March 17, 1970 R. C. ROE 3,501,382

DISTILLATION-CONDENSER WITH VERTICALLY DISALIGNED TUBES

Filed Feb. 21, 1967 6 Sheets-Sheet 1

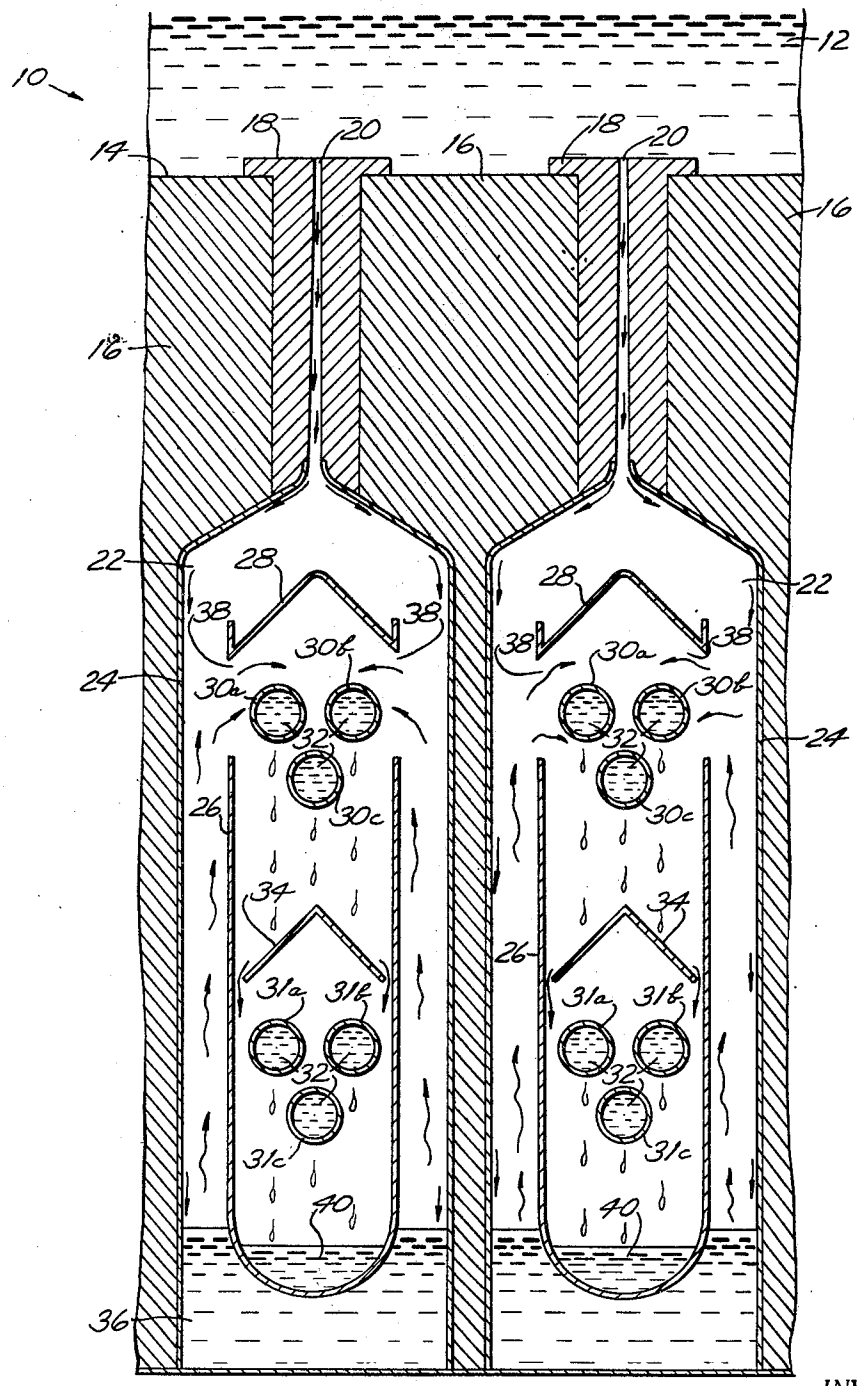


Fig. 1.

