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Feres

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[54] **APPARATUS FOR INDIRECT HEAT TREATMENT OF LIQUIDS**

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Jan. 17, 1973 Sweden 7300609

[52] **U.S. Cl.** .... **165/88;** 159/6 R

[51] **Int. Cl.**[2] **F28D 11/02**

[58] **Field of Search** .... 165/87-90; 233/13, 22, 11, 21; 159/6 R

[56] **References Cited**

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Assistant Examiner—Theophil W. Streule

[57] **ABSTRACT**

An apparatus for indirect heat treatment of liquids, especially an evaporator, comprising a frusto-conical hollow rotor mounted for rotation in a vacuum-tight casing and having three spaced substantially coextensive walls for defining two interconnected gaps for passing a heat carrier through the rotor to heat the liquids being distributed and flowing as a thin layer on the inner wall of the rotor under the centrifugal action of the rotating rotor.

15 Claims, 2 Drawing Figures

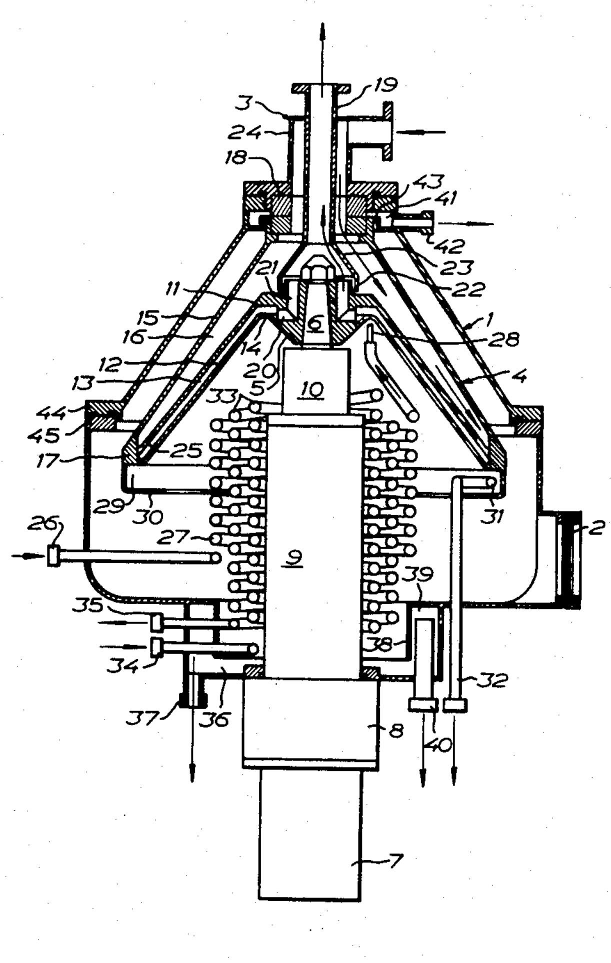

FIG.1

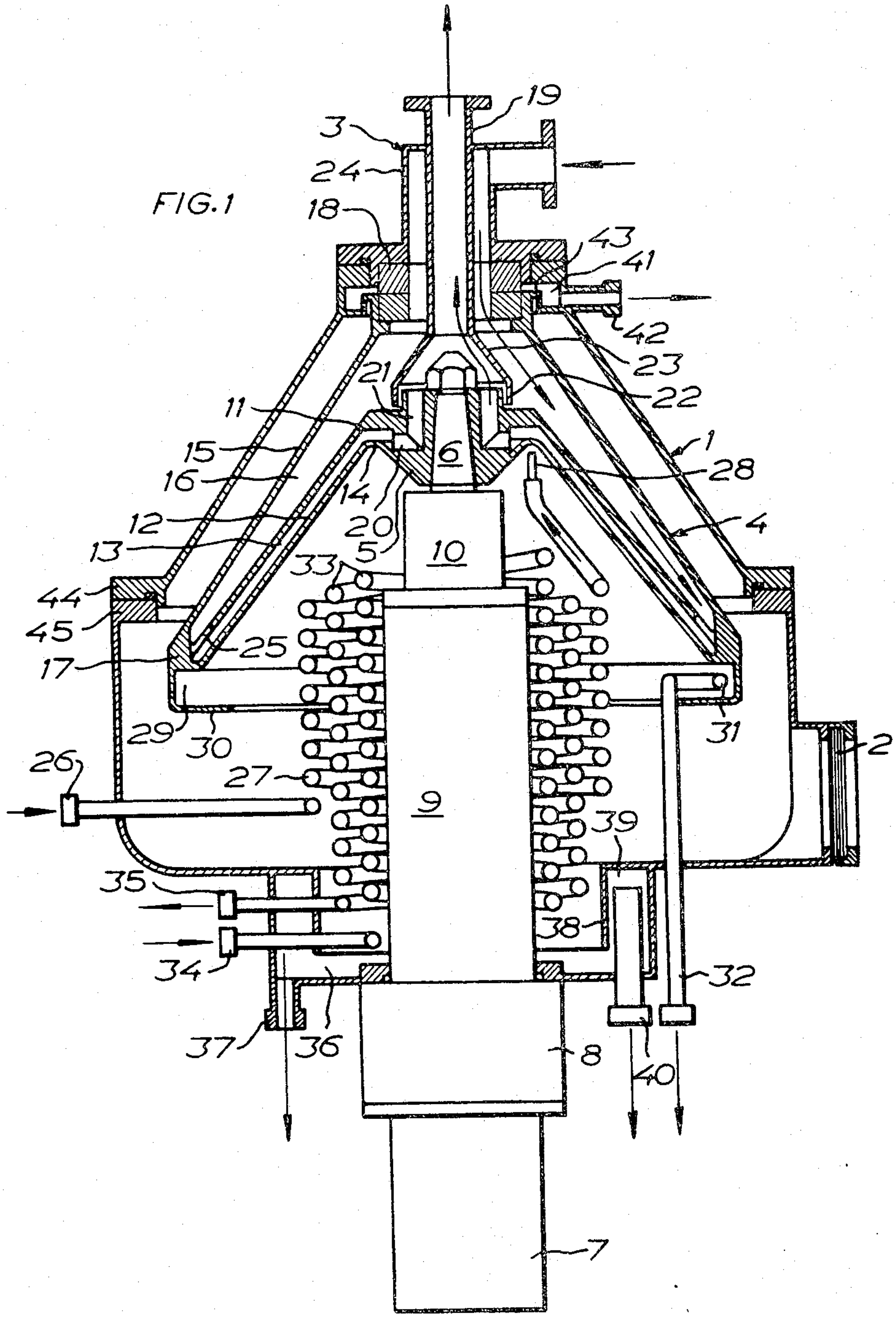
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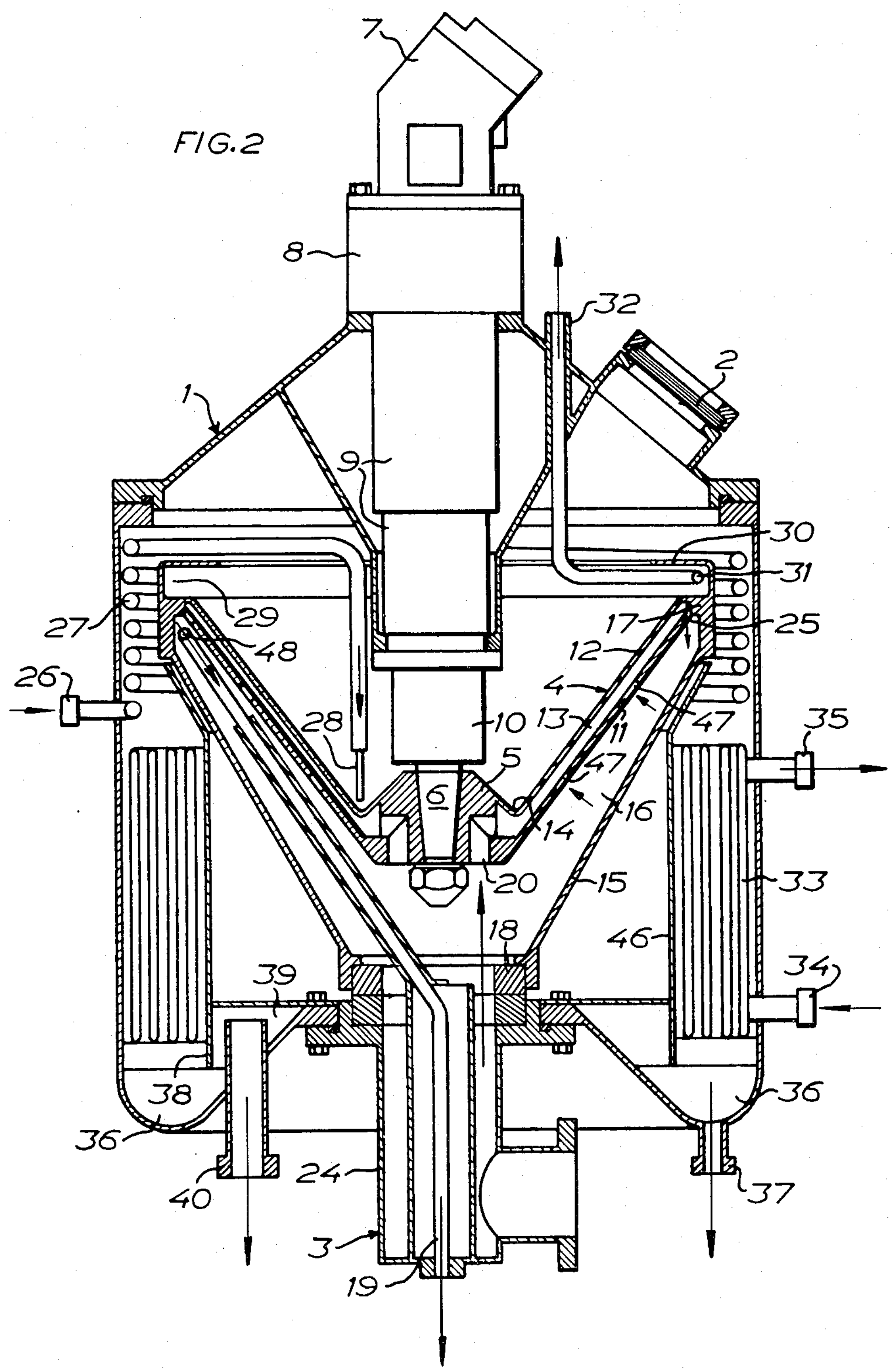
FIG.2



