drum during rotational movement of the drum and with the inlet ends spaced radially inwardly from the outlet end for termination within the wall of liquid on the periphery of the drum whereby the colder liquid of higher specific gravity flows through the tubes from the inlet end to the outlet end, an outer casing about the rotating drum and coils, and means for circulating a heat exchange medium through the space between the casing and the drum for heat exchange with the liquid passing through said tubular members during rotational movement with the drum.

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