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DISTILLATION-CONDENSER WITH VERTICALLY DISALIGNED TUBES

Filed Feb. 21, 1967 6 Sheets-Sheet 2

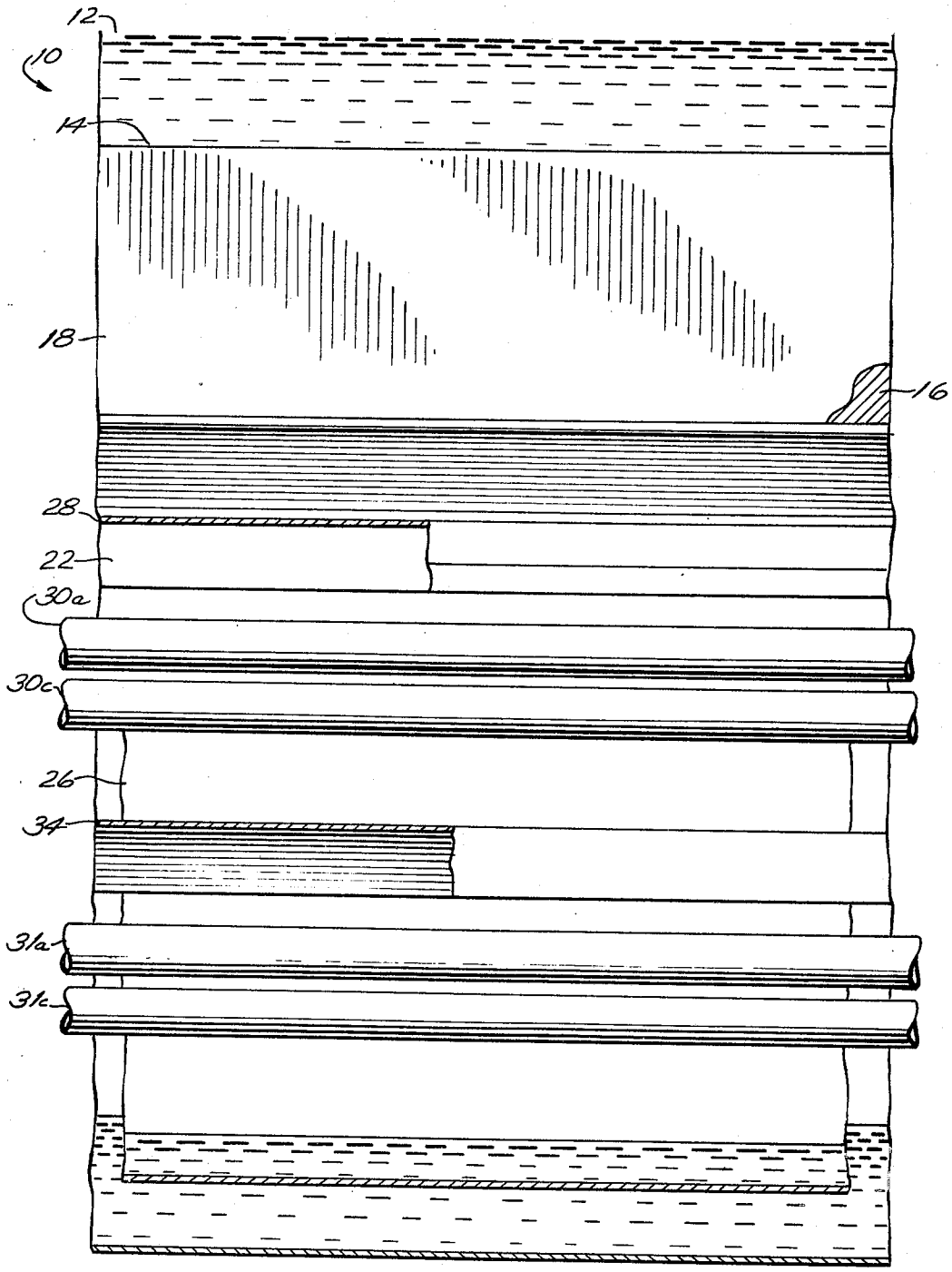


Fig. 2.

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DISTILLATION-CONDENSER WITH VERTICALLY DISALIGNED TUBES

Filed Feb. 21, 1967 6 Sheets-Sheet 3

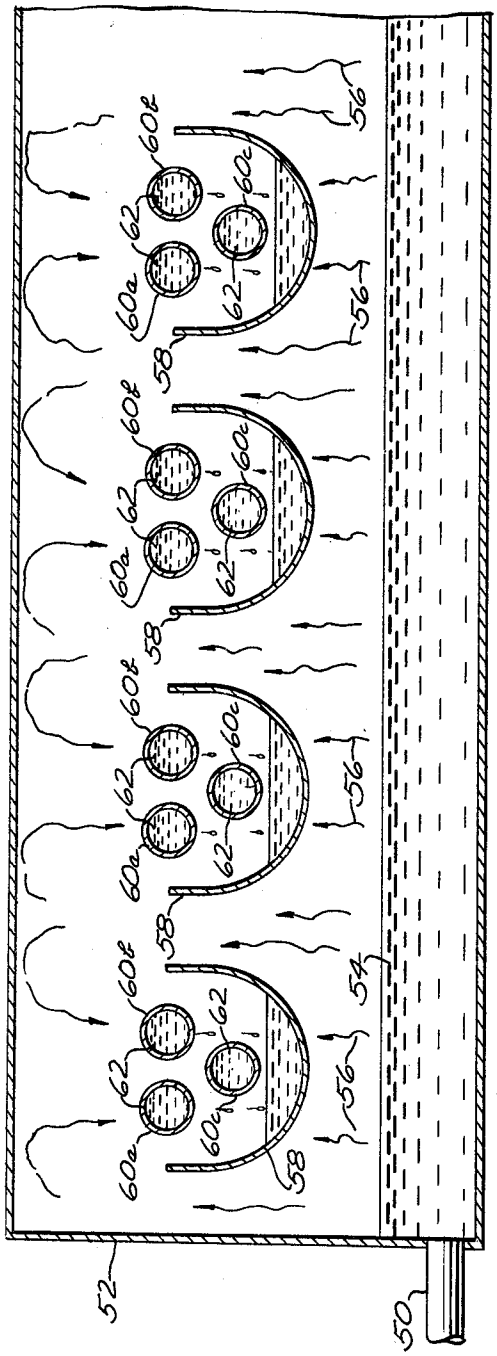


Fig. 3.

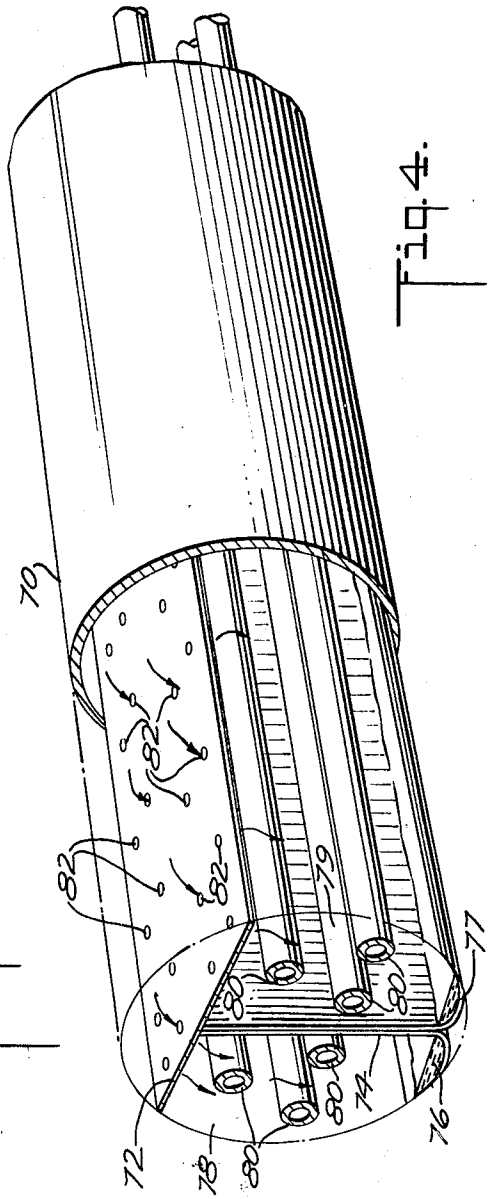


Fig. 4.

