April 27, 1965 J. N. HINDE 3,180,405

CONDENSERS

Filed March 11, 1959 4 Sheets-Sheet 1

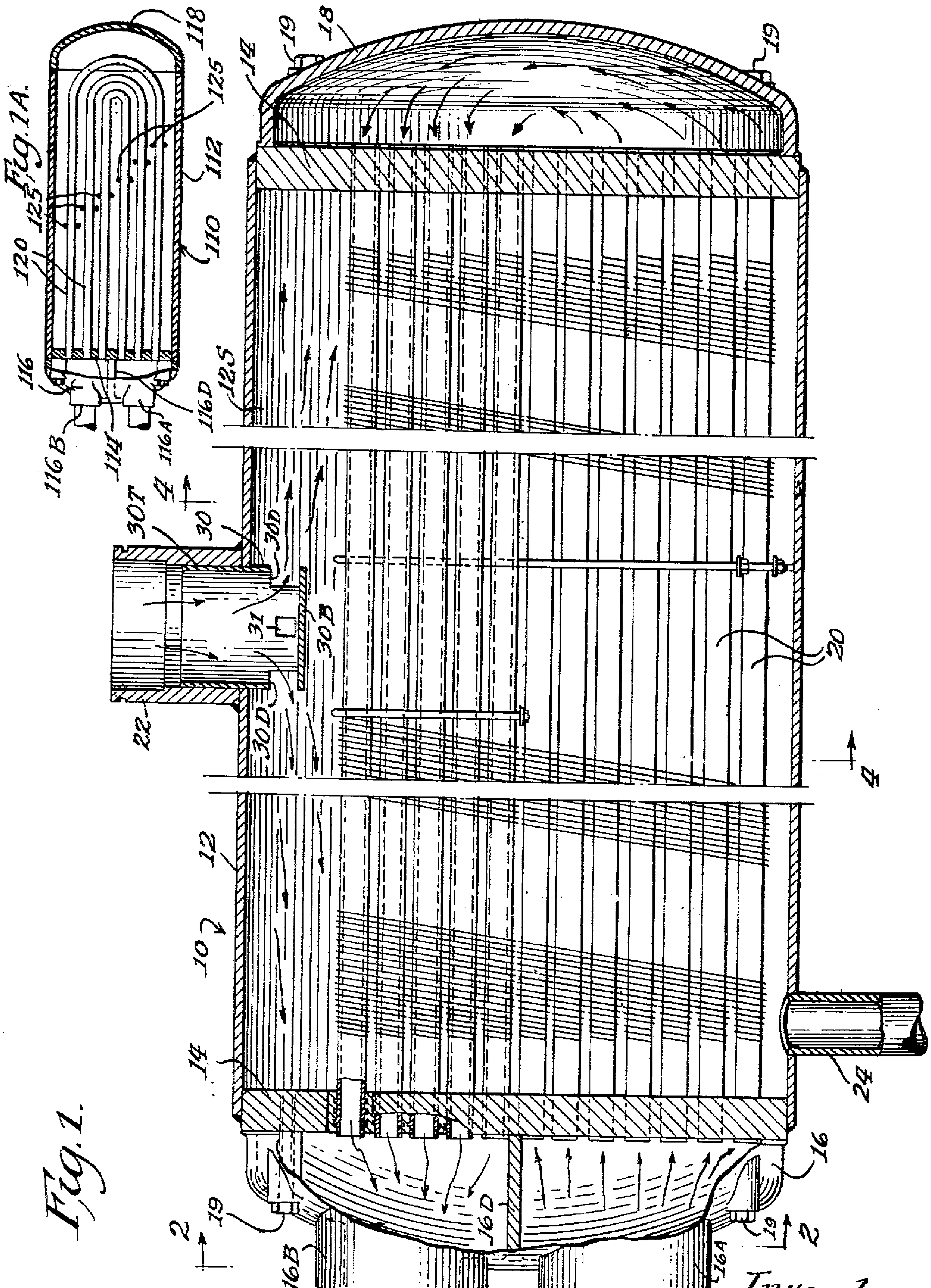

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Fig. 2.

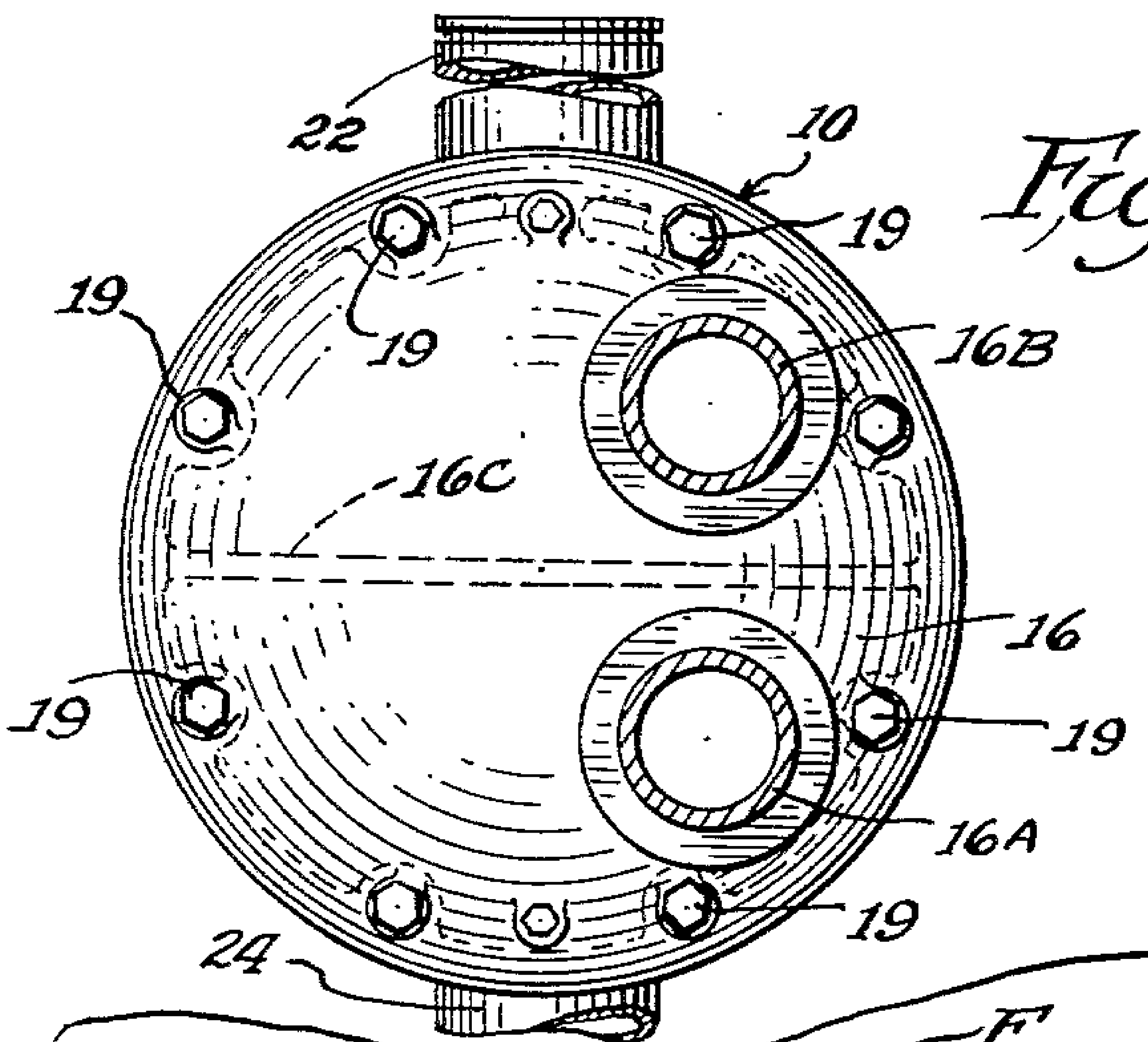

Fig. 3.