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APPARATUS FOR INDIRECT HEAT TREATMENT OF LIQUIDS

For example, Swedish Pat. Nos. 181,821, 184,175, 206,743 and U.S. Pat. No. 2,734,023 describe apparatuses for the indirect heat treatment of liquids, and these apparatuses can be exploited for continuous concentration, distillation, separation, deodorization etc.

This invention relates to an apparatus of the same type, that is, an apparatus which has a hollow rotor body which is heatable by means of a vaporous or liquid heat carrier and which is mounted for rotation in a vacuum-tight casing, the liquid to be heat-treated being distributed and flowing as a thin cohesive layer on the inner rotation-symmetrical surface of said rotor body, and the apparatus comprises a drive for the rotor body, inlet and outlet means for the heat carrier, and inlet and outlet means for the liquid subjected to the heat treatment.

One of the objects of the invention is to improve the prior-art apparatuses and to permit as rapid and effective a heat treatment of the liquids as possible with the use of an apparatus which is of simple design, reliable in operation and allows an intense heating through liquid or vaporous heat carriers and besides a rapid cleaning and exact control of the course of the heat treatment.

Another and essential object of the invention is to permit keeping the heat carrier at a higher temperature of up to and above 250°C, since the prior-art apparatuses allow only temperatures of up to about 125°C and therefore are not suitable for every type of heat treatment of liquids, such as the distillation of fatty acids and fractions of phenol where temperatures of about 200°C are required.

To achieve these and further objects the apparatus according to the invention comprises the features that the rotor body is formed substantially as a frusto-conical member and has a central supporting hub which supports the rotor body and is connected to a frusto-conical supporting partition in the rotor body, said partition being at its outer edge directly or indirectly connected, on the one hand, to a frusto-conical inner wall, the inner side of which constitutes said inner rotation-symmetrical heat exchanging surface in the rotor body and which at its inner edge is connected in a vapor- and liquid-tight manner to the central supporting hub, and, on the other hand, to a frusto-conical outer wall, the inner edge of which is directly or indirectly connected in a rotary and liquid- and gas-tight manner to the vacuum-tight casing, gaps being formed between, respectively, the inner walls and the partitions and the partitions and the outer walls in the rotor body to permit flow of the heat carrier therethrough, said gaps being interconnected at least at their outer ends and that gap which adjoins the frusto-conical inner wall possibly having inner flow-agitating or flow-conducting means, and the supporting hub having at least one channel which opens into the gap between the inner walls and the partitions to permit flow of the heat carrier therethrough, and the inlet and outlet means for the heat carrier are connected to the inner gaps of the rotor body via a head which is stationarily mounted on the vacuum-tight casing and to which the inner edge of the frusto-conical outer wall of the rotor body is directly or indirectly connected in a vapor- and liquid-tight manner.