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March 17, 1970 R. C. ROE 3,501,382

DISTILLATION-CONDENSER WITH VERTICALLY DISALIGNED TUBES

Filed Feb. 21, 1967 6 Sheets-Sheet 4

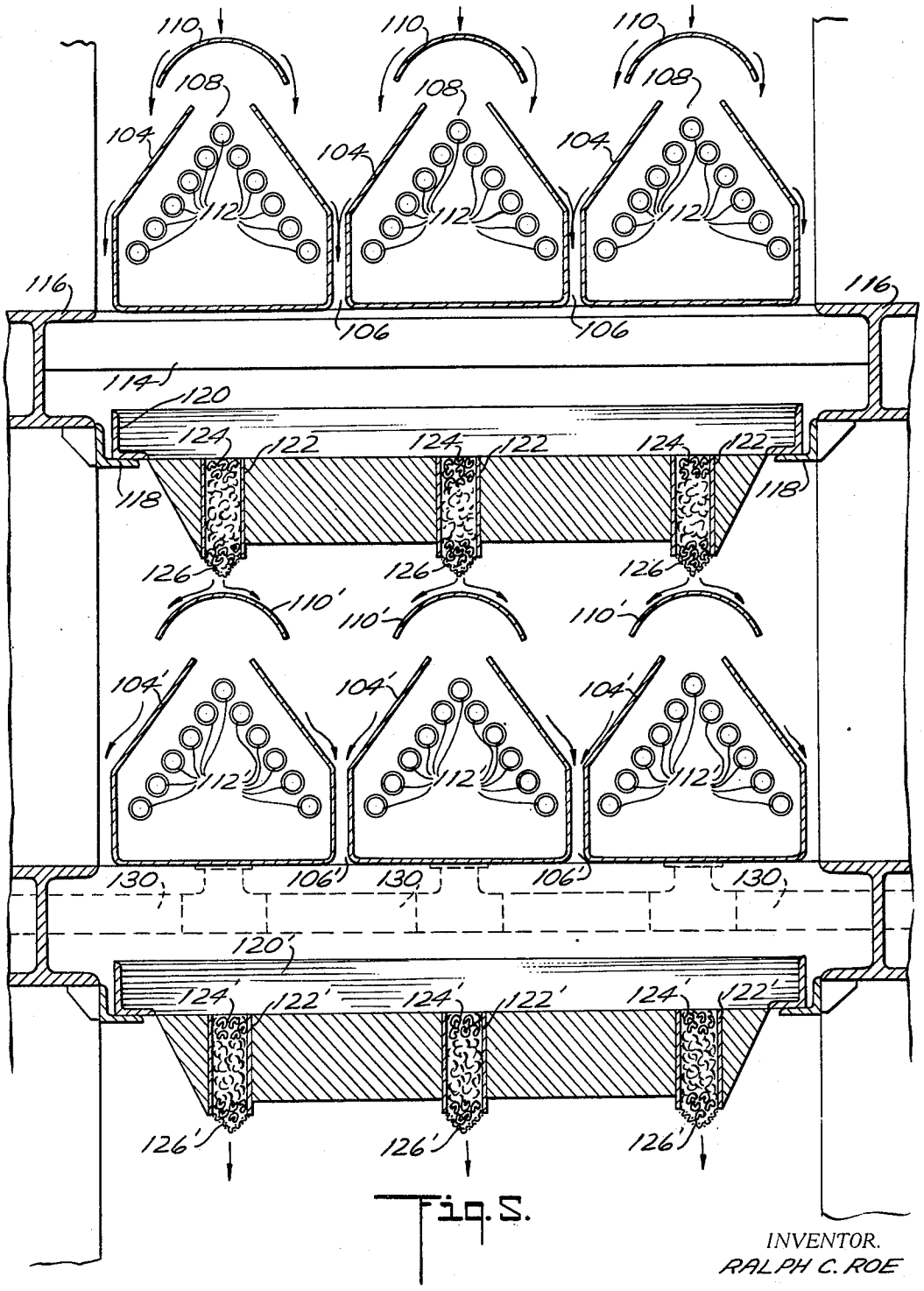


Fig. 5.

