Dec. 14, 1965 W. G. DEDERT 3,223,144

EVAPORATOR APPARATUS

Filed May 17, 1962 2 Sheets-Sheet 1

Fig. 1

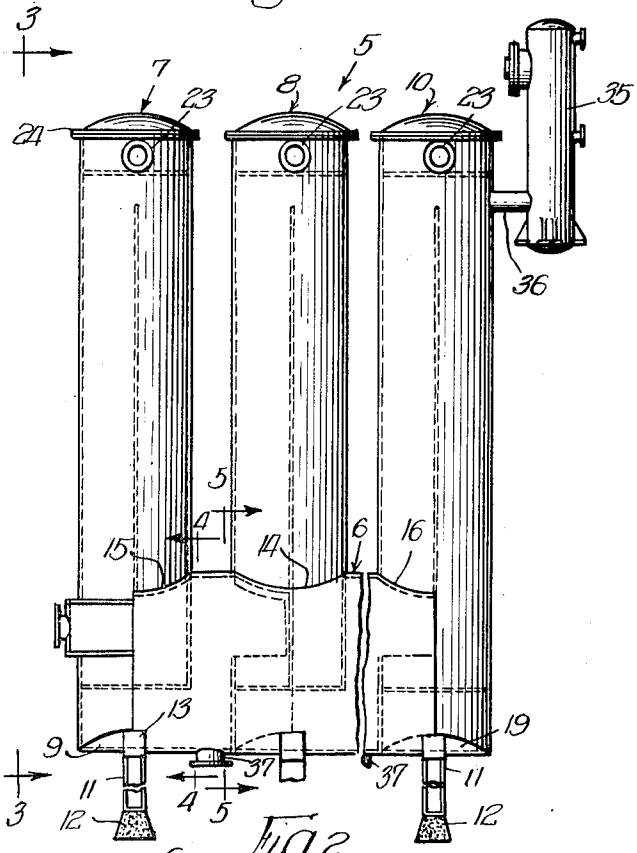


Fig. 3

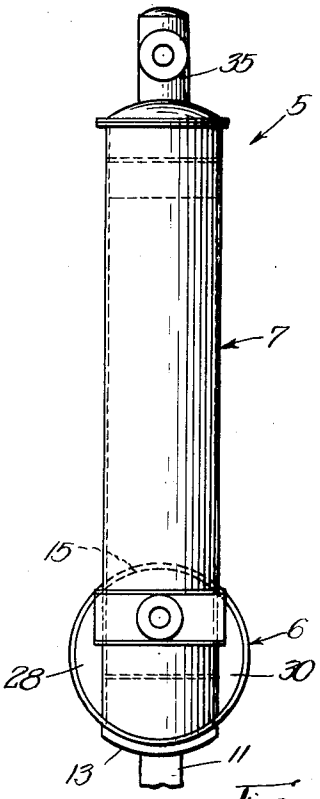


Fig. 2

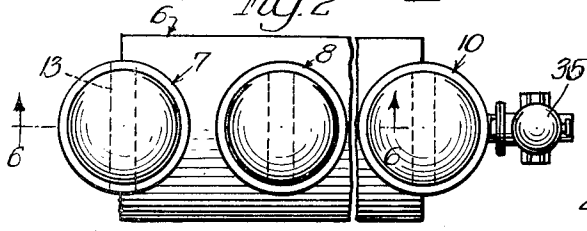


Fig. 5

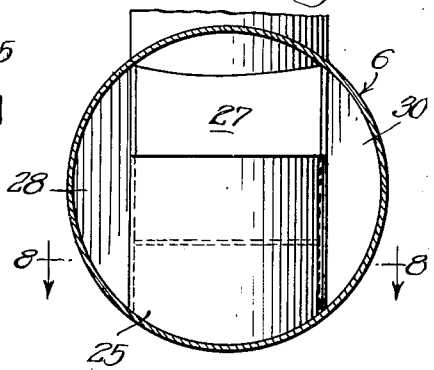
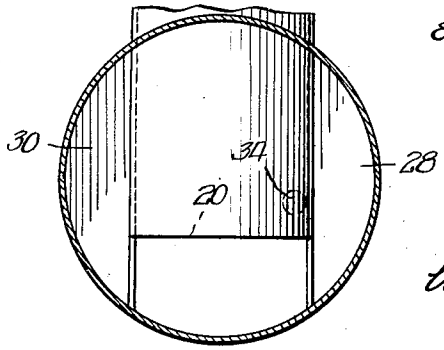