Some embodiments of the invention will be more fully described hereinbelow and with reference to the accompanying drawings, in which:

FIG. 1 shows an axial section of a distillation apparatus;

FIG. 2 shows an axial section of another embodiment of the apparatus, which is suited for concentration, distillation, separation, deodorization etc.

The apparatus illustrated in FIG. 1 has a vacuum-tight casing **1** with one or more inspection openings **2** in the form of doors or windows, and a connecting head **3** for purposes indicated more in detail in the following. A rotor body **4** is mounted for rotation in the casing **1**. This rotor body is mainly formed as a frusto-conical member and has a central supporting hub **5** which is mounted on a shaft **6** which extends from below into the vacuum-tight casing **1**. The shaft **6** is driven by a drive or motor **7** via a coupling housing **8** and passes through a bearing housing **9** and sealing device **10**. The rotor body **4** itself has a frusto-conical supporting partition **11** which at its narrow end, that is, its inner end, is rigidly connected to or integral with the hub **5**. A likewise frusto-conical inner wall **12** is provided inside the partition **11** and the inner side of said frusto-conical inner wall **12** constitutes a rotation symmetrical heat-exchanging surface. The inner wall **12** is spaced a short distance from the partition **11** so that an inner narrow gap **13** is formed. At its inner side the inner wall **12** is connected to the hub **5** via a dilatation means **14** in the form of a fold which permits movements due to length expansion phenomena during the operation of the apparatus. An outer wall **15** is arranged on the other side of the partition **11** at a slightly greater distance therefrom in order that an outer wider gap **16** shall be formed between them. The partition **11**, the inner wall **12** and the outer wall **15** are interconnected at their outer ends by means of an outer ring **17**. The outer wall **15** is also of frusto-conical shape and has its upper end rotatably connected to the casing **1** by means of a vapor- and liquid-tight slide ring seal **18**. A great advantage of so designing the rotor with a supporting partition **11** is that the inner wall **12** can be made very thin and, consequently, is particularly suited for heat transmission purposes. Moreover, flow-agitating or flow-conducting means (not shown) can be arranged in the gap **13** to provide or intensify a turbulent flow in said inner gap **13**. Said means can be, for instance, a conically and helically wound wire coil the convolutions of which define between them a flow channel starting at the channels **21** and terminating at the outlets **24**. Alternatively, said means may be vanes or like elements.

The connecting head **3** has a stationary inner flow conduit **19** for a heat vehicle, which is connected to the channels **20** of the supporting hub **5** through which channels the heat carrier is to flow and which are connected to the inner gap **13** of the rotor body. The flow conduit **19** is sealed with respect to the supporting hub with the aid of a suitable seal, in the present instance a labyrinth seal **21**, which is formed between an upstanding annular surface **22** of the hub **5** and a widened main portion **23** at the lower end of the inner flow conduit **19**. The connecting head **3** has an outer flow conduit **24** which is connected to the outer gap **16** between the partition **11** and the outer wall **15** of the rotor. The conduits **19** and **24** are each provided with one connecting socket. To permit flow of the heat carrier through the rotor the partition **11** is formed with perforations **25** at its connection with the outer ring **17**. The heat carrier, in this embodiment a liquid, can be introduced through the outer conduit **24** and discharged through the inner conduit **19**, the heat carrier flowing in the direction of the arrows through the rotor body **4**. Alternatively, the direction of flow may be the opposite one, the heat carrier being supplied through the inner conduit **19** and discharged through the outer conduit **24**. An advantage gained by this embodiment is that a turbulent flow of the liquid heat carrier can be obtained when said carrier flows through the inner narrow gap **13**. Another advantage gained by this embodiment is that a liquid heat carrier can be utilized, which is not possible in similar, previously known apparatuses.