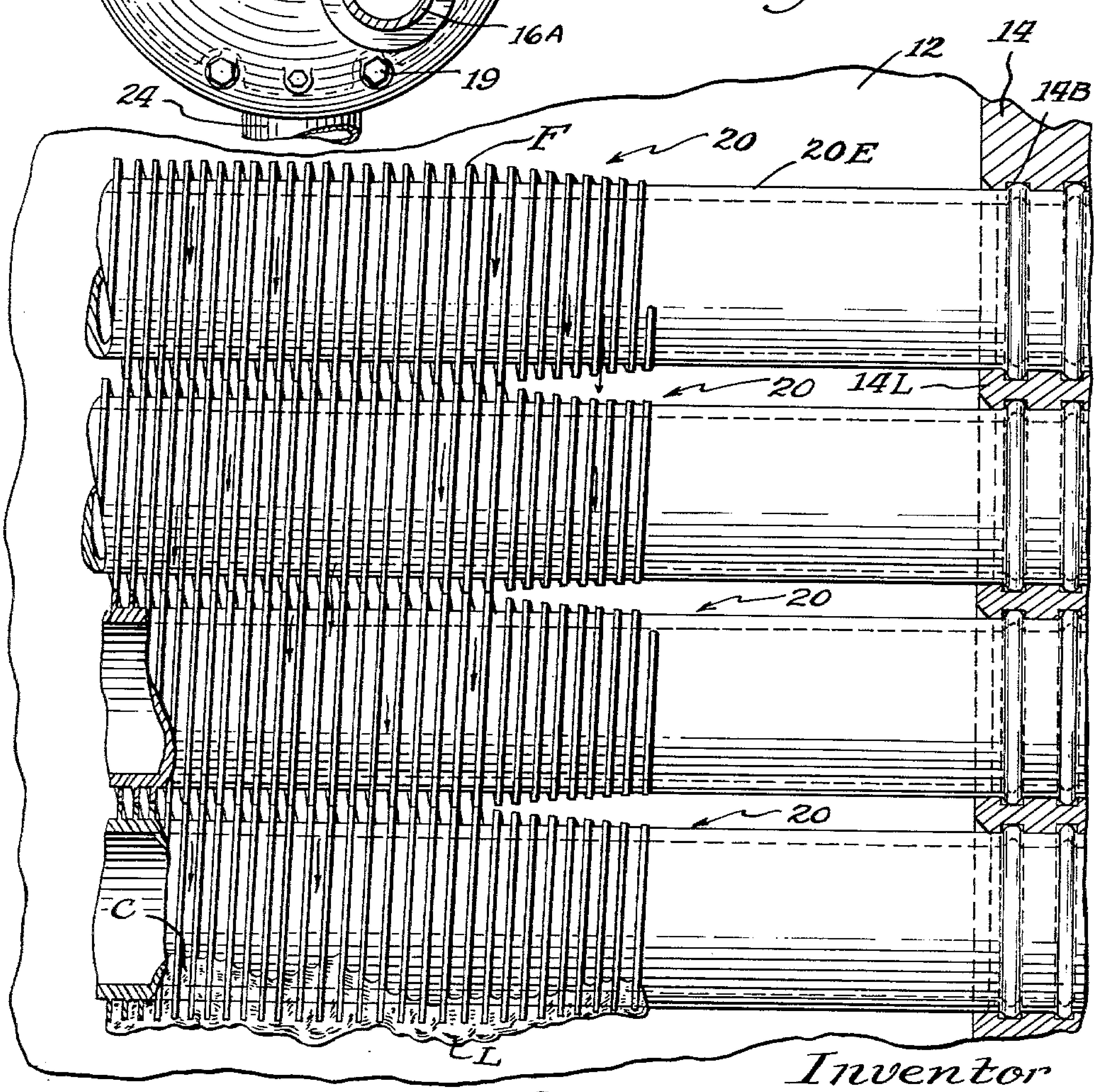

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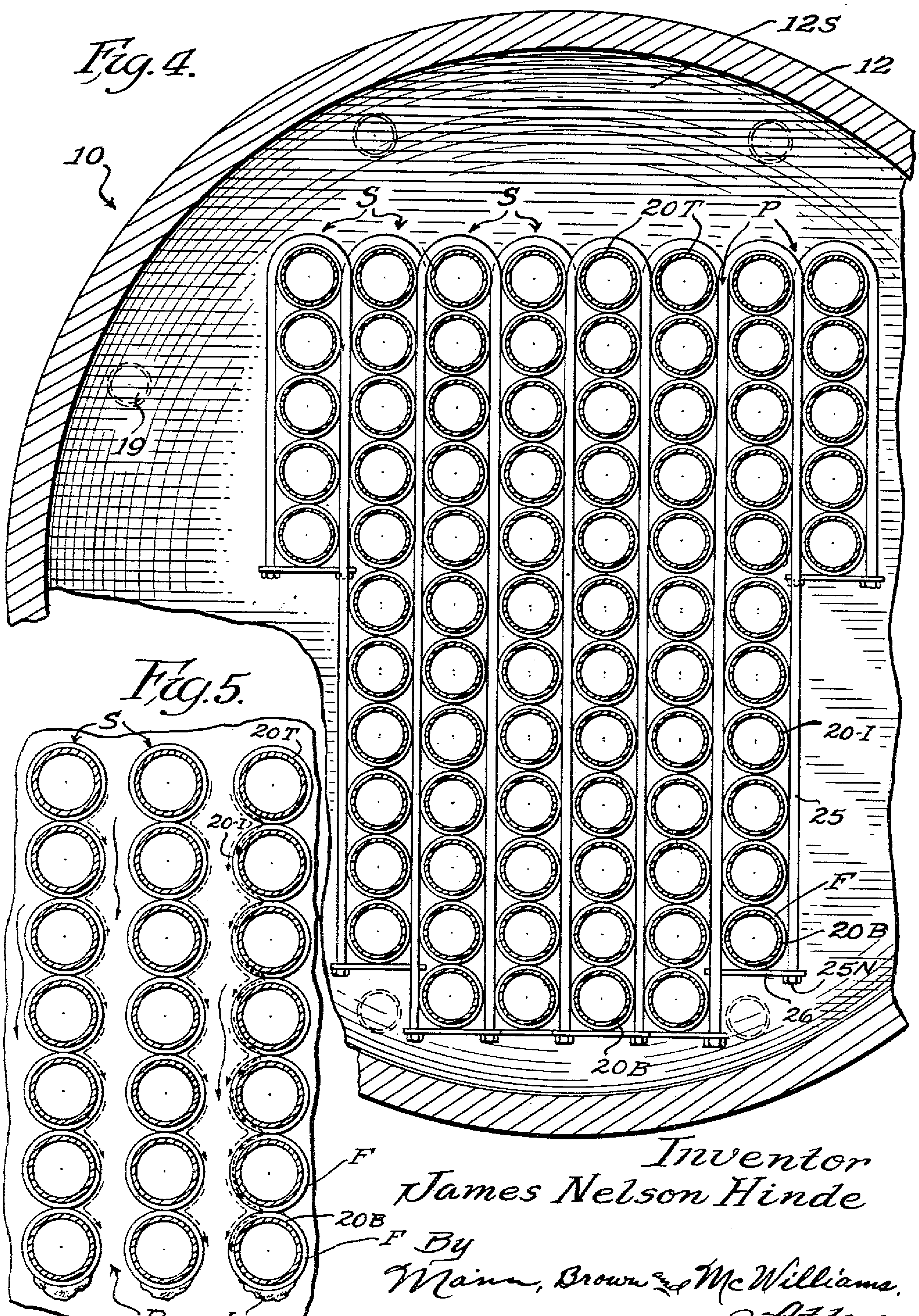
Fig. 4.