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DISTILLATION-CONDENSER WITH VERTICALLY DISALIGNED TUBES

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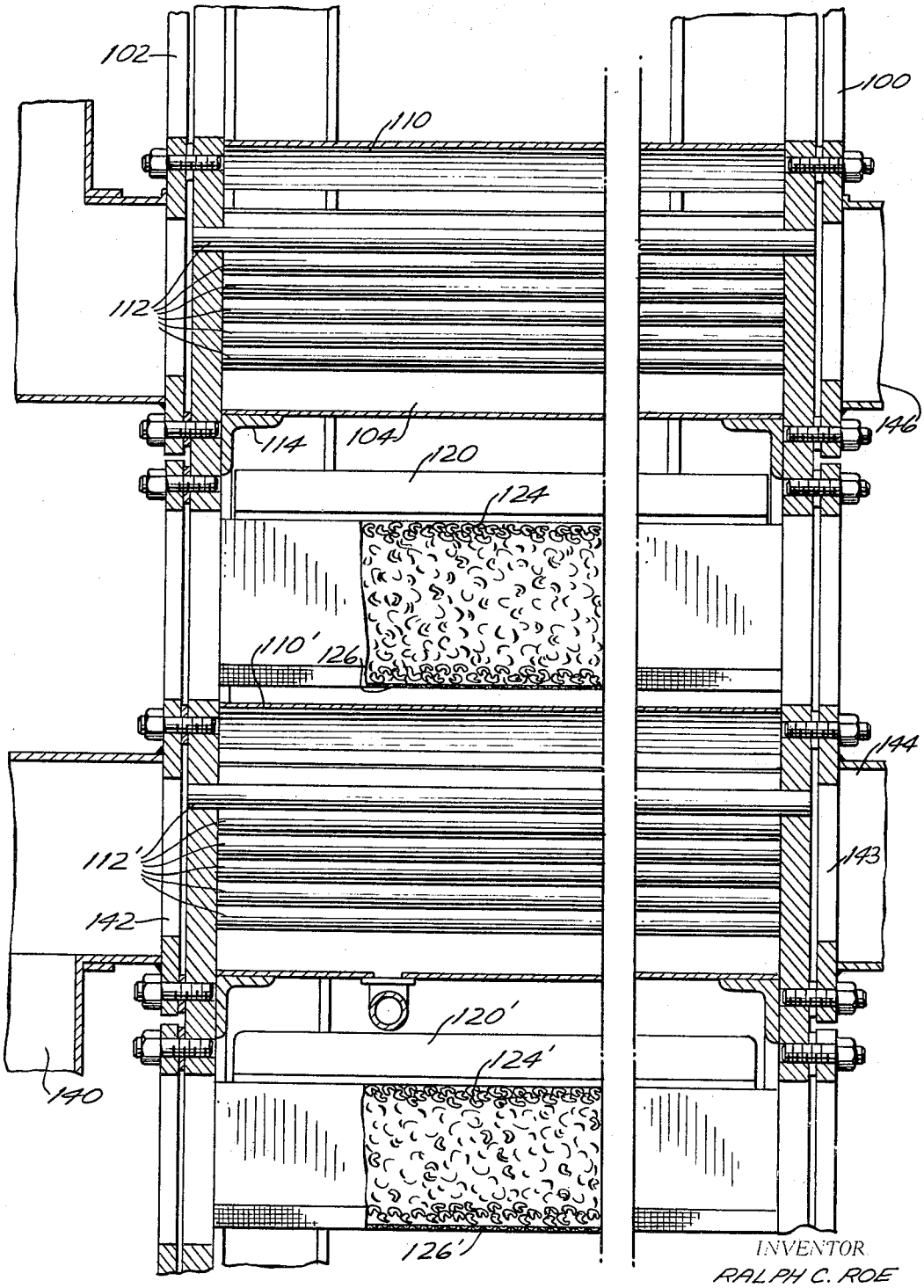


Fig. 6.