The liquid to be heat-treated is fed into the vacuum-tight casing **1** through an inlet conduit **26** which is connected to a preheater **27** in the form of a pipe coiled around the bearing housing and connected at its outlet end to a nozzle **28** which directs the liquid to be heat-treated towards the upper end of the inner wall **12** of the rotor at the dilatation means **14**. The liquid subjected to heat treatment then flows downwards along the inner wall **12**, on the one hand, by centrifugal force because of the rotation of the rotor body **4**, and, on the other hand, by gravity. The heat-treated liquid product is collected at the lower end of the rotor body in a gutter **29** which is formed by an angular flange **30** extending all the way around, and being secured to, the outer ring **17**. The heat-treated liquid is discharged from the gutter **29** with the aid of a scoop pipe **31** which is connected to an outlet **32** for the heat-treated liquid.

The vapors escaping from the heat-treated liquid flowing on the inner wall **12** are condensed and cooled with the aid of a cooler **33** which is in the form of a reciprocating helically wound pipe coil which extends inside the preheater **27** and around the bearing housing **9**. The cooler **33** has an inlet **34** and an outlet **35**.

Both the preheater **27** and the cooler **33** extend into the conical rotor body **4**, so that the vapors escaping from the heat-treated liquid will contact the preheater **27** and the cooler **33** as quickly as possible in order that these vapors be condensed as quickly as possible and the condensate be cooled off. The condensate is collected at the bottom of the casing **1** in a collecting trough **36** which has an outlet **37** for the condensate. An annular neck **38** which shields off a space **39** from which a suction conduit **40** extends, passes down into the collecting trough **36**. The conduit **40** is connected to a vacuum pump.

A small annular space **41** is provided at the top of the casing **1** for the collection of possible leakage of flushing liquid used in the slide ring seal **18** so that such leakage cannot penetrate into the casing **1** proper but is instead removed through an outlet conduit **42** preferably connected to a vacuum pump via a control sight glass (not shown). The annular space **41** is connected to the interior of the casing **1** through a narrow gap about the outer wall **15** of the rotor, the upper end of said wall being provided with a flange **43** which under centrifugal force throws the flushing liquid, if any, into the groove **41**.

The embodiment of the invention illustrated in FIG. **1** provides an extremely effective heat treatment, particularly distillation of liquids. By varying the speed of the rotor body **4** it is possible always to keep the entire heat-exchanging surface of the inner wall **12** covered with a thin liquid film so that an effective heat treatment of the liquid and a maximal exploitation of the heat-exchanging surface is ensured. By its rotation the rotor will provide an effective separation of liquid and vapor bubbles already in the liquid film proper, and liquid droplets possibly accompanying the escaping vapors will again be thrown outwardly against the liquid film since the entire vapor volume inside the rotor is revolving. It is very simple to operate and control the apparatus and it is also simple to carry out the maintenance thereof.

In the embodiment of the invention illustrated in FIG. **2** the rotor body **4** has its apex turned downwards, while the motor **7**, the coupling housing **8**, the bearing housings **9** and the shaft sealing means **10** are provided at the top of the vacuum-tight casing **1**. In the FIG. **2** embodiment the treated liquid flows in an upward direction along the inner side of the inner wall **12** by the action of centrifugal forces, and after heat treatment has been performed it is collected in the gutter **29** from which it is removed like in FIG. **1** with the aid of a scoop pipe **31**. In this case the preheater **27** for the liquid product to be heat-treated has been placed radially outside the outer ring **17** of the rotor body **4** in an annular gap between the casing **1** and the rotor. The cooler **33** for condensing and cooling the vapors escaping from the heat-treated liquid is placed beneath the preheater **27** in an annular space between the outer wall of the casing **1** and a radiation shielding screen **46** which prevents heat radiation from the rotor body **4** to the cooler **33**. Like in the embodiment according to FIG. **2** there is a collecting trough **36** at the bottom of the casing **1** and from this trough the condensate is discharged through an outlet **37**.