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CONDENSERS

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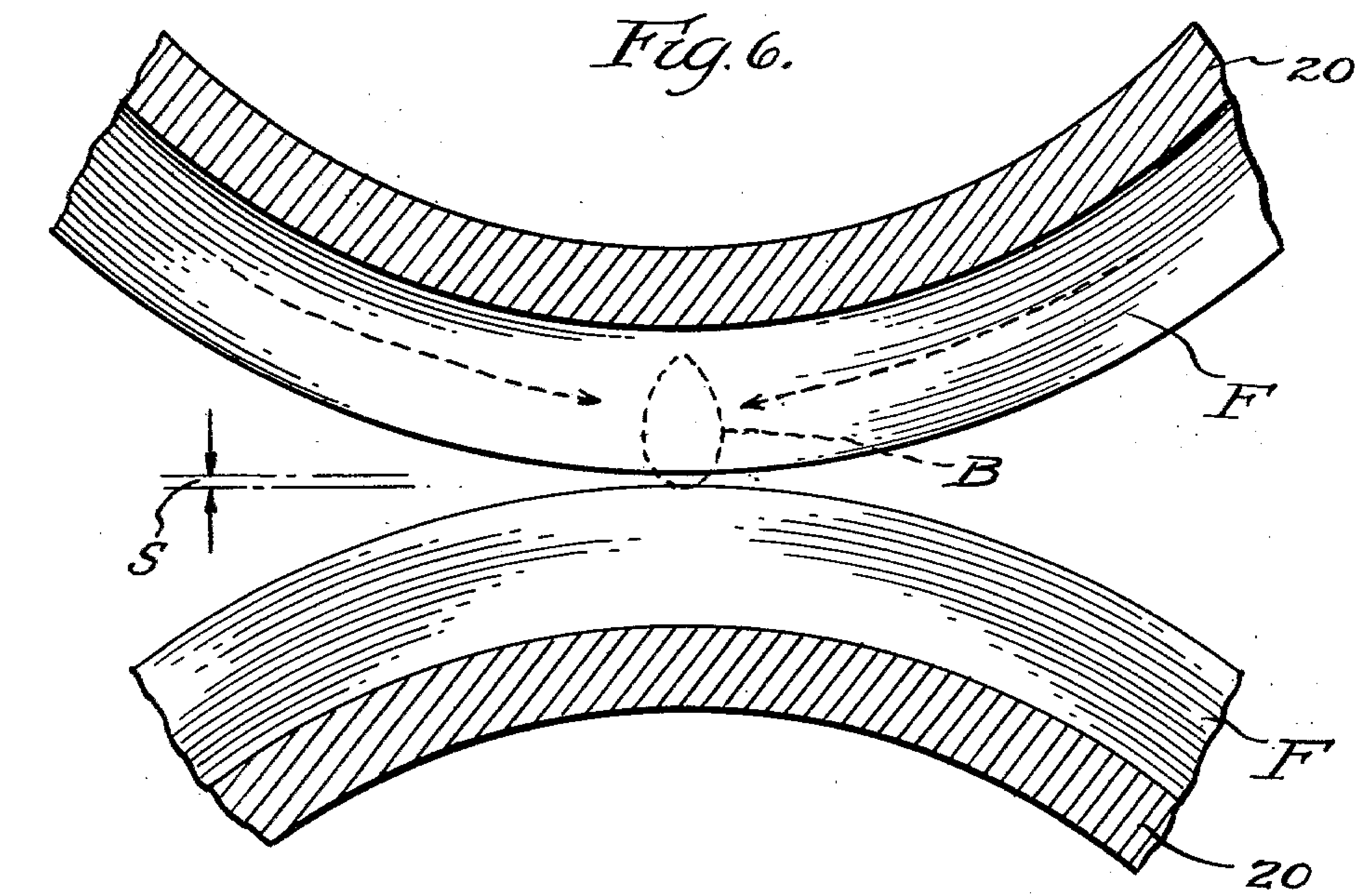