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DISTILLATION-CONDENSER WITH VERTICALLY DISALIGNED TUBES

Filed Feb. 21, 1967 6 Sheets-Sheet 6

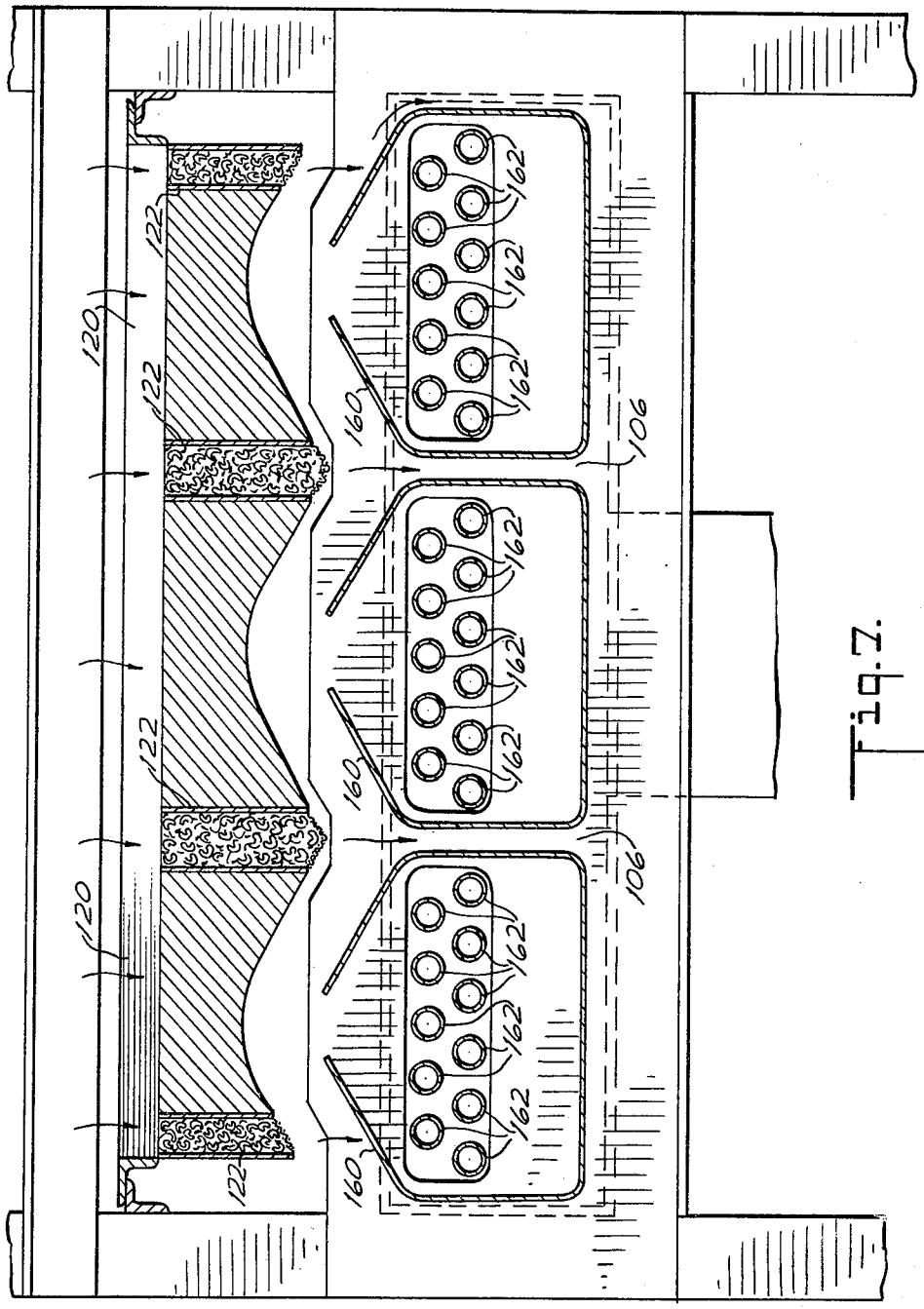


Fig. 7.

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United States Patent Office 3,501,382 Patented Mar. 17, 1970

3,501,382

DISTILLATION-CONDENSER WITH VERTICALLY DISALIGNED TUBES

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Int. Cl. B01d 3/28; F28b 9/10
U.S. Cl. 202—185 6 Claims

ABSTRACT OF THE DISCLOSURE

Surface condensers with coolant tubes arranged in vertical disalignment and occupying only small percentage of condenser volume. Surface condensers integrated in multistage controlled flash evaporation system.

This invention relates to vapor condensation and more particularly it concerns novel surface condenser arrangements useful in recovering fresh water from steam.

Surface condensers are widely used in connection with steampower plants in order to reduce the volume and therefore the back pressure of exhausted steam so that a greater measure of power may be obtained from the system. Surface condensers have also been used in evaporation-condensation systems for the recovery of fresh water from saline or otherwise contaminated solutions.

The basic structural configuration of a surface condenser involves an enclosure or outer elongated covering which is closed at each end by means of a tube sheet. A plurality of condenser tubes extend along the interior of the enclosure and pass throguh the tube sheets at each end thereof. A cooling fluid is caused to pass through the condenser tubes and serves to maintain their surfaces at a low temperature. Steam or other vapor to be condensed is then admitted into the enclosure; and when it contacts the cooler surface of the condenser tubes it condenses thereon into liquid form and drips down into a fresh water collection trough located below the tubes.

In order to obtain maximum cooling it has been the practice to increase the condenser tube surface area to the greatest extent possible and to distribute this area throughout as much of the condenser interior as possible. Accordingly, conventional condenser construction involves the use of a very large number of condenser tubes nested within the interior of the condenser. Typical prior art condensers have anywhere from 22 to 45% of the area of their tube sheets occupied by the condensing tubes.

The large number of condensing tubes used in prior condensers accounts for a major portion of the expense of these devices. In addition, structural problems result from the use of a large number of condensing tubes, since very little of the tube sheet remains at each end of the condenser to provide support for these condenser tubes. As a result, special reinforcing structures have to be provided. This also contributes greatly to the cost of the condenser.

The present invention provides a surface condenser arrangement which is less complex and therefore is more economical to construct than prior condensers of comparable capacity. Moreover, such condenser does not suffer from the structural difficulties encountered by prior art condenser arrangements.

According to one aspect of the present invention, there is provided a surface condenser unit within which a plurality of condenser tubes extend horizontally and are arranged such as to be in vertical disalignment so that no condenser tube extends directly above another tube. With this arrangement, the condensate which forms at any location along any of the tubes, drops directly down from

that location and avoids all further contact with the tubes. As a result the condenser tubes are kept nearly completely free of condensate film and therefore are maintained at maximum heat transfer effectiveness.

The present invention, in another aspect, utilizes only about 2 to 5% of the tube sheet area to be occupied by the condenser tubes. While this involves a considerable reduction in area of the condensing surfaces, it has been found that such reduction is more than compensated for by the increased availability and increased heat transfer per square foot of tube surface of the condenser surfaces to the incoming vapors to be condensed. In the past, where steam had to be forced through a congested nest of condenser tubes, it was not possible to utilize each tube to its fullest capacity since the incoming steam would initially contact the forwardmost tubes and be condensed prior to contacting the rearward tubes. Further the rearward tubes were contacted by steam to be condensed only after it has been forced through the entire tube nest; and the rearward tubes would become effective to condense the steam only after the forward tubes were rendered less effective by the buildup thereon of a film of condensate. Furthermore, in the conventional condenser there is a substantial pressure drop through the tube bank which is eliminated in this arrangement.

The present invention involves the use of relatively few condenser tubes so that the incoming vapors to be condensed are not forced over one tube prior to contacting the tube upon which they are condensed, but instead they are caused to be condensed directly upon the first tube they contact.

The present invention in a still further aspect involves the integration of the novel condensing concepts mentioned above into a controlled flash evaporation system to provide a self-contained structure for the recovery of fresh water from salt water or other contaminated solutions. According to this aspect of the invention there art provided controlled flash evaporation channels down through which water to be evaporated passes from a higher to a lower pressure. In the lower pressure region there are provided condenser tubes and baffle arrangements along with a fresh water collection trough and an unevaporated collection trough for separating and distributing the unevaporated solution and the recovered fresh water. This arrangement lends itself particularly well to multistaging in an economically constructed unit.

