July 7, 1964 T. TINKER 3,139,926

SURFACE CONDENSER

Filed Nov. 28, 1960 2 Sheets-Sheet 1

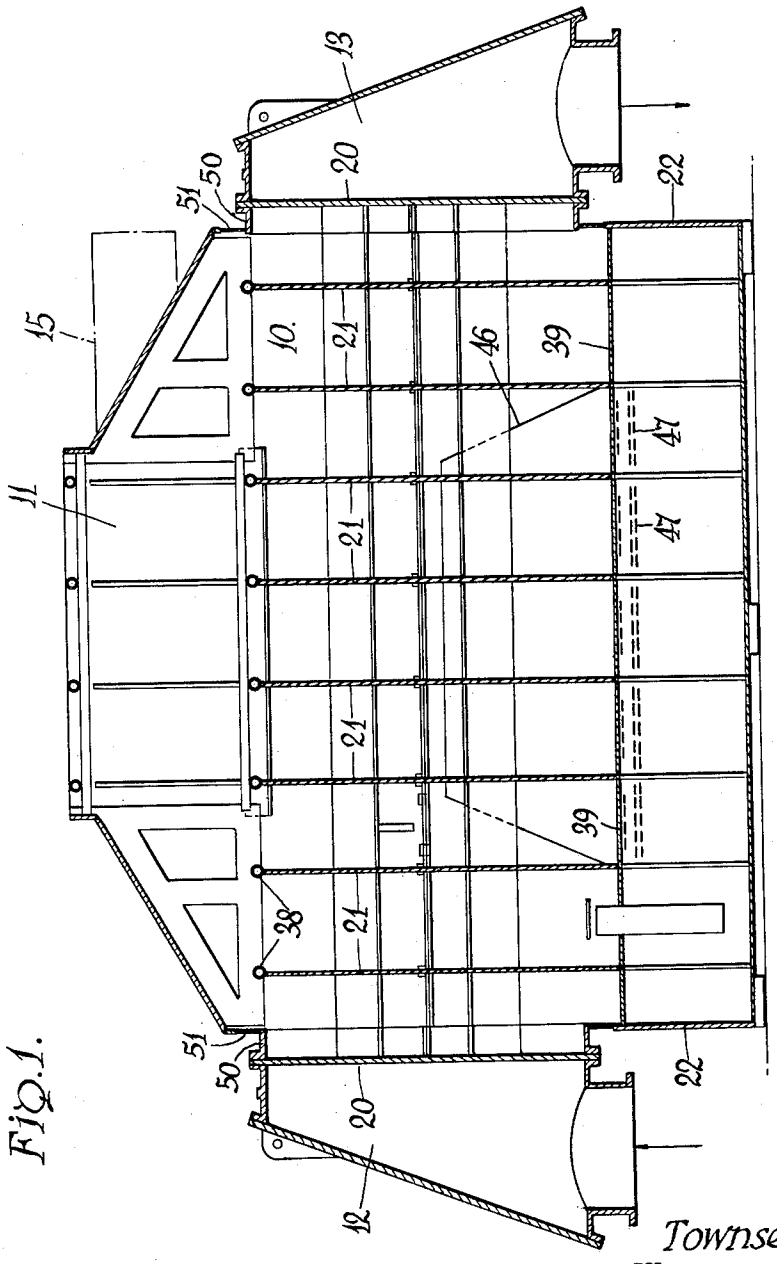


FIG. 1.