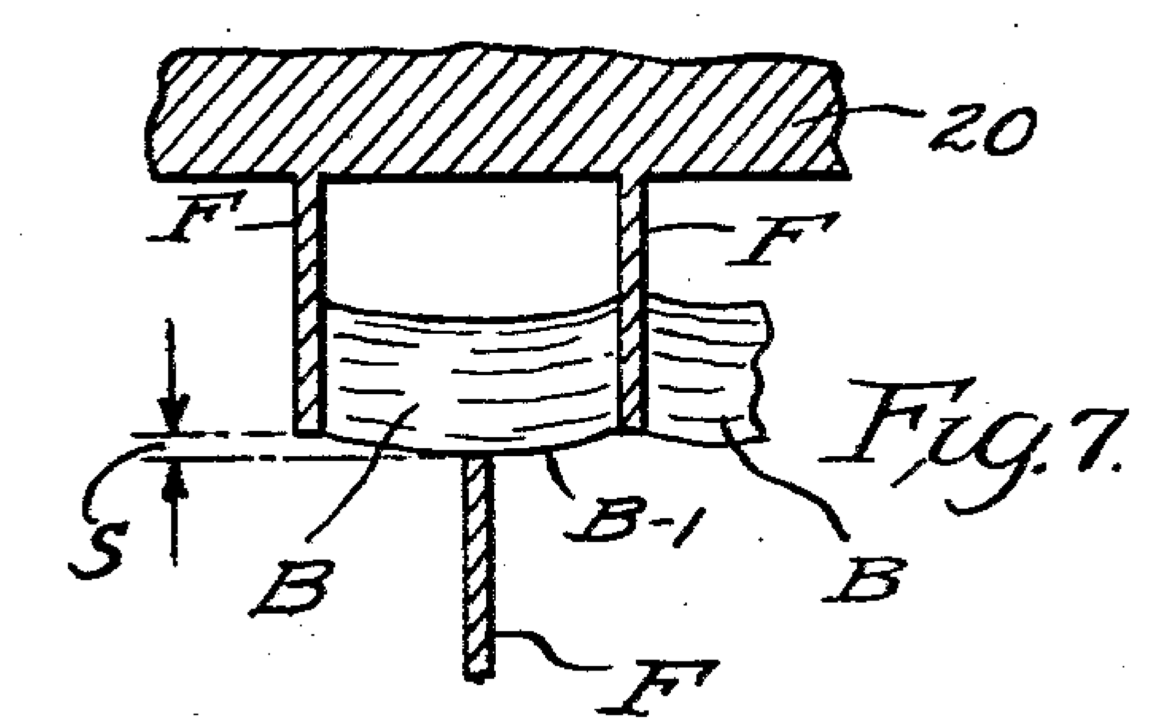

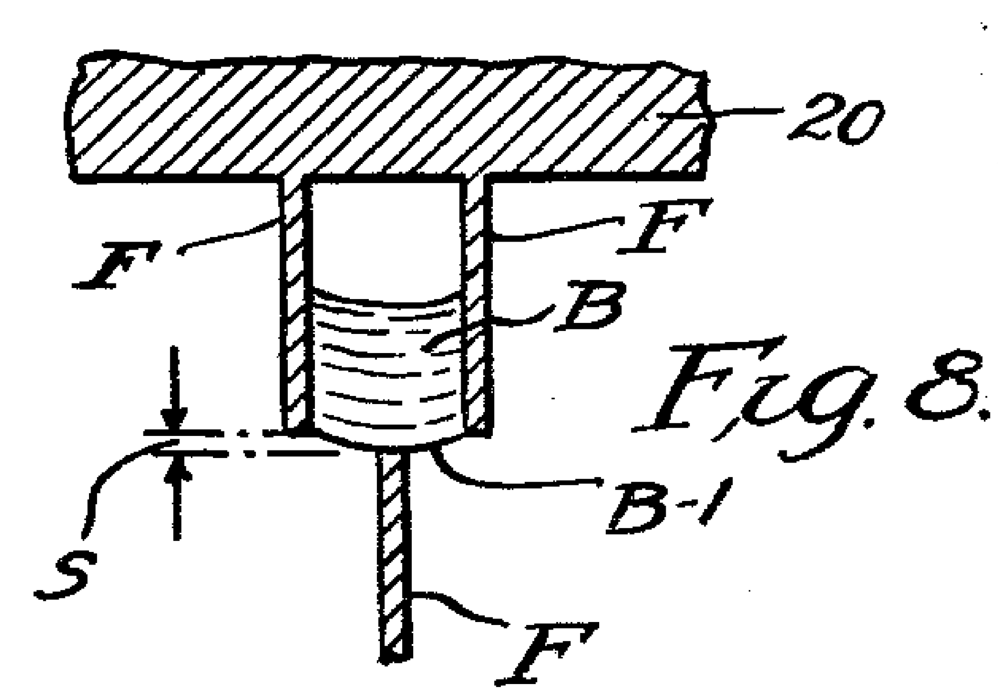

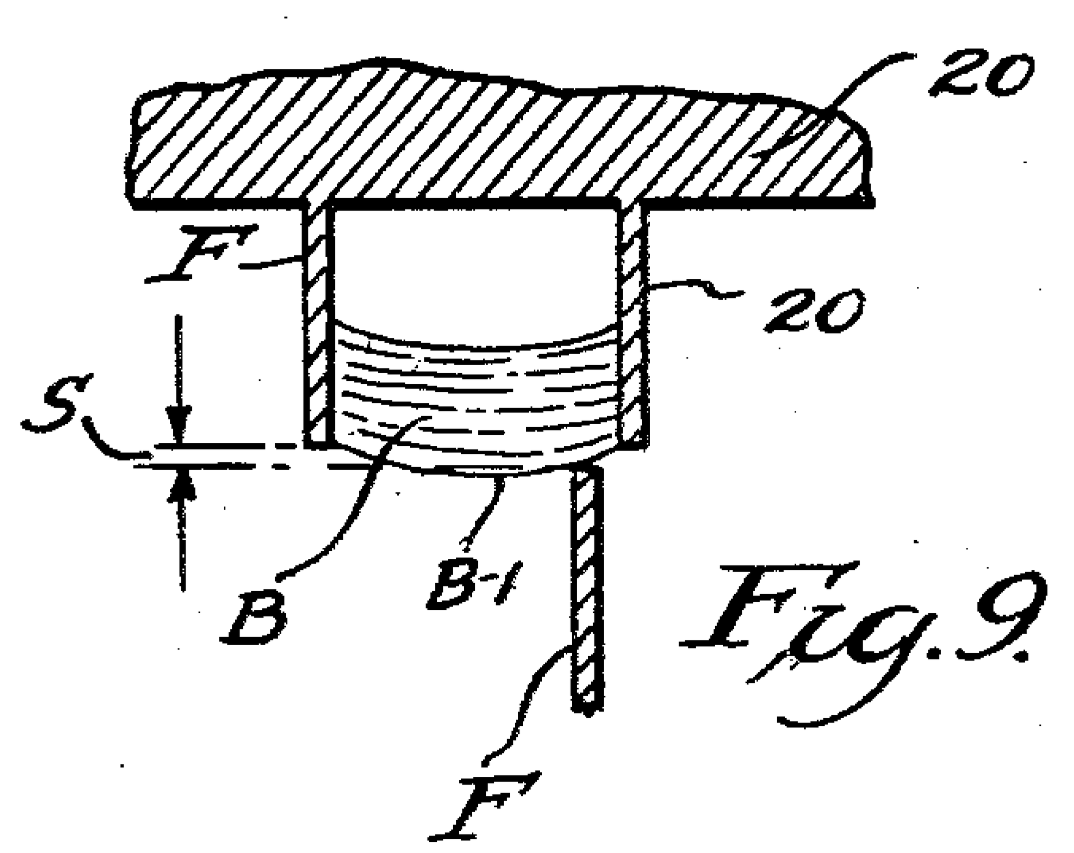

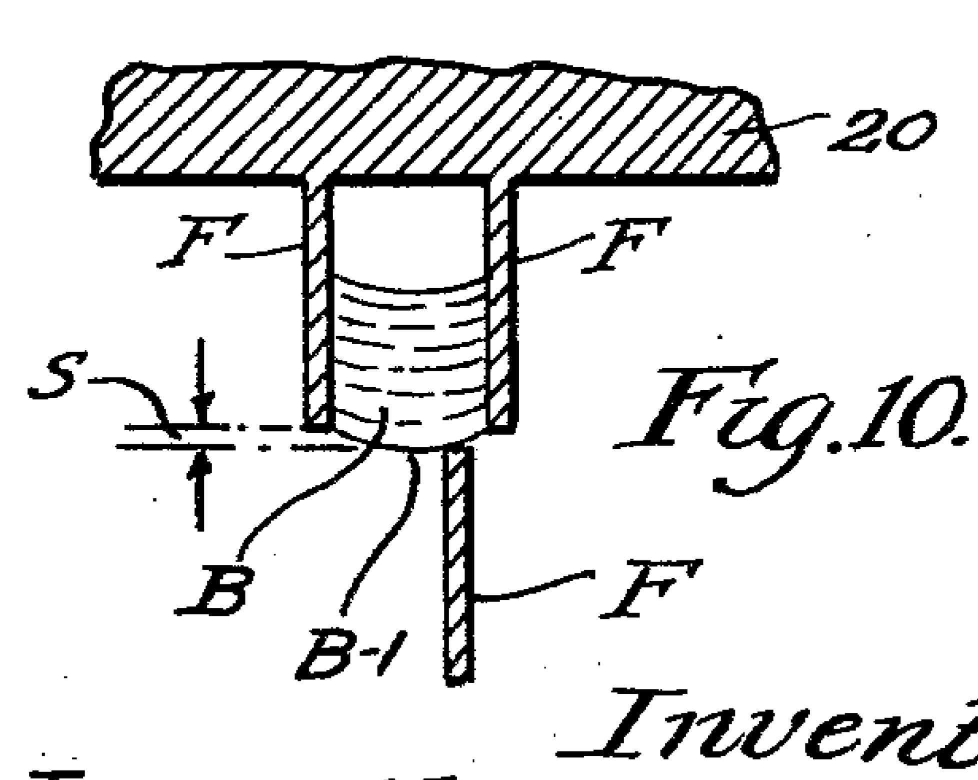

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3,180,405

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3,180,405
CONDENSERS

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Filed Mar. 11, 1959, Ser. No. 798,616
7 Claims. (Cl. 165—117)

This application is a continuation-in-part of my copending application Serial No. 646,055, filed March 14, 1957, now abandoned. This invention relates to condensers and particularly to shell and tube condensers that are adapted for use in refrigerating systems.

Condensers of the aforesaid character customarily have the tubes disposed horizontally within an elongated shell so that gaseous refrigerant introduced into the upper portion of the shell may flow downwardly over the tubes so as to be condensed on the surface of the fin tubes, and the resulting liquid refrigerant is withdrawn from the lower portion of the shell. In many instances such withdrawal of the liquid refrigerant is attained in such a way as to maintain one or more lower tubes submerged, thus to provide for sub-cooling of the liquid refrigerant. The coolant in such condensers is usually fresh or salt water, although other coolants may be used in many instances. Such shell and tube condensers are made in both straight tube and U-tube embodiments which in many respects are interchangeable, but in those situations where cleaning of the tubes is important, the straight tube type with tubes of uniform internal diameter is of course preferable.

The primary object of the present invention is to enable the condensing efficiency and capacity of such condensers to be materially increased, and an object related to the foregoing is to accomplish this in a simple and effective manner.

The accomplishment of the foregoing objectives under the present invention is based upon the attainment of a more effective and efficient flow of both the gaseous refrigerant and the condensate over the condensing surfaces of the tubes so that the desired condensing action takes place uniformly on the very maximum of available condensing surface. This involves the attainment of more uniform distribution of the gaseous flow within the shell of the condenser, the provision of improved and well defined flow paths for controlling the flow of the gaseous refrigerant, and provision for continuous and rapid removal or drainage of the condensed or liquid refrigerant from the tube surfaces so that the tube surfaces retain their maximum condensing efficiency.

The present invention contemplates the accomplishment of its objectives in such a manner that use may be made of fin tubes of the types now known, and in this respect, one of the most practical fin tubes for use in refrigerant condensers of this kind is a tube having a $\frac{3}{4}''$ outer diameter with integral fins which extend out $\frac{1}{16}''$ from a $\frac{5}{8}''$ outer diameter tube and which are spiraled around the tube from 11 to 19 times per inch. The fins are conventionally made as thin as possible, so that the width of the intermediate spaces is just slightly less than the center spacing of the fins. This provides a ratio from 3:1 to 5:1 of outside and inside areas that has been found to be particularly efficient with Freon gas.