Specific embodiments of the invention have been chosen for purposes of illustration and description, and are shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. 1 is a fragmentary section view of an evaporator system embodying novel condenser means according to the present invention;

FIG. 2 is a side view, partially broken away illustrating the fresh water recovery system of FIG. 1;

FIG. 3 is a section view, taken in elevation illustrating a second embodiment of the present invention;

FIG. 4 is a perspective view, partially broken away, illustrating a condenser arrangement according to the present invention;

FIG. 5 is a section view taken in elevation illustrating a portion of a multistage controlled flash evaporator type fresh water recovery system having integrated therein novel condenser means according to the present invention;

FIG. 6 is a partial side view of the system of FIG. 5; and

FIG. 7 is a section view taken in elevation showing one stage of a still further fresh water recovery system according to the present invention.

As shown in FIGS. 1 and 2 there is provided a fresh water recovery unit illustrated generally at **10**. At the

top of this unit there is provided a reservoir of saline water **12** from which fresh water is to be recovered. The body of saline water **12** rests upon an upper surface **14** formed by a plurality of elongated structural members **16**. These elongated structural members are interrupted periodically by downwardly extending channel members **18**. The channel members **18**, as illustrated in FIG. 2, extend horizontally along with the structural members **16** from the front to the back of the unit **10**. The channel members **18** each define a narrow evaporation channel **20** which opens to and extends vertically between the reservoir of saline water **12** and an associated condenser region **22**. The condenser regions **22** are of considerably greater width than their associated evaporation channels **20**; and, as illustrated in FIG. 2, they also extend from the front to the rear of the device.

Each condenser region **22** is lined with a waterproof liner **24**. Inside the condenser regions **22** there is provided a U-shaped separator element **26** which extends from the front to the back of the device.

Approximately halfway between the top of the U-shaped separator element **26** and the top of the condenser regions **22** there is provided a canopy-like upper baffle **28** which extends over the separator elements **26** to prevent any liquid droplets from falling directly down into the U-shaped separator element.

As shown in cross section in FIG. 1, there is provided an upper set of condenser tubes **30***a*, **30***b* and **30***c*, within the condenser region **22**. There is additionally provided a lower set of condensing tubes **31***a*, **31***b* and **31***c* just under the upper set within the condenser region. The condenser tubes extend horizontally from the front to the back of the device and are supplied with coolant liquid **32** from an external source (not shown). It will be noted that the condenser tubes in each of the sets are arranged along a triangular pattern so that no tube in any set is directly above another tube in that set. This vertical disalignment of the tubes serves to prevent drippage of condensate from any one tube down upon another tube in the set.

An intermediate baffle **34** is placed between the two sets of tubes **30** and **31** in order to direct the condensate which falls from the upper set away from the tubes of the lower set.

The system thus far described operates in the following manner: The saline water **12** located above the upper surface **14** is maintained at pressure and temperature conditions corresponding to saturation. That is, any increase in temperature or any decrease in pressure will cause vaporization of the water **12**. The saline water flows gradually down through the evaporation channels **20** in the channel members **18** toward the condenser regions **22**. During such downward flow the water experiences a gradual pressure drop which results in a controlled flash-type evaporation. In this controlled flash type evaporation, a portion of the saline water vaporizes, thereby extracting heat from the unevaporated portion. This vapor occupies a much greater volume and has much less inertia than the unevaporated liquid. Accordingly it is impelled at a rapid rate downwardly through the channel **20**. This rapid movement of vapor is accompanied by a smoothly distributed pressure gradient along the channel which results in a gradual evaporation, or controlled flash along the channel. This controlled flash evaporation is similar to that achieved according to U.S. Patent 3,214,350. Both vapor and unevaporated saline water are discharged from the bottom of the channels **20** into the condenser region **22**. The unevaporated liquid tends to adhere to the waterproof liner **24** in the condenser region and thus for the most part, follows the walls of the condenser region **22** down to a saline water collection trough **36** at the bottom of the condenser region **22**. Any premature drippage of the unevaporated saline water is prevented by the upper baffle **28** from entering into the interior of the U-shaped separator element **26**.

The vapors which issue from the descending saline water in the channels **20** fill the greater portion of the interior of the condenser regions **22**, and proceed through spaces **38** between the upper baffle **28** and the top of the U-shaped separator element **26**. These vapors enter into the interior of the U-shaped separator element **26**, and in so doing, they directly contact the outer surface of the condenser tubes **30***a*, **30***b* and **30***c*. These condenser tubes, as illustrated in FIG. 2, extend in a horizontal direction; and as illustrated in FIG. 1 they are arranged in vertical disalignment so that no condenser tube is directly above another tube. As a result, the condensate which forms at any location falls directly down from that location onto the intermediate baffle **34** and from there into the bottom of the U-shaped separator element **26** where fresh water **40** is collected. Similarly, vapors which do not contact the upper tubes **30***a*, **30***b* and **30***c*, pass downwardly past the intermediate baffle **34** and contact the lower tubes **31***a*, **31***b* and **31***c* where they condense into liquid form and drip directly into the condensate pool in the bottom U-shaped element **26**.

It will additionally be noted that the total volume occupied by the condenser tubes occupies only a few percent of the total condenser region volume. This, of course, reduces the complexity and construction costs of the device. However, it is to be noted that this drastic reduction in condenser surface area actually increases the overall condensing effectiveness of the device. In part, this is due to the fact that the horizontal orientation and vertical disalignment of the tubes prevents the buildup of insulating liquid films thereon. In further part, however, this increase in condensing effectiveness is due to the fact that the condenser tubes, in occupying only a few percent of the total condenser interior, provide large spaces between the condenser tubes which permit free and unobstructed flow of incoming vapor without appreciable pressure drop through the tubes directly to the condenser surface on which each portion of the vapor becomes liquified. As a result, fullest use is made of the entire condenser surface area.