INVENTOR.
Townsend Tinker,
BY
Bean, Brooks, Buckley & Bean.
ATTORNEYS

July 7, 1964 T. TINKER 3,139,926

SURFACE CONDENSER

Filed Nov. 28, 1960 2 Sheets-Sheet 2

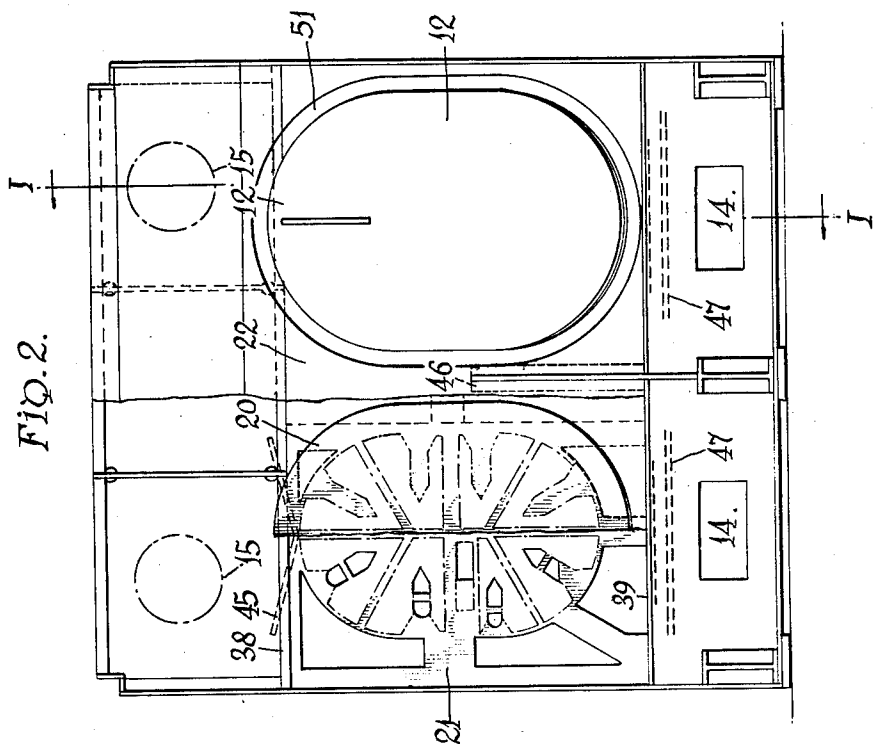


Fig. 2.

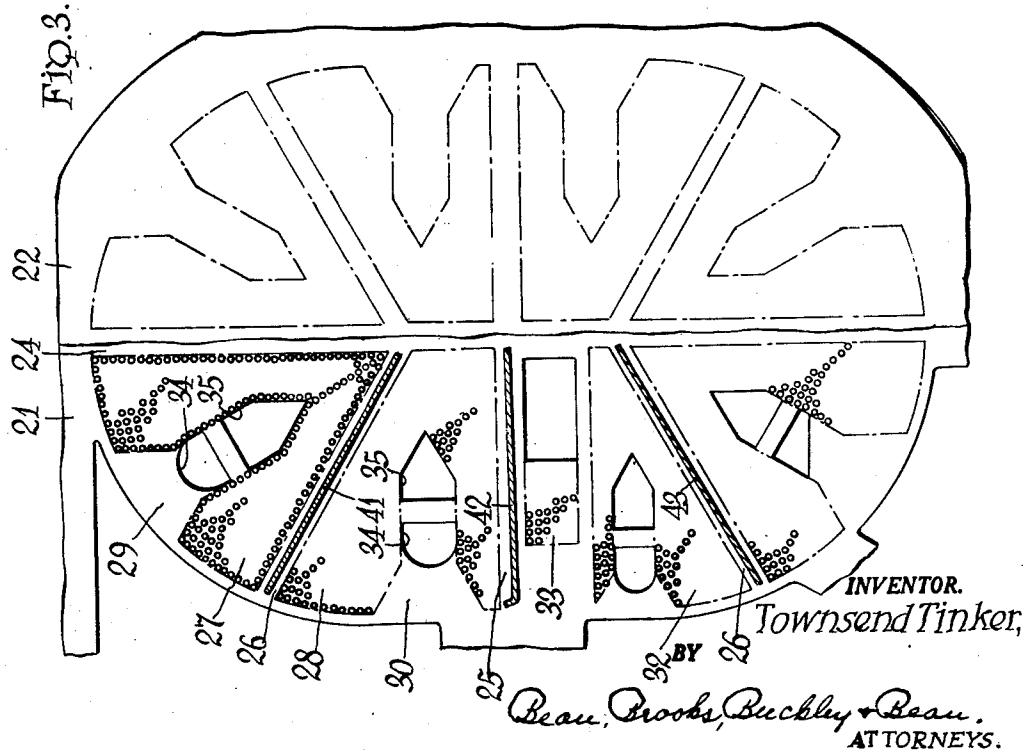


Fig. 3.