Fig. 4



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Fig. 6

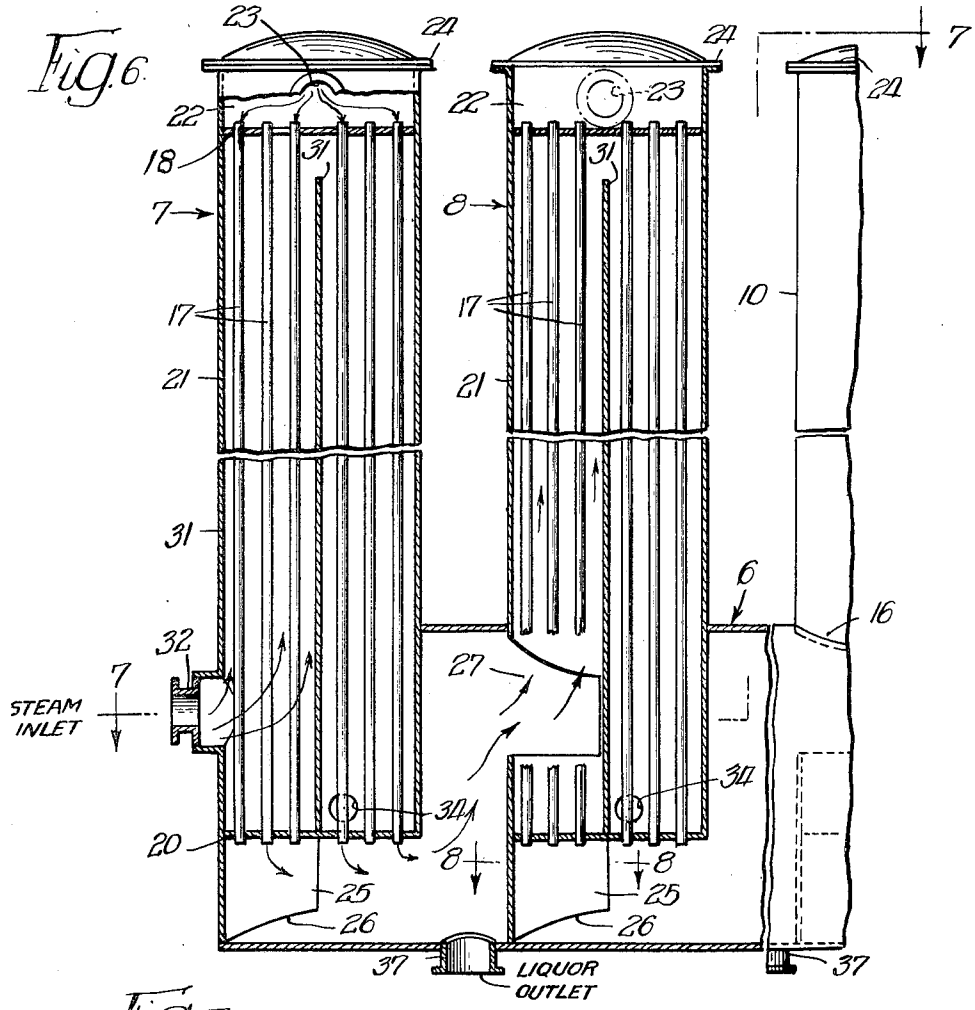


Fig. 7

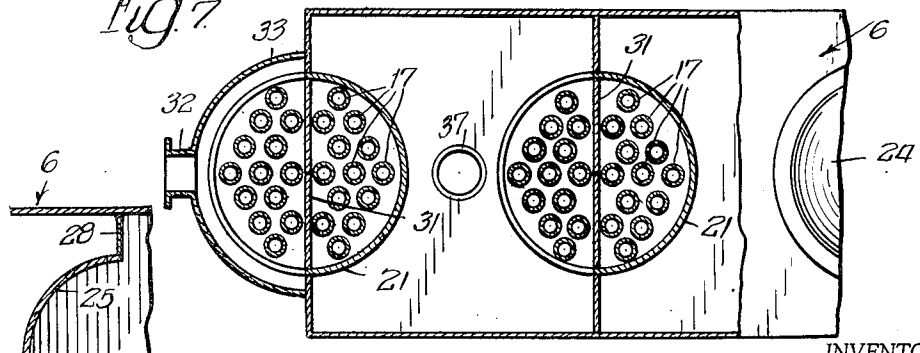


Fig. 8

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EVAPORATOR APPARATUS

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7 Claims. (Cl. 159—13)

This invention relates to innovations and improvements in heat transfer apparatus, and it relates particularly to multiple-effect evaporator apparatus.