In prior shell and tube condensers, it has long been known that as the condensing operation proceeds, the liquid refrigerant flows to the bottom of the tube or its fins on each of the horizontally positioned tubes, and because of the surface tension of the liquid refrigerant, this liquid refrigerant does not immediately fall from the lower surfaces or edges of the tubes, but tends to collect in drops or bodies of liquid. With fin tubes as heretofore used,

the drops eventually spread longitudinally of the tube so as to extend across the lower edges of several of the fins. The fins are, of course, spaced apart but a slight distance, and once the liquid refrigerant has collected on the fins, it runs down to the lower portions of the fins and forms into a narrow body of liquid that bridges the distance between two adjacent fins. The surface tension of the liquid causes this liquid to be held in place between the lowermost portions of the fins, and further condensation causes the liquid level to rise with a capillary action between the fins. This gathering of liquid between the fins progresses gradually upwardly until, in many instances, the liquid refrigerant closes and fills the spaces between the fins as far upwardly as two-thirds of the diameter of the tube. When Freon is used, the upward travel or gathering of the liquid refrigerant between the fins usually does not extend upwardly beyond the tube axis. The extent to which the liquid may extend upwardly between the fins, is, of course, governed in part by the spacing of the fins and in part by the surface tension and viscosity of the liquid refrigerant, and in this respect it is noted that the oil that is often carried with the refrigerant from the compressor and through the system tends to increase the surface tension and viscosity and aggravates the problem presented by the gathering of liquid between the fins.

As the liquid gathers between the fins up to the level that is determined as above described, a portion of the liquid extends downwardly beneath the lower edges of the fins, and as further liquid is gathered gradually, this lower suspended portion assumes a drop formation beneath the fins so that it is released drop by drop from the main body of the gathered liquid and falls downwardly from the tube toward the lower portions of the condenser shell or toward tubes that are located at a lower level. Even after separation of such a drop, a considerable quantity of liquid remains between the fins at the point where the drop separation has taken place and hence full condensing efficiency is not achieved in the adjacent region even after separation of such a drop. Usually about 15% of the adjacent fin area remains covered after such discharge of a drop of liquid refrigerant, and the continued condensing action then starts further build-up of liquid between the fins so that varying proportions of the fin surfaces are disabled by such collected liquid at all times.

This intermittent downward discharge of the liquid refrigerant from the tubes, in the form of drops has heretofore led workers in this field to arrange the tubes of a condenser in what may be termed staggered relationship in an effort to minimize contact of the falling drops with other tubes of the condenser. This staggered or triangular pitch arrangement of the tubes has been considered necessary because such liquid traveling downwardly in the form of drops tends to cause additional gathering or building up of liquid on any lower tube that it may encounter in its downward travel.

In view of the foregoing, it is a further and more specific object of the present invention to enable the effect of such surface tension and drop formation in the liquid refrigerant to be minimized in condensers of the aforesaid character, and a more specfic object is to provide condensers of the aforesaid character in which direct drainage or flow paths are provided for the condensed liquid refrigerant to be minimized in condensers of the fins and tubes will remain clear of collected liquid refrigerant and will for the most part be effective at all times to attain the desired condensing action.

The use of the staggered tube relationship in prior shell and tube condensers has resulted in the provision of rather complex or indeterminate flow paths for the gaseous refrigerant, and a further object of the present invention is to establish a new arrangement for the tubes of such condenser whereby the flow paths for the gaseous refrigerant from the inlet and downwardly past the tubes are less complex, and are well defined so as to prevent turbulence that causes pressure drop without increasing the gas velocity, and whereby the velocity of the gaseous refrigerant may be determined and controlled in the condenser design so as to attain a maximum velocity past the tubes with a minimum pressure drop.

In liquid cooled condensers of the aforesaid character, the cooling of the gaseous refrigerant progresses as such gaseous refrigerant flows across the tubes, and as the refrigerant is condensed, a lower pressure is produced at the point of condensation which tends to draw a further supply of gaseous refrigerant toward the point or area where the condensing action has taken place, and it is a further object of the present invention to so introduce the gaseous refrigerant into the condenser shell that a supply of gaseous refrigerant is available substantially uniformly along the top of the condenser shell so that this available supply of gaseous refrigerant may then be drawn downwardly in a substantial uniform manner across and between the tubes as such movement is induced by the progressive condensing action.

In shell and tube condensers it is well recognized that pulsation of the gas often initiates vibration of the tubes, and where tube supports are employed, such vibration results in rattling of the structure as well as in wear of the tubes at the points where they strike against such supports. As a result resort is often had to elaborate and expensive tube supports involving cushioning elements for the tubes. In view of this, it is a further important object to enable such vibration and noise to be eliminated in a simple and inexpensive manner.

Other and further objects of the present invention will be apparent from the following description and claims, and are illustrated in the accompanying drawings, which, by way of illustration, show preferred embodiments of the present invention and the principles thereof, and what is now considered to be the best mode in which to apply these principles. Other embodiments of the invention embodying the same or equivalent principles may be used as desired by those skilled in the art without departing from the invention.

In the drawings:

FIG. 1 is a vertical sectional view showing a liquid cooled condenser embodying the features of the invention, the condenser being of the straight tube type;

FIG. 1A is plan sectional view of an alternative embodiment of the invention wherein U-tubes are employed;

FIG. 2 is a left hand elevational view of the condenser shown in FIG. 1, the view being taken from the line 2—2 of FIG. 1;

FIG. 3 is a fragmentary vertical sectional view taken between the stacks of tubes;

FIG. 4 is an enlarged vertical sectional view taken substantially along the line 4—4 of FIG. 1;

FIG. 5 is a simplified and somewhat schematic view of similar portions of FIG. 4 and illustrating the paths of gas flow and the flow of condensate;

FIG. 6 is a greatly enlarged cross sectional view of two tubes arranged one above the other in slightly spaced relation; and

FIGS. 7, 8, 9 and 10 are sectional views illustrating tubes spaced slightly in a vertical sense and with the tubes having the fins spaced in different amounts and with the fins of the lower tube located in different longitudinal relationships with respect to the upper fins.

For purposes of disclosure the invention is herein illustrated in FIGS. 1 to 5 as embodied in a straight tube, shell type condenser 10, while in FIG. 1A the invention is shown in plan section and at a reduced scale as embodied in a U-tube, shell type condenser 110. The condenser 10 comprises an elongated cylindrical shell 12 adapted to be mounted in a horizontal position and having tube sheets 14 fixed in opposite ends thereof, and end heads 16 and 18 are secured by studs 19 to the respective tube sheets 14 for directing flow of cooling media through a plurality of tubes 20 that extend lengthwise through the shell 12 and are mounted at their opposite ends in the tube sheets 14. The end heads 16 and 18 shown are so formed as to attain 2-pass operation of the condenser, but this is merely illustrative. Other pass arrangements may be used to attain desired coolant velocity. In this form the head 16 has a liquid inlet 16A and liquid outlet 16B separated by a horizontal division wall 16D, while the head 18 is formed without internal divisions, thus to provide for 2-pass operation. The condenser 10 has a gas inlet 22 at the top of the shell 12 while a bottom outlet 24 is provided in the shell for discharge of the condensate.

Under and in accordance with the present invention, relatively simple and inexpensive structural improvements have been made in the condenser which control and direct the flow of both the gas and the condensate to better advantage, and this results in the attainment of greatly improved condensing efficiency. Such improvements are concerned primarily with the arrangement and relationship of the tubes 20 and with the efficient initial distribution of the gas for subsequent flow downwardly past the tubes.

Thus, in form herein illustrated, the tubes 20 are illustrated as fin tubes of a type that is well known in the trade as "Wolverine" fin tubing, made by the Wolverine Tube Division of Calumet and Hecla Consolidated Copper Co., Inc. This tubing is made from copper or other desired metals with integral spiral fins F that are closely spaced so that in most instances, for refrigeration work, from 11 to 19 fins are provided per inch of tube length. The tube size, material, shape and wall thickness, and the fin spacing, the fin thickness and the fin depth may, of course, be varied according to the proposed use, and the present invention is applicable to condensers independently of such variations.