INVENTOR.
Townsend Tinker,
BY
Beau, Brooks, Buckley & Beau.
ATTORNEYS.

United States Patent Office 3,139,926 Patented July 7, 1964

3,139,926

SURFACE CONDENSER

Townsend Tinker, Birmingham, Mich., assignor to American Radiator & Standard Sanitary Corporation, New York, N.Y., a corporation of Delaware

Filed Nov. 28, 1960, Ser. No. 72,151
9 Claims. (Cl. 165—111)

This invention relates to heat exchange apparatus and more particularly to surface condensers of the type employed in condensing steam on a relatively large scale such as in electric power generator installations and the like.

Surface condensers have been the subject of engineering study and design for many years and their general qualifications and requirements are well known in the art. However, with constantly increasing capacity requirements the problems of efficient condensation and the accompanying necessity of efficient heat exchange and efficient fluid flow in steam condensers has become more complex and more critical.

As a broad factor affecting condenser efficiency it may be noted that constantly increasing sizes of tube bundles or tube banks tends to introduce inefficiencies incident to the relatively long but often unequal distances which the steam must traverse from its initial contact with the tubes at the periphery of the bank or bundle to its ultimate discharge as condensate or noncondensable gas. Furthermore, since the periphery of a tube bundle increases only fractionally with respect to the area of the bundle the problem of efficient passage of the condensing steam through the tube bundle is made more complicated and the relationship between the available flow area for the steam at various depths in the tube bundle or bank does not bear a proper and efficient relationship to the decreasing volume of the condensing steam.

Thus steam entrance velocities tend to become excessive in the case of large tube bundles and incidental pressure losses result in lower steam pressures, lower condensing temperatures and a loss of effective temperature differential. Since pressure drops increase as the square of the flow velocity across the tube rows, it is highly desirable to hold the velocity across the outer layers of tubes to a moderate degree.

In an effort to counteract or ameliorate this tendency toward inefficiency, tube bundles have been proposed wherein the pitch of spacing of individual tubes which lie in the vicinity of the periphery of the tube bundle is greater than the pitch of spacing of tubes lying more toward the center of the tube bundle. This aims in the proper general direction of reducing the otherwise excessive entrance velocities of the entering steam but is subject to other objections on the basis of mechanical and thermal design and fluid flow efficiency.

A further consideration which affects overall efficiency of a surface condenser installation is the necessity for uniform steam distribution in a direction lengthwise of the tubes. To obtain optimum efficiency from this standpoint the desired uniform longitudinal distribution should be attained and established as soon as possible with respect to the flow path of the steam. Ideally this would mean attaining uniform longitudinal distribution before or at the point where the steam first encounters the periphery of the tube bundle. Since instantaneous longitudinal distribution is not attainable, an arrangement which permits the steam to distribute itself longitudinally over as long a stretch as possible from the intake duct to the point of tube contact is highly desirable.

A further closely interrelated problem in the successful design of large capacity surface condensers of this general type involves the problem of efficiently conducting condensate from the tube bundle. If this be left to mere gravity precipitation the condensate from the numerous rows of condensing tubes of a large tube bank will cascade over the lower tubes and lower their thermal efficiency and condensing capacity.

The use of condensate drainage plates to avoid this undesirable condition is well known but in the arrangement of the present invention the drainage plates cooperate and combine with the novel tube arrangement to provide a highly efficient steam condensing and condensate drainage arrangement.

Speaking generally, the surface condenser arrangement of the present invention presents a novel combination which comprises two primary elements of tube arrangement and condenser construction with the above-mentioned drainage plate arrangement as a third contributing element, even though the latter is not new apart from the present combination. One or several tube banks may be employed in the given condenser installation, each bank comprising a great number of horizontal tubes arranged within a given cross-sectional area which may be oblong, elliptical or circular.