In various evaporator installations, particularly in so-called multiple-effect evaporator installations, interconnections are provided between a plurality of individual evaporators for conducting vapors from one effect to another. Such connections are usually of the external type in the form of exposed conduits and piping running between individual evaporator devices or units (commonly referred to as the "first-effect", "second-effect", etc.).

In accordance with the present invention the main external connections can be eliminated. As a result of the invention improvements of a substantial nature are obtained which are reflected in more efficient and economical operation and construction.

A key feature of the invention is the provision of a header tube (which is usually cylindrical and in a horizontal position) into which project, in sealed off relationship, corresponding ends of a plurality of individual evaporators or heat transfer units having internal heating tubes. While the tubular header could be disposed in a vertical position and the individual evaporators could project laterally therefrom, the more conventional and useful arrangement is for the tubular header to be disposed in a horizontal position with the individual evaporators extending vertically thereabove in single file orientation with the bottom ends thereof projecting into the header tube to the full depth of the header.

An important object of the invention is the provision of heat transfer apparatus of the class described, such as multiple-effect evaporator installations, wherein there is a header tube and a plurality of individual multi-tube evaporators oriented transversely of the header tube with corresponding ends of the individual evaporators projecting into the header tube in sealed off relationship therewith with structural arrangements made on the interior of the header tube involving the sealed off inwardly projecting evaporator ends, so that the following advantages are obtained: external connections for transmitting or conducting the vapors from one evaporator or effect to the next evaporator or effect are eliminated with such communication and conducting confined to the interior of the header tube; maximum utilization of materials is obtained with the side wall or outer shell portions of the sealed off, inwardly projecting evaporator ends providing a major part of transverse divider walls or bulkheads on the interior of the header tube; excellent strength characteristics are obtained for the installation as a result of the unique construction wherein the inwardly projecting and sealed off bottom ends of the evaporator units interlock structurally as well as functionally with the header tube; and, installation or fabrication of the apparatus is facilitated since maximum use can be made of pre-fabricated components while the making of numerous exterior connections is avoided.

Certain other objects of the invention will, in part, be obvious and will in part appear hereinafter.

For a more complete understanding of the nature and scope of the invention reference may now be had to the following detailed description thereof taken in connection with the accompanying drawings wherein:

FIG. 1 is a side elevational view of a multiple-effect evaporator installation constituting one practical embodiment of the invention;

FIG. 2 is a top plan view of the apparatus shown in FIG. 1;

FIG. 3 is a left end elevational view of the apparatus shown in FIG. 1 taken on line 3—3 thereof;

FIG. 4 is a fragmentary sectional view on enlarged scale taken on line 4—4 of FIG. 1;

FIG. 5 is a fragmentary sectional view on enlarged scale taken on line 5—5 of FIG. 1;

FIG. 6 is a view on enlarged scale, partly in side elevation and partly in vertical section, taken on lines 6—6 of FIG. 2;

FIG. 7 is a partly horizontal sectional and partly top plan view on line 7—7 of FIG. 6; and

FIG. 8 is a detail sectional view taken on lines 8—8 of FIGS. 5 and 6.

Referring to FIGS. 1–3, the multi-effect evaporator apparatus shown therein is indicated generally at 5 and comprises a horizontal header tube **6** and a plurality of upstanding individual evaporators **7**, **8** and **10** the bottom or lower ends of which project or extend down into the header tube **6**. In the arrangement shown the evaporator **7** constitutes the so-called first-effect, being one end of the unit, while the evaporator **10** constitutes the last effect, being on the opposite end. Intermediate the first and last effects there will be a plurality of intermediate effects as represented by the evaporator **8**.