Such fin tubing as used in prior liquid cooled condensers has been disposed horizontally so that the gas may flow in a downward direction, transversely of the tubes, along and between the fins, and the condensate formed on the fins of each tube thus tends to drain to the lower edges of such fins. This condensate gradually collects at the lower edges of the fins and builds up between fins so as to partially disable the condensing surfaces, as described hereinabove. Under the present invention this objectionable action is reduced and substantially eliminated by arranging the fin tubes 20 in a series of tiers or stacks S that are spaced apart laterally to provide well defined vertical flow paths P for the gaseous refrigerant between adjacent stacks S, and with the fins F of adjacent tubes 20 in each stack S so related to each other that drainage of liquid from each fin will take place before the liquid has accumulated to such a volume as to build up by capillary action in the space between the adjacent fins. In the embodiment of the invention illustrated in FIGS. 1 to 5, this is accomplished by arranging the fins F of adjacent tubes 20 in each stack in firm contact so as to provide continuous downward drainage paths for the condensate.

In accomplishing the foregoing in the embodiment of FIGS. 1 to 5, the tubes 20 are modified somewhat from their usual commercial form in order that the fins F of adjacent tubes 20 in each stack S may engage each other while at the same time providing the necessary width of ligament between adjacent tubes as such tubes are mounted in the tube sheets 14. Thus, it may be pointed out that the ordinary commercial form of Wolverine 19-fin tubes is such that the fins terminate a substantial distance from the ends of the tubes to provide unfinned end portions which have an outer diameter the same as the outer diameter of the fins. Under the present invention, however, the unfinned end portions are reduced in diameter, and this is illustrated particularly in FIG. 3 of the drawings where unfinned end portions 20E are illustrated as having the same outer diameter as the other portions of the tube. This is accomplished by a tube-reducing operation performed on a die or swaging machine, and when the ends 20E have been thus reduced, they may be mounted in openings 14B in the tube sheet by any conventional manner of tube mounting, and adequate ligaments 14L are thus afforded between the adjacent tubes 20.

In FIGS. 1, 4 and 5, an arrangement of the several tubes 20 in stacks S has been illustrated whereby an 80-tube condenser is provided, and the tubes 20 in such stack S are held together with the adjacent fins F in firm contact by clamping means that extend downwardly through the passages P between the stacks. Such clamping means are provided in the present instances by U-bolts 25 that are fitted downwardly over each stack S, as shown in FIGS. 1 and 4, and cross bars 26 extend between the lower arms of the respective U-bolts 25 and are clamped in place thereon by nuts 25N. The nuts 25N are tightened so that fins of adjacent tubes 20 in the stack S are held in engagement with each other. While a single U-bolt 25 is shown for each stack S in the present instance, it is to be noted that two or more spaced clamping bolts 25 may be used as required where the tubes 20 are relatively long. Moreover, the lower ends of the U-bolts 25 may have the lower ends extended as shown in dotted outline, so as to rest on the bottom of the shell 12, thus to provide support for the tubes, and by this means the tubes may be supported at intervals as required in many instances. Such support is, of course, simple and economical in character. The use of the clamping means 25 assures the desired contact of the fins even though a slight increase in vertical spacing may be used at one or more points such as along the line of contact of the division wall 16D with the tube sheet. In such a case the clamping means merely bends the tubes 20 slightly to bring the fins F into contact.

The U-bolts 25, in clamping the tubes 20 of a stack in engagement with each other, also serve a further important function in that they prevent individual vibration of the tubes 20 and join the tubes of each stack into a single unit which possesses sufficient size and moment to prevent vibration of the unit as a whole. Thus, there is no rattle of wear of parts, and this is accomplished by a simple and inexpensive structure that may also serve as a tube support as hereinbefore described.

As pointed out hereinabove, the compressed gaseous refrigerant enters the top of the shell 12 of the condenser, and while several inlets may be provided in longer condensers at spaced points along the top of the condenser, the present embodiment illustrates but a single inlet 22 from which gaseous refrigerant is discharged into a distribution space 12S that extends along the top of the stacks S of the tubes. Under the present invention the compressed gaseous refrigerant is introduced into the space 12 in such a way that the gaseous refrigerant is well distributed throughout the entire length of the space 12S. This is accomplished by the provision of a nozzle structure 30 mounted within the inlet 22 and extended downwardly into the space 12S so as to discharge the gaseous refrigerant endwise in opposite directions within the space 12S. Thus, the nozzle 30, as herein shown in the form of a tube 30T that fits snugly into the inlet 22 and which is secured therein so that the lower end portion of the tube 30T extends downwardly into the space 12S for a substantial distance. The lower end of the tube 30T is closed by a bottom wall 30B of sheet metal that is held in place by a pair of sheet metal brackets 31. Discharge openings 30D are cut into the opposite sides of the tube 30T just above the bottom wall 30B, and there discharge openings 30D are arranged to face in opposite directions so that the gaseous refrigerant will be discharged longitudinally in the space 12S toward opposite ends of this space. In practice it has been found that the best results are obtained by so sizing the openings 30D that a back pressure of from 0.2 to 0.5 of one pound per square inch is created within the nozzle 30. This results in an adequate velocity of the discharged gaseous refrigerant so that the refrigerant will flow to the extreme ends of space 12S.

With the gaseous refrigerant thus distributed in a substantially uniform manner throughout the upper space 12S, such refrigerant is present at all times in an adequate supply and flows in a uniform manner downwardly through the spaces P between the stacks S of finned tubes 20. Having been uniformly distributed by the nozzle structure 30, such flow under the present invention takes place in a uniform and controlled manner downwardly through the passages P, and as the refrigerant is condensed on the tube surfaces, the condensate is rapidly drained down each stack of tubes so as to maintain maximum condensing efficiency of the tubes. Thus, as illustrated particularly in FIG. 5, the contacting fins F provide a continuous drainage path from the top tube 20T of each stack about the several intermediate tubes 20-I and the bottom tube 20-B of the stacks. In such flow, the adverse effects of surface tension are avoided, and objectionable build-up of condensate on the top tube 20T or any of the intermediate tubes 20-I is avoided. The flow of condensate takes place along the several fins F in the manner indicated by the dotted arrows in FIG. 5, and the condensate from an upper tube flows in a normal manner to the fin surfaces of the next lower tube without build-up or drop formation, this result following because of metal to metal contact of the adjacent fins in each stack.

Where the lowermost tubes are covered by the liquid so as to be used for liquid subcooling, it will be evident that there is no build-up of liquid on the exposed tubes. In other instances where no sub-cooling is to be attained, a somewhat different action takes place. Thus, when the condensate reaches the bottom tube 20B there is necessarily a build-up of liquid as indicated at L in FIGS. 3 and 5, and as to the bottom tube 20B of each stack, such build-up of liquid between fins F takes place in the general manner indicated at C in FIG. 3. This build-up of condensate applies, however, only to the lowermost tube 20B of each stack S so that the adverse effects of this build-up are limited to the bottom tube of each stack, and all of the other tubes 20 of each stack S are maintained substantially free of condensate so that the maximum condensing efficiency of these other tubes is maintained.

With liquid cooled condensers constructed in accordance wtih the present invention as hereinabove described, it has been found that the condensing efficiency has been increased by approximately thirty percent, and as a result of this condenser for a selected capacity may be produced with a saving in tube length of approximately thirty percent. Such reduction in size and weight is of great advantage in many uses, as for example, in shipboard installations and in package units such as water coolers and the like. The reduction in tube length is substantial insofar as the original cost of the condenser may be concerned, and because of reduction in the length of the flow path for the coolant, there is a marked reduction in the pressure drop between the inlet and outlet of the coolant circuit for a desired coolant velocity. This enables lower input pressures to be used in the coolant circuit, and where special pumping equipment is required for this purpose, substantial reduction in the cost and operational expenses of such pumping equipment is also attained.