According to the present invention each tube bank comprises a number of sections wherein each section is generally of the shape of a sector or tapered section and wherein the lanes separating the sectors form a plurality of generally radiating paths extending from the interior of the tube bank to its periphery.

Furthermore, each of the generally sectoral sections has a relatively deep indentation in its periphery extending inwardly toward the center of the tube bank so that each sector comprises a tube section with the tubes forming a V. Thus steam coming to the periphery of the tube bank or coming to the periphery of a given sector of the tube bank is provided in effect with an extended tube bank periphery comprising the tubes disposed along the surface of the foregoing generally V-shaped indentation plus the actual peripheral tubes at each side of such indentation.

In combination with the foregoing novel tube sector arrangement the condenser structure of the present invenvention provides the usual series of intermediate support plates but with the special provision of openings or windows therein in registry with the aforesaid indentations in each tube sector, so that steam prior to actually beginning its passage through the tube bundle proper may become readily and directly distributed lengthwise of the condenser by passage into the aforesaid indentations and longitudinally through the registering openings in the support plates.

The longitudinal distribution of steam thus effected is in addition to and in extension of longitudinal distribution which is or may be effected before the steam reaches the tube bank proper and has the effect of extending the flow distance through which longitudinal distribution of steam may take place before actually beginning its passage in contact with the tubes.

A further generally contributing factor in the condenser structure of the present invention, while not essential to the foregoing general combination, adds materially to the resultant overall condenser efficiency and comprises the positioning of drainage plates along the generally radiating lanes which divide the foregoing novel tube sectors, or at least along some of such lanes.

Due to the generally sectoral arrangement and the radiating extent of these division lanes the drainage plates will thus be naturally inclined at substantial angles to the horizontal so that condensate from each sector is readily drained therefrom without the aforementioned highly objectionable cascading flow downwardly through a tube bank.

The following specification and the accompanying drawings disclose the application of the above novel principles in a typical surface condenser, it being understood that the general details of construction apart from the above principles of general arrangement may be in accordance with known surface condenser design. It is to be understood that the embodiment thus set forth herein is by way of example only and that the principles of the invention are not limited excepting as defined in the appended claims.

In the drawings:

FIG. 1 is a general longitudinal cross sectional view of a surface condenser constructed in accordance with one form of the present invention, the cross section being taken approximately on the line I—I of FIG. 2;

FIG. 2 is an end elevational view of the surface condenser of FIG. 1 with portions thereof broken away; and

FIG. 3 is a fragmentary enlarged elevational view taken similarly to FIG. 2 and showing fragmentarily a tube sheet and tube support plate of the left-hand bank of tubes.

Like characters of reference denote like parts in the several figures of the drawings and it is to be understood that the general structural arrangement of parts may be generally similar in design to conventional surface condensers excepting as to the pattern of distribution of the tubes, the cooperating tube support plate passageways, and ancillary details which will be referred to later herein.

Referring to FIG. 1, the surface condenser depicted herein by way of example is of the horizontal tube type and comprises a generally rectangular shell or casing **10**, a steam inlet chamber **11** at the top thereof, an inlet water box **12** at one end for introducing circulating cooling water, and an outlet water box **13** at the other end of shell **10**. The shell **10** further includes a base structure **14** which comprises a hotwell for receiving the water formed by condensed steam.

In the illustrative instance two tube banks are provided as shown in FIG. 2 and accordingly pairs of water inlet boxes **12** and water outlet boxes **13** are provided at opposite ends of shell **10**. Steam to be condensed is generally introduced to the steam inlet chamber **11** by downward flow from the exhaust duct of the turbine or turbines served thereby.

Referring to the tube bank at the left-hand side of FIG. 2 and also the enlargement of this structure illustrated in FIG. 3, the numeral **20** designates a tube sheet at the inlet ends of the water circulating tubes of this bank and the same is partially broken away both in FIG. 2 and FIG. 3 to illustrate, as at **21**, one of a series of intermediate tube supporting plates which are spaced along the lengths of the tubes.