The header tube **6** and the outer shells of the evaporators **7**, **8** and **10** are preferably cylindrical in shape although they could be oval or square in cross-section. Normally, the header tube **6** will have a diameter somewhat greater than the diameters of the upstanding evaporator units although the diameters could be approximately equal.

The horizontal header tube **6** is suitably supported such as by a plurality of piers **11—11** having suitable foundations **12** with the header tube **6** resting on a plurality of arcuate pillow blocks **13** (FIG. 3) supported on the upper end of each of the piers. It will be understood that any other suitable arrangement may be used, e.g. the whole apparatus could be suspended from a superstructure. Each of the end evaporators **7** and **10** protrudes to one-half its diameter beyond the adjacent end of the header tube **6** as shown, with bottom lips **9** and **19** (FIG. 1) closing the bottoms of the protruding halves of the end evaporators **7** and **10**, respectively. The lips **9** and **19** may be integral projections on opposite ends of the header tube **6** or they may be welded in place.

It will be apparent from FIG. 1 that a series of circular openings **14** are cut into the top wall of the header tube **6** so as to receive the lower or bottom ends of the evaporators **8**. At the opposite ends of the header tube **6** semicircular openings **15** and **16** are cut so as to receive one-half of the bottom end of each of the end evaporators **7** and **10**, respectively. After the evaporator units **7**, **8** and **10** are lowered into place the crack or seam between each of the openings **14**, **15** and **16** and the adjacent side wall of the outer shell of the evaporator units is sealed off in fluid tight relationship, as by welding.

Each of the evaporators **7**, **8** and **10** is of the type which has an internal heat exchanger of the type having open-ended tubes **17—17** (FIG. 6) extending between upper and lower tube sheets **18** and **20**, respectively. It will be seen that each of the tube sheets **18** and **20** is welded to the interior of the outer cylindrical shell **21** of each evaporator and inwardly positioned with respect to the terminal ends of the outer shells. The inward positioning at the top provides a vapor chamber or head space **22** in each evaporator into which a liquid undergoing evaporation may be introduced through a side con-

nection **23**. Each tube shell **21** is closed by a cover or dome **24** in known manner.

At the bottom of the evaporators each tube sheet **20** is likewise inwardly (i.e. upwardly) spaced from the lower end of the evaporator shell **21** with each tube sheet being located well within the header tube **6**.

Referring to FIG. 6, it will be seen that with respect to the left end evaporator unit **7** (i.e. the first-effect) and each of the intermediate evaporator units **8**, a semi-cylindrical arcuate portion is removed (or omitted) at the lower end of each evaporator shell, so as to leave only a semi-cylindrical or arcuate portion **25** at each lower end. It will be seen that the lower edge of this portion **25** is contoured or shaped so as to fit the curvature of the header **6** as indicated at **26—26** in each evaporator and the resulting seams may be permanently closed by welding. By reason of this construction, with one-half of the lower end of the evaporator shells being omitted underneath the lower tube sheets **20** it will be seen that the lower open end of each of the vertical tubes **17** has direct communication into the interior of the header tube **6**.

Each of the semi-cylindrical arcuate portions **25** below the adjacent bottom tube sheet **20**, together with the semi-cylindrical arcuate portion lying thereabove but within the header tube **6**, constitutes a substantial portion of a bulk head which is associated with each of the evaporator units, each such bulkhead partitioning off the interior of the header tube **6** at each evaporator. In each of these arcuate, semi-cylindrical outer shell portions (except the first-effect evaporator **7**) a window **27** is cut which provides entry access for vapors into the respective heat exchange chambers formed between the tube sheets.

Since the semi-cylindrical arcuate portion of the lower end of each shell which forms part of the bulkhead is not sufficiently wide to extend all the way to the opposite sides of the header tube **6** it is necessary to fill in on the sides with chord-shaped insert plates which are designated at **28** and **30** in FIGS. 4, 5 and 8. These inserts may be readily welded in place.

On the interior of each of the internal heat exchangers an upstanding baffle **31** partitions off the chambers so that steam or other heating vapors rise up through one side upon entering the lower left-hand side of the chamber and then pass down around the top of the baffle which does not extend all the way to the upper tube sheet. In this manner an inverted U-shaped flow path is established for the heating vapors in each of the heat exchange chambers. The steam or other heating vapors enter the first-effect or first evaporator **7** through an exterior connection **32** which opens into an arcuate header cover **33** which covers up an arcuate window in the lower left-hand side of the tube shell **21** of the unit **7**. Each of the evaporator units is provided with a condensate discharge outlet at the bottom of the lower right-hand side as shown in FIG. 6 and designated therein at **34** to which connections may be made through the wall of the header tube **6**.