FIG. 3 shows, in fragmentary cross section, an alternate form of evaporator-condenser arrangement. In the arrangement of FIG. 3 saline water is directed via an inlet tube **50** into the bottom of a rectangular housing **52** so that there is maintained therein a body **54** of liquid saline water. The pressure and temperature of the water entering through inlet tube **50** are at saturation temperature slightly higher than the pressure within housing **52**. Therefore in order to bring pressure and temperature within housing **52** into equilibrium, a portion of the water entering through inlet tube **50** will flash on the surface of the water pool **54** so that vapors, illustrated schematically by the arrows **56**, are emitted from the upper surface of the water. Immediately above the surface of the body **54** of saline water, there are located generally U-shaped trough like collection elements **58** which open upwardly. A triangularly arranged array of condenser tubes **60***a*, **60***b* and **60***c* extend lengthwise inside each collection element **58**. As in the preceding embodiment, these condenser tubes convey fluid coolant **62** which maintains their outer surfaces at a temperature below the saturation conditions existing within the housing **52**. As the vapors **56** proceed upwardly within the housing **52**, they eventually contact the cooler surfaces of the condenser tubes **60**. As a result, the vapors condense on these surfaces in liquid form.

In the embodiment of FIG. 3, as in the preceding embodiment, it will be noted that the condenser tubes **60***a–c* are arranged to occupy only a very small percentage of the total volume within the housing **52**. Thus, all of the vapors within the housing may travel directly to the condensing surfaces on which they are to be condensed and they are not forced first to pass over other, non-effective condensing surfaces. Additionally, as in the preceding embodiment, the condenser tubes **60** are ar-

ranged in vertical disalignment so that the condensate which forms on their outer surfaces will drop directly into the collection troughs **58** without building up on other condensing tubes thereby impairing their efficiency.

FIG. 4 illustrates a unique condenser arrangement utilizing the principles of the present invention in a manner which may serve to reduce to an even greater degree the costs of condenser construction. As shown in FIG. 4 there is provided a tubular outer housing **70** which may, for example, be formed of pipe or conduit. Toward the upper portion of the interior of the housing **70**, there is provided a horizontally extending inlet plate **72** which extends across the interior of the housing **70** to form a chordal cross section therein. A diametrically positioned partition **74** extends downwardly from the under surface of the inlet plate **72** to a location close to the bottom of the housing **70**. At that location, the partition **74** branches off into two adjoining symmetrical U-shaped configurations which merge with the sides of the housing **70** to form longitudinally extending lower collection channels **76** and **77**. A plurality of condenser tubes **80** extend along inside the housing **70** in vertical disalignment on each side of the partition **74** in regions **78** and **79** just above the collection channels **76** and **77**. Means (not shown) are provided for conveying coolant fluid through the coolant tubes.

Steam or other vapor to be condensed in the apparatus shown in FIG. 4 is passed along inside the housing **70** above the inlet plate **72**. This steam or vapor is then admitted into the regions **78** and **79** in distributed manner via a plurality of inlet holes **82** arranged along the inlet plate **72**. This steam or vapor passes from the various inlet holes **82** directly to the tubes **80** without undergoing any tortuous or turbulent movement. Each elemental portion of this when it is condensed and when it has been converted to steam is condensed directly and immediately upon the condenser surface which it strikes. It then drips directly down in liquid form into the collection channels **76** and **77** thus preventing any buildup of heat insulating liquid film on the condenser tubes.

The arrangement shown in FIG. 4 is especially useful in comparing condenser tubes having different positional arrangement and surface characteristics. For example, the tubes on the left side of the partition **74** may be made of titanium while those on the opposite side may be made of a cupro-nickel composition. So long as the openings **82** in the inlet plate **72** are equally distributed, it can be assumed that the amount of steam or vapor admitted to the tubes on opposite side of the partition **74** will be controlled by the condensing ability of the tubes **80** in areas **78** and **79** respectively on each side of the division plane. Accordingly, the amount of condensate retrieved along the tube channels **76** and **78** serve as a measure of the effectiveness of the different tube arrangements and tube surface and material characteristics in condensing the vapors.

FIGS. 5 and 6 show a still further embodiment of the present invention, such embodiment comprising a multistage controlled flash evaporator with integral condensation provided therein. The system shown in FIGS. 5 and 6 comprises front and rear plate assemblies **100** and **102** between which the various integrated evaporators and condensers (to be described hereinafter) extend. As shown in FIG. 5, toward the top thereof, there are provided a plurality of condenser housings **104** arranged side by side with spaces **106** remaining therebetween. The condenser housings **104**, which may be of sheet metal stock, extend between the front and rear plate assemblies **100** and **102**. In cross section, as illustrated in FIG. 5, the condenser housings have essentially rectangular bottom portions and slanted top portions which terminate in a top opening **108**. Canopy or umbrella-like covers **110** extend over the top opening **108** of each of the condenser housings **104** and are displaced a certain distance thereabove to permit vapors from the surrounding region to enter through the top **108** of the condenser housings **104**. The covers **110**, however, do prevent any liquid droplets which may drop directly downwardly from above, from entering in through the opening **108**.

Within each of the condenser housings **104** there are provided a plurality of condenser tubes **112**. As illustrated, these condenser tubes **112** are arranged with their centers located along two slanted lines which are generally parallel with the upper portion of the condenser housings **104**. It will be appreciated that the condenser tubes **112**, being thusly positioned in vertical disalignment, are arranged such that any condensate which forms on the external surface of one of the tubes, will not drip directly down upon another tube, but instead will fall into the bottom of the condenser housing **104**.

The condenser housings **104** are supported on cross braces **114** which in turn are hung on channel members **116**. Also supported from the channel members **116** are brackets **118** which support a shallow reservoir **120**. This reservoir receives the saline water which has dripped over the covers **110**, onto the upper surfaces of the condenser housings **104** and has flowed down in through the spaces **106** between the condenser housings. This liquid water then drips down into the shallow reservoir **120** where it remains until gradually it flows down through evaporation passages **122**. These evaporation passages extend downwardly from the bottom of the shallow reservoir **120** and are filled with packing material **124** which is supported inside the passages **122** by means of screen **126** at their lower ends. The packing material **124** divides the evaporation passages **122** into a myriad of tortuous passageways extending downwardly through the evaporator passage **122**. These passageways are restricted in cross section so that as vapors are formed from the water flowing down through them these vapors will occupy the major portion of the spaces between the individual particles of the packing material **124**. These vapors are induced to flow rapidly downwardly through the evaporator passages **122** by virtue of the pressure differential which exists across the passages **122**. This pressure differential is converted, by the downward velocity of the vapors, into a uniformly distributed pressure gradient along the evaporation passages. As a result of this gradient there is provided a controlled flash evaporation of the saline water in a manner corresponding to the controlled flash achieved in the embodiment of FIGS. 1 and 2.