The tube sheets **20** at the opposite ends of the tube banks are shown in FIG. 1 and in the illustrated instance the tube sheets are offset outwardly of the respective end walls of the shell **10**, such end walls being designated by the numeral **22**. The individual tubes which extend between the tube sheets **20** at opposite ends of the condenser have been omitted in FIG. 1 for simplicity of illustration.

The manner in which the tubes are distributed about the tube sheets is illustrated clearly although to some extent diagrammatically in FIG. 3 and it will be there noted that the tubes of each bank are first divided into four quadrants by a vertical lane **24** and a horizontal lane **25**, the lanes comprising narrow spaces which are free of tubes.

Each quadrant is in turn divided into two roughly V-shaped or sectoral shaped zones by further lanes **26** which extend obliquely and in what may be described as a radial direction although the oblong or oval general outline of the tube bank may dictate some deviation from a true radial ilne. The oblique lanes **26** also comprise relatively narrow spaces which are devoid of tubes.

The upper left-hand quadrant of FIG. 3 fairly illustrates the general tube arrangement of the other quadrants and it will be noted that the upper tube sector thus defined and designated by the numeral **27** is V-shaped whereas the adjacent lateral tube sector designated **28** is somewhat V-shaped although blunted at its inner or apex end.

These V-shaped tube sectors are provided with relatively deep indentations or bays which are devoid of tubes, the entrance portions thereof being designated by the numerals **29** and **30** in FIG. 3, and these indentations or bays extend into the V-shaped sectors **27** and **28** to such an extent that they form a sort of block V tube layout for each sector.

The two right-hand quadrants of FIG. 3 are identical with the one just described as indicated by the dot and dash lines in FIG. 3 and the lower left-hand quadrant is generally similar but the lateral sector designated **32** in FIG. 3 is abbreviated to form an additional tube section **33**.

The tube section **33** is known in the art as an air cooler section and air which is entrained with the incoming steam and which reaches the central region of the tube bank as a non-condensable gas is drawn over the tubes of the air bank **33** prior to discharge from the apparatus. The use of an air cooler section in this general manner is known in the art and is not novel to the present invention.

Again referring to the upper left-hand quadrant of FIG. 3, the support plates **21** are provided with pairs of openings **34** and **35** in registry with the inner portions of the inlet bays **29** and **30** which form continuous longitudinal passageways through the several support plates whereby steam entering the bays **29** and **30** and the corresponding bays of the other three quadrants is entirely free to flow in a direction lengthwise of the tubes to become uniformly distributed throughout the lengths of the tube banks.

Referring now again to the series of intermediate tube supporting plates **21** and more particularly to FIG. 1 of the drawings, these intermediate supporting plates may be welded at their upper ends to tubular cross bars **38** and at their lower ends to a floor **39** which overlies the hotwell **14**. Floor **39** may be suitably perforated to permit condensate from the condenser section to pass to the hotwell.

In FIG. 3 the numerals **41**, **42** and **43** denote pairs of drainage plates which lie between adjacent tube sectors, the drainage plates being welded at their ends between each adjacent pair of tube support plates **21**. The upper pair of drainage plates **41** drain condensate falling from the tubes of the sectors **27** to the vertical line **24** and the lower drainage plates **43** drain condensate from the sector **32** and its counterpart at the other side of the tube bank to the periphery of the tube bank. Condensate falling to the central drainage plates **42** from the tube sectors **28** likewise flows down the center lane **24**.

The following adjuncts are now new in the present apparatus but are alluded to briefly merely for general descriptive purposes. The numeral **45** designates pairs of grille or grid members known as impingement grids which serve to prevent direct blast of the incoming steam against the upper tubes of the top sectors **27**.

In FIGS. 1 and 2 the numeral **46** designates a vertical conduit which is open at the top and communicates at its lower end with hotwell **14**. This conduit is known as a steam scoop and it receives a downward blast of steam directly from the inlet chamber **11**, the steam passing through the control space between the impingement grids **45**.

This steam enters the upper portion of the hotwell and tends to reheat condensate passing thereto to improve deaeration. In FIGS. 2 and 3 the numeral **47** designates conventional de-aeration grids which are disposed in the upper portions of hotwell **14**.