In order to impose a vacuum on the interior of the heat exchanger of the last effect, i.e. evaporator **10**, it is provided with a thermal condenser **35** of known type which is connected to the shell of the evaporator **10** by means of a connection **36** below the upper tube sheet of that condenser.

Each of the chambers formed in the header tube **6** between the bulk heads associated with adjacent evaporator units is provided with a liquor outlet or drain **37**.

It will be seen that there is no exterior plumbing or piping which interconnects the adjacent evaporator units. On the contrary the vapors from one effect are delivered into the heat exchange chest of the next effect entirely within the interior of the header tube **6**. The operation of the multi-effect evaporator apparatus **5** may be illustrated in connection with its use to concentrate a solution of say ammonium sulfate liquor. The weak or dilute solution is introduced into the headspace at the

top of the last effect or evaporator **10** through the connection **23** thereof and falls or flows downwardly through the vertical heater tubes of the internal heat exchanger and it is collected at the bottom and removed through the liquor outlet connection **37** for the last effect evaporator **10**. The liquor is raised in temperature in this first pass but vapors are not removed. The liquor from unit **10** is pumped to the top of the inlet connection **23** into the headspace of the next adjacent evaporator unit **8** and after passing down through the heat exchanger therein is removed from the bottom of the horizontal chamber in the tubular header **6** associated therewith and introduced into the top of the next effect. This sequence is followed until the liquor is removed from the chamber associated with the second-effect evaporator **8** and introduced into the top of the first-effect evaporator **7** on the left-hand end. During this progressive movement of the liquor through the evaporator units it is being heated to progressively higher temperatures and becomes more concentrated as it moves upstream from one effect to the other as the vapors which flash off at the bottom of each effect are used to heat the next downstream unit.

Steam is introduced into the first effect, or evaporator **7** through the steam inlet connection **32** as described. Each time the liquor passes down through the vertical tubes **17** it receives a transfer of heat through these tubes from the steam or water vapor surrounding them. When the liquor discharges from the open end of the tubes just below the lower or bottom tube sheet **20** part of the liquor flashes off into vapors and these vapors flow into the side window **27** of the next effect as indicated by the arrows in FIG. 6. Finally, in the last effect, or right end evaporator **10**, the vapor introduced into that chamber is discharged through the condenser **35**.

It will be apparent that a number of design changes may be made in the apparatus **5**. Thus, the internal baffles **31** may be omitted or shortened, the opposite ends of the header tube **6** may be extended beyond the end evaporator units **7** and **10**, a header tube of relatively smaller diameter may be used thereby reducing the sizes of the fill-in chord-shaped inserts **28** and **30**, etc. When the apparatus is assembled as described and the various seams are welded, a very strong unit is provided which does not require additional reinforcement.

Since certain changes and modifications can be made in the embodiments of the invention as described and shown in the accompanying drawings without departing from the spirit and scope of the invention, it is intended that all matter described above or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. Heat transfer apparatus comprising a generally horizontal header tube and a plurality of individual evaporators oriented uprightly of said header tube with corresponding lower ends of said individual evaporators projecting into said header tube from the upper side to the bottom side in sealed-off relationship therewith, each of said evaporators having an outer shell and an internal heat exchanger of the type having open-ended tubes extending between inner upper and lower tube sheets, disposed inwardly of the opposite ends of each shell with one of said tube sheets being disposed within said header tube, a portion of the side wall of the outer shell lying below the lower tube sheet of each evaporator end projecting within said header tube being omitted so as to provide free communication between the interiors of the adjacent ends of said open-ended tubes and the interior of said header tube, with the remainder portion of the inwardly projecting end of each outer shell forming at least a substantial part of a bulkhead which partitions off the interior of said header tube and blocks vapor flow through said header tube between adjacent evaporators each of said inwardly extending evaporator ends having an entrance window formed

in its outer shell above the lower tube sheet to permit vapor discharge into said header tube from the adjacent upstream evaporator with regard to vapor flow to enter said window and the vapor space surrounding the tubes of the associated internal heat exchanger.