In the embodiment according to FIG. **2** the inner construction of the rotor is slightly different because the rotor has been arranged with its broader end turned upwards. In the embodiment illustrated, use is made of a vaporous heat carrier which enters the connecting head **3** through the outer conduit **24**. The vapor flows upwards, passing through the channels **20** of the hub **5** and a number of through holes **47** in the partition **11**. Vapor condenses on the surface of the inner wall **12** in the form of small droplets which are thrown by centrifugal force outwards against the partition **11**, flowing along said partition in an upward direction towards the outer ring **17** where the condensate is collected. By the condensate droplets being thrown outwards against the partition in this way an efficient heat transmission is rendered possible from the vapor to the inner wall **12**, whereby an effective heat exchange is provided. The condensate is removed with the aid of a scoop pipe **48** which is connected to the outlet conduit **19**. The embodiment according to FIG. **2** can be modified for use of a liquid heat carrier by substituting the connecting head **3** having the cap **23** in FIG. **1** for the connecting head **3** having the scoop pipe **48**. To permit this the hub **5** has to be modified and be given the same apperance as in FIG. **1** and in addition it must be equipped with an annular surface **22**. By this modification of the embodiment according to FIG. **2** it is possible to use higher temperatures of the heat carrier since the carrier may be liquid.

The embodiment according to FIG. **2** is particularly suited for concentration, distillation, separation, deodoriztion etc. The apparatus can be used for heat-sensitive liquids and also for highly viscous liquids. In treating heat-sensitive liquids evaporation takes place at low temperature in that vacuum is established in the vacuum-tight casing **1**, and a great advantage is that the time of stay of the liquid on the heat-exchanging surface is short.

Contrary to conventional thin-film evaporators which operate by gravity, the present invention exploits centrifugal force for the generation of the thin film. Centrifugal force permits a controlled and continuous distribution of the liquid solution on the evaporator surface, and the control of the thickness of the liquid film is readily made by visual or stroboscopical observation of the inner wall **12** of the rotor body through the inspection window **2**. The vapors escaping from the heat-treated film are led the shortest way to a condenser which comprises the preheater **27** and the cooler **33**, where the vapors are condensed for removal in liquid form. Since it has been possible to make the distance from the heat-exchanging surface to the cooler/condenser very short in the embodiments according to FIGS. **1** and **2**, the separated portion of the liquid is subjected to high temperature only for a short time, and because of that the apparatus is particularly suited for the distillation of heat-sensitive liquids.

The apparatus according to the present invention is advantageous in that the vapors removed from the heat-treated liquid are dry and free from caught liquid particles since a centrifugal separation of vapor and liquid is obtained in the liquid film proper on the surface of the rotor body and since liquid particles that may accompany the vapor will be exposed to a centrifugal separation because the entire vapor volume in the rotor body is rapidly revolving. The thickness of the liquid film on the evaporation surface **12** can be varied int. al. by variation of the speed of the rotor body and the rate of supply of the liquid. By heating the liquid to a temperature slightly below the evaporation temperature before the liquid is supplied to the heat-exchanging surface the evaporation capacity will increase. The apparatus according to the invention also makes it possible to carry out a high-grade concentration in one step thanks to the effective heat exchange.

The apparatus according to the present invention is very advantageous in that it is possible, by reason of the extremely short time of stay in the apparatus, rapidly and easily to establish balance conditions in continuous operation and in that it is possible visually to control the heat-treating process. All this implies great savings of the amount of treated liquid that is necessary for the running-in and the optimization of the operating parameters. Likewise the cleaning and maintenance of the apparatus is very simple and can be rapidly effected, for which reason small liquid batches can be treated in the apparatus for testing or other purposes and products can rapidly be exchanged without long operational standstill. In the embodiments according to FIGS. **1** and **2** it is thus possible, by opening the inspection window or windows **2**, readily to get at the heat-exchanging surface **12**, cleaning it mechanically as well as chemically. It is also possible to introduce a washing and flushing liquid for similar purposes through the inlet **26**.

It takes only a few minutes to start the apparatus, inclusive of the control of the operating parameters (rotor speed, operating pressure, amount of liquid supplied per unit of time, temperature control of the heat carrier, amount of coolant per unit of time). Because of the insignificant time of stay in the apparatus balance conditions can be set considerably more rapidly. At the end of the treatment the apparatus should preferably be cleaned immediately, after the supply of the heat carrier has been stopped.