In FIGS. 1 and 2 the numeral **15** designates cylindrical shells comprising feed water heaters which may be dis-

posed in the path of the incoming steam. This is a conventional expedient and may or may not be employed in conjunction with the instant apparatus.

Novel means are provided to permit differences in thermal expansion between the tubes and the shell of the condenser. As shown particularly in FIG. 1, each tube sheet **20** is attached at its margins to the outer end of a short hub or ring **50** and the inner end of each ring **50** is attached to a relatively flexible plate **51**, the latter being attached at its outer marginal edges to the end walls **22** of the shell of the condenser. The annular plate **51** is sufficiently thinner than the metal plate used generally in constructing the shell of the condenser as to permit limited flexibility of such annular plate **51** whereby the distance between the tube sheets **20** may vary in proportion to the length of the shell generally under varying thermal conditions.

I claim:

1. In a surface condenser comprising a bank of horizontally extending water circulating tubes, means for introducing steam generally peripherally to said tube bank for heat exchange contact with said tubes, and hotwell means beneath the tube bank for receiving condensate therefrom, said tube bank being divided into a plurality of sections, said several sections being spaced from adjacent sections by spaces extending generally radially with respect to the tube bank to form generally sectoral shaped sections, said sections having generally V-shaped peripheral indentations terminating within the same and devoid of tubes whereby the tubes at the margins of said indentations have initial contact with steam entering said indentations, and a series of support plates spaced longitudinally along said tubes, said support plates having openings therein in longitudinal registry with said indentations whereby the indentations and the support plate openings form substantially continuous longitudinal steam distribution passage means.

2. In a surface condenser comprising a bank of horizontally extending water circulating tubes, means for introducing steam generally peripherally to said tube bank for heat exchange contact with said tubes, and means beneath the tube bank for receiving condensate therefrom, said tube bank having generally central horizontal and vertical lanes therethrough dividing said tube bank into quadrants, and a generally radial lane through each quadrant dividing the same into two groups of tubes, each of said groups of tubes having generally V-shaped peripheral indentations terminating within the same and devoid of tubes whereby the tubes at the margins of said indentations have initial contact with steam entering said indentations, and a series of support plates spaced longitudinally along said tubes, said support plates having openings therein in longitudinal registry with said indentations whereby the indentations and the support plate openings form substantially continuous longitudinal steam distribution passage means.

3. In a surface condenser comprising a bank of horizontally extending water circulating tubes, means for introducing steam generally peripherally to said tube bank for heat exchange contact with said tubes, and hotwell means beneath the tube bank for receiving condensate therefrom, said tube bank being divided into a plurality of sections, said several sections being spaced from adjacent sections by spaces extending generally radially with respect to the tube bank to form generally sectoral shaped sections, said sections having relatively deep peripheral indentations terminating within the same and devoid of tubes whereby the tubes at the margins of said indentations, have initial contact with steam entering said indentations, and a series of support plates spaced longitudinally along said tubes, said support plates having openings therein in longitudinal registry with said indentations whereby the indentations and the support plate openings form substantially continuous longitudinal steam distribution passage means.

4. In a surface condenser comprising a bank of horizontally extending water circulating tubes, means for introducing steam generally peripherally to said tube bank for heat exchange contact with said tubes, and hotwell means beneath the tube bank for receiving condensate therefrom, said tube bank having lanes generally at right angles to each other and intersecting adjacent to the center of said bank to divide the same into spaced quadrants, and a generally radial lane through each quadrant dividing the same into two spaced groups of tubes, each of said group of tubes having relatively deep peripheral indentations terminating within the same and devoid of tubes whereby the tubes at the margins of said indentations have initial contact with steam entering said indentations, and a series of support plates spaced longitudinally along said tubes, said support plates having openings therein in longitudinal registry with said indentations whereby the indentations and the support plate openings form substantially continuous longitudinal steam distribution passage means.