2. Heat transfer apparatus comprising a generally horizontal cylindrical header tube and a plurality of individual evaporators oriented uprightly of said header tube with corresponding lower ends of said individual evaporators extending into the upper side of said header tube and extending to the lower side in fluid-tight relationship therewith, each of said evaporators having a cylindrical outer shell the diameter of which does not exceed the diameter of said header tube and an internal heat exchanger of the type having open-ended tubes extending between upper and lower tube sheets disposed adjacent and inwardly of the opposite ends of each shell with one of said tube sheets disposed within said header tube, a corresponding portion of the sidewall of the outer shell lying below the lower tube sheet of each evaporator end extending within said header tube being omitted so as to provide free communication between the interiors of the adjacent ends of said open-ended tubes and the interior of said header tube, with the corresponding remainder portion of the inwardly extending end of each outer shell forming at least a substantial part of a bulkhead associated with each inwardly extending evaporator end which partitions off the interior of said header tube and blocks off vapor flow through said header tube, each of said inwardly extending evaporator ends having an entrance window formed in its outer shell above the lower tube sheet to permit vapor discharge into said header tube from the adjacent upstream evaporator with regard to vapor flow to enter said window and the vapor space surrounding the tubes of the associated internal heat exchanger.

3. Heat transfer apparatus comprising a horizontal header tube and a plurality of upstanding individual evaporators having their bottom ends projecting down into said header tube to the lower side thereof in sealed-off relationship therewith, each of said evaporators having an outer elongated shell and an internal heat exchanger of the type having open-ended tubes extending between upper and lower transverse tube sheets disposed inwardly of the shell ends, a corresponding portion of the bottom end of the sidewall of the outer shell lying below the lower tube sheet of each evaporator end projecting within said header tube and below the adjacent tube sheet being omitted so as to provide free communication between the lower ends of said open-ended tubes and the interior of said header tube, with the remainder portion of each outer shell end forming a substantial part of a bulkhead associated with each inwardly projecting evaporator end which partitions off the interior of said header tube and blocks off vapor flow through said header tube, each of said inwardly projecting evaporator ends having an entrance window formed in its outer shell wall above the lower tube sheet so as to permit vapors discharged into said header tube from the adjacent upstream evaporator with regard to vapor flow to enter said window and the vapor space surrounding the internal tubes of the associated internal heat exchanger.

4. Multi-effect evaporator apparatus comprising a horizontal cylindrical header tube and a plurality of individual evaporators upstanding therefrom with the lower end of each evaporator dipping down into said header tube and extending to the bottom thereof in sealed-off relationship therewith, each of said evaporators having a cylindrical outer shell of smaller diameter than that of said header tube and an internal heat exchanger of the type having open-ended tubes extending between upper and lower transverse tube sheets disposed inwardly of the shell ends with the lower tube sheet being within said header tube, that one-half portion of the outer shell of each of said evaporators which lies below the lower tube sheet and within said header tube on the corresponding side of each evaporator being omitted so that the lower ends of said open-ended tubes are in communication with the interior of said header tube, the semi-cylindrical remaining portion of the outer shell of each of said evaporators which lies within said header tube and is opposite said omitted portion constituting a substantial part of a bulkhead associated with each inwardly projecting evaporator end which partitions off the interior of said header tube and blocks off vapor flow through said header tube, each of said semi-cylindrical bulkhead-forming portions having an entrance window therein above the adjacent lower tube sheet whereby vapors discharged from the lower ends of each set of open-ended tubes of one evaporator effect enter through one of said windows into the vapor space surrounding the tubes of the associated internal heat exchanger of the adjacent downstream evaporator.

5. The apparatus of claim 4 wherein each of said bulkheads is formed in part by one of said semi-cylindrical portions and completed by two chord-shaped insert plates on opposite sides of each semi-cylindrical portions.

6. The apparatus of claim 4 wherein the lower edge of each of said semi-cylindrical portions is trimmed so as to fit the inner contour of said header tube and the seam following said edge is sealed.

7. The apparatus of claim 4 wherein the opposite ends of said header tube are closed by end bulkheads formed in part by protruding semi-cylindrical portions of the outer shells of the end evaporators and completed by a pair of chord-shaped insert plates on opposite sides of each protruding semi-cylindrical shell portions.

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