It has been pointed out hereinabove that the space between the stacks S of the tubes provides a well defined flow path for the gaseous refrigerant, and by varying the spacing of the stacks in the design of the condenser, it is possible to control the flow velocity and pressure drop of the gaseous refrigerant so as to obtain the maximum condensing efficiency. Thus, increased width in the passage P is required as the height or number of tubes in a stack S is increased, or where a refrigerant having a higher condensing coefficient is used. Within the practical limits of size for tube and shell condensers, it is found that based on the foregoing considerations the passages P may require variation between 1/64 inch and 1/4 inch to attain the optimum gas velocity and pressure drop.

In the embodiment of the invention illustrated in FIG. 1A of the drawings, the condenser 110 is shown in plan section and has a shell 112 that has refrigerant inlet and outlet means (not shown) of the kind hereinbefore described in respect to FIG. 1 and the shell 112 is closed at one end by a head 118 that is welded in place, while at the other end, a tube sheet 114 is fixed in the end of the shell 112. The tube sheet 114 serves as a mounting for opposite ends of a plurality of U-shaped fin tubes 120, each such U-tube being located in a horizontal plane. The tube sheet 114 has an end head 116 fixed thereto by bolts, and the head 116 has a vertical division wall 116D so that cooling liquid entering an inlet 116A may pass into corresponding ends of all of the U-tubes 120 and will be discharged on the other side of the division wall 116D where it may flow from the outlet 116B.

The U-tubes 120 have the opposite legs arranged at different spacings so that the tubes of corresponding form are arranged in stacks in the manner hereinbefore described in respect to the other embodiment of the invention, and by reason of the different spacings of the legs of the U-tubes of the respective stacks, vertical passages P are provided between adjacent stacks for downward flow of gaseous refrigerant. One or more clamping structures including U-bolts 125 may be associated with each stack of tubes 120, thus to assure engagement of the fins F of the adjacent tubes in the respective stacks. With a U-tube type of condenser embodying the present invention, the distribution of the gaseous refrigerant above the stacks of tubes is accomplished by means of a nozzle structure 30 of the character hereinbefore described.

In the foregoing description the invention has been described in its preferred form where there is actually edge contact of the fins of vertically adjacent tubes in each stack thereof, but it must be kept in mind that while such edge contact of the fins is considered to represent the best mode of carrying out the present invention, the advantageous results hereinbefore set forth may be accomplished so long as the edges of the vertically adjacent fins are sufficiently close to each other to drain the accumulated condensate frequently and before it has covered any appreciable area of the fins. Thus, in FIGS. 6 to 10, the drainage paths of the condensate have been illustrated at a greatly enlarged scale so as to bring out the effective drainage action that is attained even without edge contact of the fins in those instances where the adjacent fins of vertically adjacent tubes in a stack are out of contact but are maintained sufficiently close to each other to cause frequent transfer of gathered condensate from the space between the lower portions of adjacent fins F to individual fins of the next lower tube.

As a basis for a discussion of FIGS. 6 to 10 of the drawings it may be pointed out that in the manufacture of a condenser, the longitudinal relationship of vertically adjacent tubes in a particular stack determines whether or not the fins of adjacent tubes are aligned one to the other. If such fin alignment is maintained, actual physical contact of vertically adjacent fins may be attained, and in this respect, where the fin tube is spirally finned type, such alignment of the fins may be attained by rotatively adjusting the tubes prior to the time when the tubes are fixed in position in the tube sheet. However, if the axes of adjacent fin tubes are maintained sufficiently close in a vertical sense, then, regardless of the relative longitudinal location of the fins, there will be frequent transfers of condensate from the respective fin spaces of an upper one of the tubes to the individual fins of the next lower tube so that efficient drainage of the tubes will be attained.

Thus, in FIG. 6 of the drawings, the fins F of two vertically adjacent tubes 20 are illustrated as being spaced apart in a limited and relatively small amount S in a vertical sense, and when the tubes 20 are in this relationship, the condensate tends to run downwardly along the fins F of the upper tube 20, and to form a bridge B of liquid extending between the lowest points of adjacent fins F. For purposes of definition, it is convenient to define a lengthwise reference line passing through lower extremities of the fins on any upper tube. In each of drawings FIGURES 6 to 10, this imaginary reference line is coincident with the upper dimension line for the distance S. It will become apparent that the critical maximum spacing S is measured in a vertical dimension between the upper extremity of a fin on a lower tube and the imaginary line defined between the lower extremities of the fins of the next tube above.

The precise way in which the bridge B of condensate forms between adjacent fins F is not clearly understood, but the bridge B initially forms at the lowermost point between the adjacent fins F, and as further condensate runs downward at the sides of the fins, the size or dimensions of the bridge B of condensate increase, and due to the capillary action in the extremely narrow space between the fins, the condensate is held between the fins and continues to gather until such time as the lower portion of the bridge B of liquid engages a fin F of the next lower tube 20.

It has been found that where the vertical spacing S of the fins of adjacent tubes of a stack is maintained on the order of .010 inch, or less, the drainage function is accomplished in such a way that the tubes are cleared of liquid almost as completely as where edge to edge contact of vertically adjacent fins is maintained. With a spacing of about .010 inch, this result takes place regardless of the longitudinal relationship of the fins of vertically adjacent tubes, and regardless of the particular fin spacing. Thus, in FIGS. 7 and 9, the fins of vertically adjacent tubes have been illustrated at different longitudinal relationships in respect to finned tubes that have a relatively great fin spacing. In FIGS. 9 and 10, the fins of vertically adjacent fins have been illustrated in different longitudinal relationships in respect to fin tubes having the fins at a closer or smaller spacing.

When the bridge B of liquid is formed between adjacent fins F, the lower surface of the liquid tends to assume a downwardly convex form, and as the amount of liquid in the bridge B increases, the downward convexity of the lower surfaces B–1 of such liquid increases. When the lower surface B–1 has extended downwardly for a sufficient distance to engage the fin F of the next lower tube, the liquid in the bridge B is drained to the lower fin which it has engaged so that the bridge of liquid B between the fins F is broken and the liquid drains away. This process is repeated fairly rapidly but in dependence upon the rate of condensation, and where the vertical spacing S is maintained at about .010 inch, the accumulation of liquid between the fins F is maintained relatively small, and efficient condensing action of substantially the entire area of the fins of the upper tube 20 is assured.

It has been further found that as the vertical space S is increased, larger and larger amounts of liquid collect between the adjacent upper fins F, and the drainage of such liquid becomes less efficient. In other words, all of the liquid is not drained from the fin space in each drainage operation. Up to a spacing of about .020 inch, the drainage action is reasonably effective so that a relatively high condensing efficiency will be attained, although such efficiency will necessarily be somewhat less than the efficiency attained when the spacing is maintained at less than .010 inch. Thus where the fins of vertically adjacent tubes in a stack are so close to each other that the lowermost portion of the fins of an upper tube are not substantially more than 0.02 inch above the uppermost portions of the fins of the next lower tube, condensate collecting between and depending from the fins of the upper tube makes contact quickly with a fin of the next lower tube so as to be drained from the upper tube before there has been any appreciable masking of the condensing surfaces of the upper tube. Finally, when the spacing S between the vertically adjacent tubes is increased to .030 inch, it is found that there is an objectionably large accumulation between the fins that is comparable to the accumulation that is encountered in the bottom one of the tubes of a stack as illustrated at C in FIG. 3 of the drawings.

With the foregoing considerations in mind, it has been determined that while edge to edge contact of the vertically adjacent fins is not essential, it is nevertheless best practice to arrange these fins relatively close to each other in a vertical sense, and when this is done, vertical alignment of adjacent fins may be disregarded in the manufacturing operations.