5. In a surface condenser comprising a bank of horizontally extending water circulating tubes, means for introducing steam generally peripherally to said tube bank for heat exchange contact with said tubes, and hotwell means beneath the tube bank for receiving condensate therefrom, said tube bank having a plurality of generally V-shaped peripheral indentations terminating within the same and devoid of tubes disposed at various points about the periphery thereof whereby the tubes at the margins of said indentations have initial contact with steam entering said indentations, and a series of support plates spaced longitudinally along said tubes, said support plates having openings therein in longitudinal registry with said indentations whereby the indentations and the support plate openings form substantially continuous longitudinal steam distribution passage means.

6. In a surface condenser comprising a bank of horizontally extending water circulating tubes, means for introducing steam generally peripherally to said tube bank for heat exchange contact with said tubes, and hotwell means beneath the tube bank for receiving condensate therefrom, said tube bank having a plurality of relatively deep peripheral indentations terminating within the same and devoid of tubes disposed at various points about the periphery thereof whereby the tubes at the margins of said indentations have initial contact with steam entering said indentations, and a series of support plates spaced longitudinally along said tubes, said support plates having openings therein in longitudinal registry with said indentations whereby the indentations and the support plate openings form substantially continuous longitudinal steam distribution passage means.

7. In a surface condenser comprising a bank of horizontally extending water circulating tubes, means for introducing steam generally peripherally to said tube bank for heat exchange contact with said tubes, and means beneath the tube bank for receiving condensate therefrom, said tube bank having generally central horizontal and vertical lanes therethrough dividing said tube bank into quadrants, and a generally radial lane through each quadrant dividing the same into two groups of tubes, each of said groups of tubes having generally V-shaped peripheral indentations terminating within the same and devoid of tubes whereby the tubes at the margins of said indentations have initial contact with steam entering said indentations, and a series of support plates spaced longitudinally along said tubes, said support plates having openings therein in longitudinal registry with said indentations whereby the indentations and the support plate openings form substantially continuous longitudinal steam distribution passage means, and condensate drainage plates extending along said horizontal lane and said generally radial lanes.

8. In a surface condenser comprising a bank of horizontally extending water circulating tubes, means for in-

troducing steam generally peripherally to said tube bank for heat exchange contact with said tubes, and hotwell means beneath the tube bank for receiving condensate therefrom, said tube bank being divided into a plurality of sections, said several sections being spaced from adjacent sections by spaces extending generally radially with respect to the tube bank to form generally sectoral shaped sections, said sections having relatively deep peripheral indentations terminating within the same and devoid of tubes whereby the tubes at the margins of said indentations have initial contact with steam entering said indentations, and a series of support plates spaced longitudinally along said tubes, said support plates having openings therein in longitudinal registry with said indentions whereby the indentations and the support plate openings form substantially continuous longitudinal steam distribution passage means, and condensate drainage plates extending along all non-vertical spaces between adjacent sections.

9. In a surface condenser comprising a bank of horizontally extending water circulating tubes, means for introducing steam generally peripherally to said tube bank for heat exchange contact with said tubes, and hotwell means beneath the tube bank for receiving condensate therefrom, said tube bank having lanes generally at right angles to each other and intersecting adjacent to the center of said bank to divide the same into spaced quadrants, and a generally radial lane through each quadrant dividing the same into two spaced groups of tubes, each of said group of tubes having relatively deep peripheral indentations terminating within the same and devoid of tubes whereby the tubes at the margins of said indentations have initial contact with steam entering said indentations, and a series of support plates spaced longitudinally along said tubes, said support plates having openings therein in longitudinal registry with said indentations whereby the indentations and the support plate openings form substantially continuous longitudinal steam distribution passage means, and condensate drainage plates extending along said generally radial lanes.

References Cited in the file of this patent

UNITED STATES PATENTS

1,776,349	Delas	Sept. 23, 1930
1,855,231	Grace	Apr. 26, 1932
2,344,269	Saco	Mar. 14, 1944
2,653,799	Stahn et al.	Sept. 29, 1953
2,830,797	Garland	Apr. 15, 1958
2,988,335	Disinger	June 13, 1961

FOREIGN PATENTS

1,053,008	Germany	May 19, 1959