Each of the evaporator passages **122** opens directly out onto the top of one of the covers **110** of the next lower stage of the system. Both unevaporated saline water and evaporated vapors issue from the screen **126** of the evaporator passages **122**. The vapors fill the region around the condenser housings **104** while the unevaporated saline water drips down onto lower stage covers **110'**, and flows down along the tops of lower stage condenser housings **104'**, and proceeds down through the spaces **106'** to a lower stage shallow reservoir **120'**.

It will be seen that the several stages of this unit are of substantially identical construction and that any number of stages can be added depending upon the total pressure differential which the system may accommodate.

Also as shown in FIG. 5, in dotted outline, there are provided at spaced locations fresh water collection conduits **130** which relieve the condenser housings **104** of the buildup of fresh water which drips down from the condensing tubes **112**.

As shown in FIG. 6 there is provided a coolant system comprising a coolant inlet conduit **140** which is connected to the wall assembly **102** and which opens via a header **142** into the condenser tubes **112'** in the lower stage. At the opposite end of the unit there is provided another header **143** and collection conduit **144** which receives the coolant fluid from the condenser tubes **112** and transmits it via a conduit **146** up to the next higher stage of the system. Even though the coolant fluid has absorbed a certain amount of heat in the lower stage, and its tempera-

ture is raised, nevertheless in the next higher stage a higher temperature coolant fluid will suffice to produce condensation in that stage because of the higher pressures and temperatures of the vapors and unevaporated liquid present therein.

FIG. 7 shows an alternate form of condenser arrangement for use in the fresh water recovery system of FIGS. 5 and 6. In this alternate arrangement various condenser housings **160** are provided with condenser tubes **162** arranged in horizontal banks of two layers. As shown, the tubes of the upper bank are staggered with respect to the tubes of the lower bank so that condensate which forms on the outside of any tube will drip directly downwardly to the bottom of the housing without contaminating or increasing the film thickness of any other condenser tube. In the arrangement of FIG. 7, the covers **110** are eliminated by positioning the evaporator passages **122** in such a manner that they open directly downwardly into the spaces **106** between the various condenser housings. With the arrangement of FIG. 7, it is possible to reduce the vertical height per stage for a given amount of pressure drop per stage.

It will be appreciated from the above that the present invention achieves improved condensation of vapors with structures which are far less costly to produce and to maintain than has heretofore been considered possible. Thus, by selectively arranging condenser tubes both with respect to the vapor inlet and by restricting the amount of condenser surface in the unit a very efficient and low cost system is achieved.

What is claimed as new and desired to be secured by Letters Patent is:

1. A condenser comprising an enclosure forming a substantially sealed chamber, means providing an entrance for admitting both vaporized and unvaporized liquid to said chamber within a region above an hereinafter defined array of condenser tubes for condensing the vapor to a pure liquid state, a common collection means for condensate collection disposed substantially in vertical alignment with respect to said chamber entrance and having an opening facing the same, a plurality of condenser tubes forming at least one array of tubes mounted by said enclosure in a manner such that their longitudinal axes are substantially parallel and horizontal to the enclosure, at least some of the tubes of said array being positioned within said opening of said common collection means and all of said tubes in said array located in at least three parallel vertical planes with each tube in each plane being staggered to be in vertical disalignment with an adjacent tube in an adjacent plane so that liquid condensate formed on the exterior surface of each tube drops past a tube in a lower plane and directly into the common collection means thereby to avoid contact with all lower condenser tubes of said array, means to admit coolant to and withdraw coolant from said tubes in said array, deflection means mounted within said chamber between said entrance means and said opening to deflect past said opening to said common collection means the unvaporized liquid entering said chamber, and means for collecting the pure liquid condensate from said common collection means.

2. The condenser of claim **1** including a second array of condenser tubes of similar make-up to the first array, said second array of condenser tubes mounted within said common collection means, and a baffle element within said common collection means and between said arrays thereby to deflect falling condensate past said second array.

3. The condenser of claim **1** wherein said common collection means includes a trough positioned directly under said condenser tubes.

4. A condenser as in claim **1** wherein said condenser tubes are arranged to permit direct contact of each thereof by vapors passing through said vapor entrance means.

5. A condenser as in claim **1** wherein the volume occupied by said condenser tubes is about 2 to 5% of the total volume of the interior of said chamber.

6. A condenser construction comprising a horizontally extending tubular housing, a partition plate extending in a generally horizontal direction across the upper interior of said housing and dividing said interior into upper and lower regions, said partition plate being perforated at several locations therealong to provide a distributed inlet for vapor from the upper to the lower region, a partition diametrically positioned to extend downwardly from under the surface of the partition plate and terminating in two adjoining symmetrical U-shaped configurations which merge with the sides of the condenser housing to form longitudinally extending lower condenser collection channels, a bank of condenser tubes extending along through said lower region and arranged therein with respect to the bottom of said housing so that condensate which forms thereon drops directly down to the bottom of said housing, the condenser tubes of said bank being arranged in vertical disalignment and in staggered array with respect to the bottom of the housing so that no condenser tube is directly above another and that condensate which forms on higher tubes drops down and passes lower condenser tubes in the drop to the bottom of said housing thereby avoiding any contact with said lower condenser tubes.

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U.S. Cl. X.R.

165—113; 202—186, 236