As a practical matter, it has been determined that by making the tube mounting openings in the tube sheet **14** at a vertical spacing which exceeds the outer diameter of the fin tube by substantially .002 inch, the operation of mounting the fin tubes **20** in the tube sheets **14** is simplified, and yet with the resulting vertical spacing of .002 inch between the fins of the vertically adjacent tubes, efficient drainage of the fin spaces is assured despite any variations in the longitudinal relationship of vertically adjacent fins. Moreover, when a spacing of approximately the above magnitude is employed, the application of the clamping structures **25** merely causes slight bowing of tubes so that the fins F of vertically adjacent tubes engage or enter into spaces between opposed fins. Thus in either event, proper drainage is assured. Near the ends of the tubes there will of course be a vertical space between the fins, but since this space is extremely small, proper drainage is attained.

While in the foregoing description an increased condensing efficiency of about 30 percent has been described, it has been found that this figure is overly conservative and is greatly exceeded in practice, particularly where the invention is embodied in shell and tube condensers of large capacity.

The fins that are illustrated herein are circular in elevation, but it should be understood that there are other equivalent configurations having an upper fin shaped to concentrate condensate at a lower gathering point or portion of such fin that is contiguous to an upper condensate-receiving point or portion of the next lower fin in the tier.

Thus, for example, where a four foot by eight inch shell was used with forty ¾ inch O.D. 19 fins per inch Wolverine tubing in a 4-pass relation for 105° F. condensing temperature with the water entering at 85° F. and the water leaving at 95° F, the prior art staggered arrangement of the tubes produced a condensing capacity of 11 tons with Freon 12 or Freon 22, while arrangement of the tubes in stacks according to this invention resulted in a condensing capacity of 16 tons. Thus the efficiency was increased by 45 percent.

In the structures compared in the foregoing example, it will be noted that the same number of fin tubes have been used, but it must be kept in mind that with the tubes arranged in stacks under the present invention, it is possible to place more tubes in a shell of a particular size, and when advantage is taken of this capability of the present invention, even greater increases in condensing efficiency may be obtained from condensers having the same size shell as prior condensers. Thus with the same kind of tubing arranged in a two-pass relationship within an 8 foot by 18 inch shell, and operating with the same condensing temperature and water entering and water leaving temperatures, it was found that a still greater increase in overall efficiency was obtained. In a condenser with the tubes arranged in the staggered relationship of the prior art 208 tubes were used, and a condensing capacity of 100 tons was obtained with Freon 12 or Freon 22, while with the tubes arranged in stacks in accordance with the present invention, 258 tubes were used, and a condensing capacity of 214 tons was obtained. This represents a 115 percent increase in efficiency over the prior condensers of the same external size.

It will be apparent that the present invention enables the condensing efficiency of water cooled condensers to be materially increased, and as a result of this increase of efficiency, the cost of the condenser is reduced. It will also be apparent that the present invention enables more effective and efficient flow of both the gaseous refrigerant and the condensate to be attained in a liquid cooled condenser, and it will also be evident that this result is attained by means that are simple and effective in character.

It will also be apparent that under the present invention the flow paths for the gaseous refrigerant are well defined so that the flow of gaseous refrigerant may be uniformly controlled, and the design of the condenser may be varied to attain the desired rate of flow of gaseous refrigerant with respect to the tubes. It will also be apparent that the condensate produced in the present condenser is rapidly drained from the condensing surfaces so that the maximum condensing efficiency is maintained in the condenser.

Short and closely spaced fins have been found in the industry to be most efficient in condensing refrigerants such as Freon, and such short and closely spaced fins give the desired ratio of inside and outside areas coupled with a more compact condenser design and an efficient coolant velocity. However, it is with the narrow fin spaces of such tubes that capillary action interferes most with tube drainage and is most detrimental to condenser efficiency. Hence, the present invention enables efficient drainage to be attained in the most troublesome situations that are encountered in condenser manufacture and design.

Thus while I have illustrated and described preferred embodiments of my invention it is to be understood that changes and variations may be made by those skilled in the art without departing from the spirit and scope of the appended claims.

I claim:

1. In a shell and tube condenser including an elongated shell provided with coolant inlet and outlet passages and having a top inlet for a condensable gas and a lower outlet for condensate, a plurality of horizontally disposed coolant tubes interconnecting said coolant inlet and outlet passages, said tubes being arranged in juxtaposed vertical tiers with substantially all tubes of a given tier lying in a common vertical plane, the tubes of said tiers having circular fins along their length spaced apart a distance such that droplets of condensate forming on a fin surface of any given tube accumulate and bridge across to an adjacent fin surface of said given tube and, in the absence of additional structure adjacent a lengthwise reference line between lower extremities of said bridged fin surfaces, tend to be held between said lower extremities by capillary action, and tend to accumulate additional condensate between the bridged fin surfaces, the relative vertical location of any given pair of upper and lower juxtaposed tubes in such tier establishing the upper extremities of the fins of the lower tube, at least as close, in vertical dimension, as .02 of an inch to the lengthwise reference line between lower extremities of the fins of the upper tube, whereby the tendency of droplets of condensate to accumulate between adjacent fins of a given tube is avoided and overcome by condensate draining substantially continuously from the lower extremities of the fins of the last named tube to the upper extremities of the fins of the next lower tube.

2. A shell and tube condenser according to claim 1, wherein the spacing of the fins of the tubes of adjacent tiers defines a downward passage having a width of between $\frac{1}{64}$ inch and ¼ inch.

3. A shell and tube condenser according to claim 1, wherein the spacing of the fins of the tubes of adjacent tiers defines a downward passage having a width of between 1/64 inch and 1/4 inch, and wherein nozzle means forming a continuation of said top inlet are disposed within said shell to discharge condensable gas longitudinally of the shell and above the downward passages.

4. A shell and tube condenser according to claim 1, wherein the tube fins are helical in form and integral with their associated tube.

5. In a shell and tube condenser including an elongated shell provided with coolant inlet and outlet passages and having a top inlet for a condensable gas and a lower outlet for condensate, a plurality of horizontally disposed coolant tubes interconnecting said coolant inlet and outlet passages, said tubes being arranged in juxtaposed vertical tiers with substantially all tubes of a given tier lying in a common vertical plane, the tubes of said tiers having circular fins along their length spaced apart a distance such that droplets of condensate forming on a fin surface of any given tube accumulate and bridge across to an adjacent fin surface of said given tube and, in the absence of additional structure adjacent a lengthwise reference line between lower extremities of said bridged fin surfaces, tend to be held between said lower extremities by capillary action, and tend to accumulate additional condensate between the bridged fin surfaces, the relative vertical location of any given pair of upper and lower juxtaposed tubes in such tier establishing the upper extremities of the fins of the lower tube in tangency to a lengthwise reference line between lower extremities of the fins of the upper tube, whereby the tendency of droplets of condensate to accumulate between adjacent fins of a given tube is avoided and overcome by condensate draining substantially continuously from the lower extremities of the fins of the last named tube to the upper extremities of the fins of the next lower tube.

6. In a shell and tube condenser including an elongated shell provided with coolant inlet and outlet passages and having a top inlet for a condensable gas and a lower outlet for condensate, a plurality of horizontally disposed coolant tubes interconnecting said coolant inlet and outlet passages, said tubes being arranged in juxtaposed vertical tiers with substantially all tubes of a given tier lying in a common vertical plane, the tubes of said tiers having circular fins along their length spaced apart a distance such that droplets of condensate forming on a fin surface of any given tube accumulate and bridge across to an adjacent fin surface of said given tube and, in the absence of additional structure adjacent a lengthwise reference line between lower extremities of said bridged fin surfaces, tend to be held between said lower extremities by capillary action, and tend to accumulate additional condensate between the bridged fin surfaces, the relative vertical location of any given pair of upper and lower juxtaposed tubes in such tier establishing the upper extremities of the fins of the lower tube in one to one corresponding contact with the lower extremities of the fins of the upper tube, whereby the tendency of droplets of condensate to accumulate between adjacent fins of a given tube is avoided and overcome by condensate draining substantially continuously from the lower extremities of the fins of the last named tube to the upper extremities of the fins of the next lower tube.

7. A shell and tube condenser according to claim 5, wherein clamping means are associated with each of said tiers of tubes for clamping at least the mid-portions of the tubes of the tier with the fins of the vertically adjacent tubes in engagement.

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