What I claim and desire to secure by Letters Patent is:

1. An apparatus for indirect heat treatment of a liquid comprising a vacuum-tight casing, a substantially frusto-conical rotor body mounted for rotation in said casing, said rotor including a central supporting hub means, a frusto-conical supporting partition wall, a frusto-conical outer wall, and a substantially frusto-conical inner wall constituting an inner rotation-symmetrical heat exchange surface on said rotor body, said partition wall being connected at its narrow end to said hub means, said outer wall being connected at its narrow end in a rotary and fluid-tight manner to said vacuum-tight casing and said inner wall being connected at its narrow end in a fluid-tight manner to said central hub means, said partition, said outer and said inner walls being interconnected at their wider ends, and said inner wall and said partition, and said partition and said outer wall being spaced apart to form gaps therebetween permitting flow of heat carrier fluid therethrough, apertures in said partition wall interconnecting the gaps on each side of said partition wall at least at their outer ends near the wider end of said rotor body, said hub means having at least one channel which opens into the gap between said inner and said partition wall means to permit flow of the heat-carrier fluid therethrough, a drive shaft supported with one end cantilevered into said vacuum-tight casing and supporting said rotor body for rotation therewith, motor means connected to the other end of said shaft for rotating said shaft and said rotor body, a connecting header mounted on said vacuum-tight casing and having inlet and outlet conduits for the heat-carrier fluid, said inlet and outlet conduits being connected to said gaps in said rotor body, inlet means arranged to direct the liquid to be treated into said vacuum-tight chamber and onto the exposed surface of said inner wall near its narrow end, and outlet means for the heat treated liquid.

2. An apparatus as claimed in claim **1**, wherein the stationarily mounted head of the casing has a stationary inner flow conduit for the heat carrier, which is connected to the channel or channels of the supporting hub through which the heat carrier is intended to flow and which is sealed against the supporting hub around said hub or the channels thereof, and a stationary outer flow conduit for the heat carrier, which is sealed against the outer wall of the rotor body and the vacuum-tight casing.

3. An apparatus as claimed in claim **2**, wherein the outer flow conduit is sealed against the outer wall of the rotor body and the vacuum-tight casing by means of a mechanical seal operating with a flushing liquid.

4. An apparatus as claimed in claim **1**, wherein said partition wall has through holes distributed over the surface of said partition and interconnecting the two inner gaps of the rotor body.

5. An apparatus as claimed in claim **1**, wherein the entire rotor body is welded to form a continuous unit and wherein, the conical inner wall of the rotor body is connected to the supporting hub via a dilation device.

6. An apparatus as claimed in claim **1** wherein the rotor body at its large end has an inwardly directed flange to form an annular collecting gutter for liquid to be subjected to heat treatment, said liquid being supplied at the hub of the rotor body and allowed to flow along the inner side of said rotor body in an outward direction, the outlet for said liquid being in the form of a scoop pipe inserted in said collecting gutter.

7. An apparatus as claimed in claim 1, wherein a preheater for the liquid being treated is provided in the vacuum-tight casing.

8. An apparatus as claimed in claim 1, wherein a condenser and/or cooler for substances separated from the heat-treated liquid is provided in the vacuum-tight casing.

9. An apparatus as claimed in claim 7, wherein the rotor body is arranged with its large base end turned downwards, and the preheater and, respectively, the condenser and/or the cooler is provided within and optionally extends downwards beneath the rotor body.

10. An apparatus as claimed in claim 8, wherein the rotor body is arranged with its large base end turned upwards, and the preheater and respectively, the condenser and/or cooler is provided radially outwardly of the rotor body.

11. An apparatus as claimed in claim 10, wherein a stationary scoop pipe for the heat carrier is provided in the annular gap of the rotor body between the partition and the outer wall.

12. An apparatus as claimed in claim 11, wherein the preheater for the treated liquid is a pipe coil extending about the rotor body outside of the large end thereof.

13. An apparatus as claimed claim 12, wherein the condenser and/or the cooler is arranged about the rotor body in the area of and above the small end thereof.

14. An apparatus as claimed in claim 13, wherein the condenser and/or the cooler is shielded against heat radiation from the rotor body by means of a screen.

15. An apparatus as claimed in claim 1, wherein the drive is mounted on the concave side of the rotor body, and the inlet and outlet means for the heat carrier are connected to the rotor body from the convex side of said body.

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