Aug. 23, 1966 D. K. RICHARDSON ETAL 3,267,693

SHELL-AND-TUBE TYPE LIQUID CHILLERS

Filed June 29, 1965 3 Sheets-Sheet 1

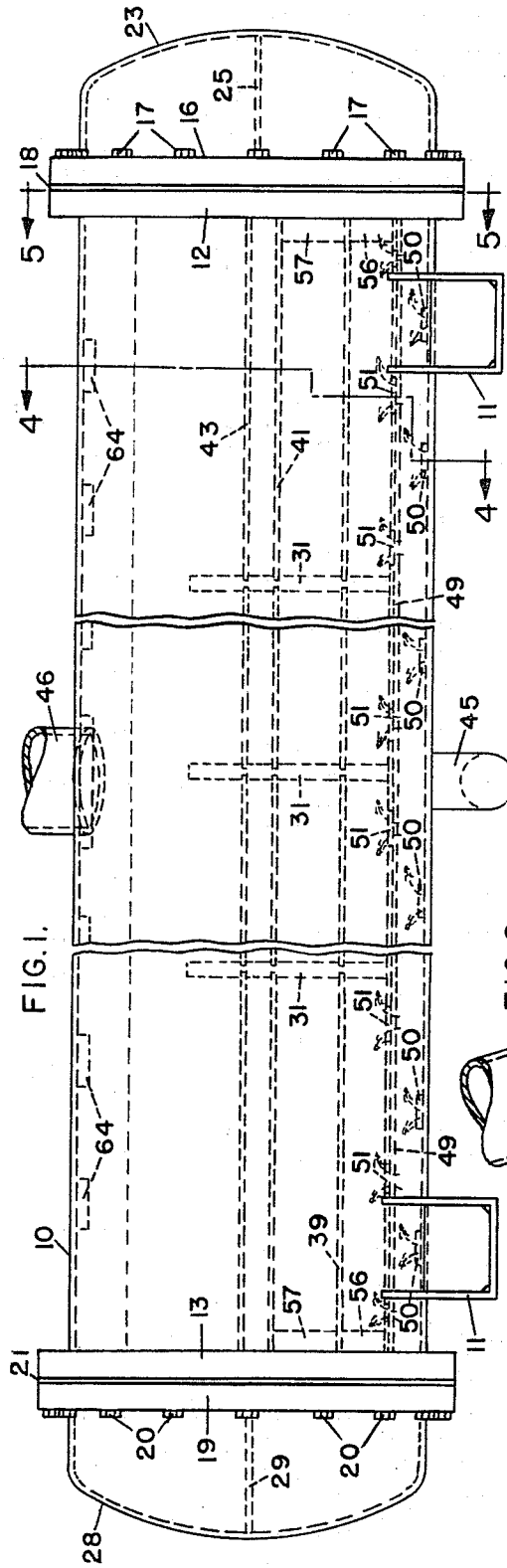


FIG. 1.

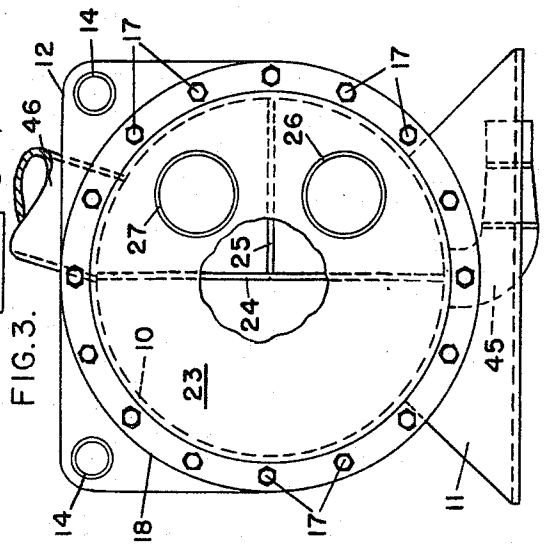


FIG. 3.

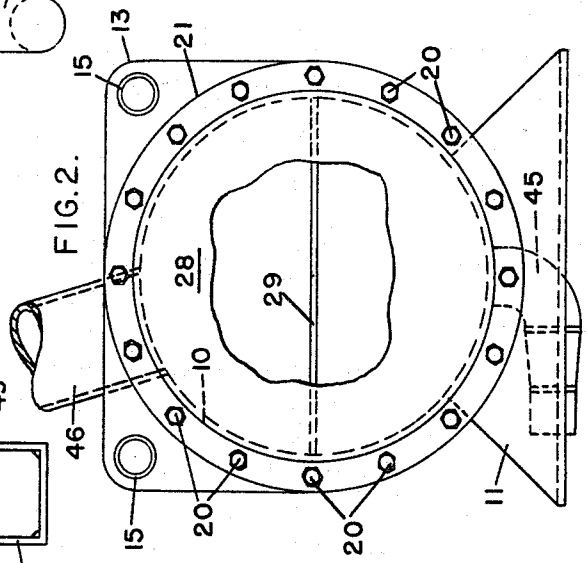


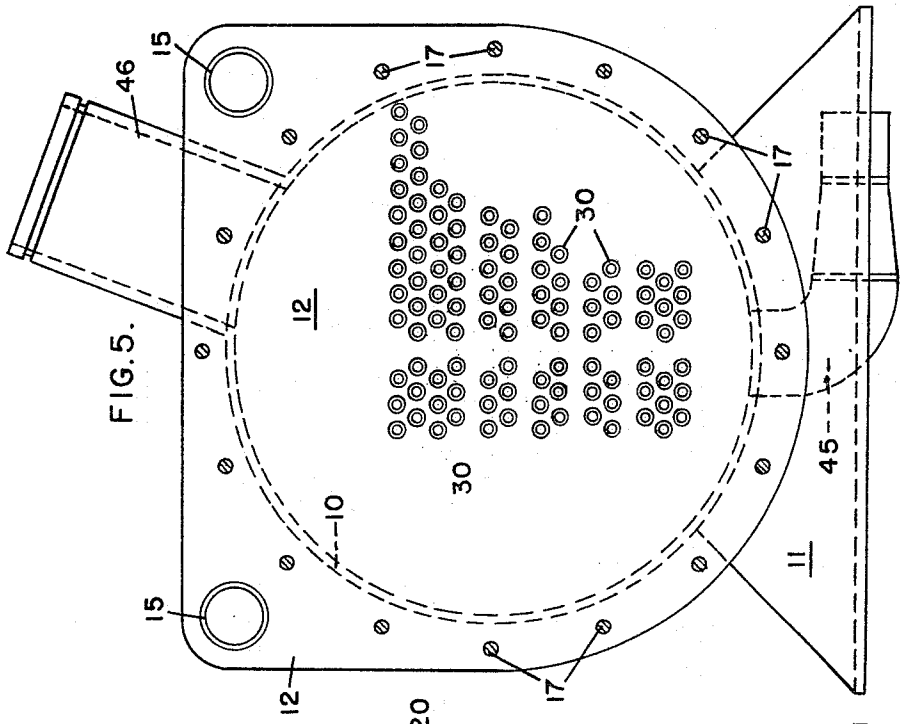
FIG. 2.

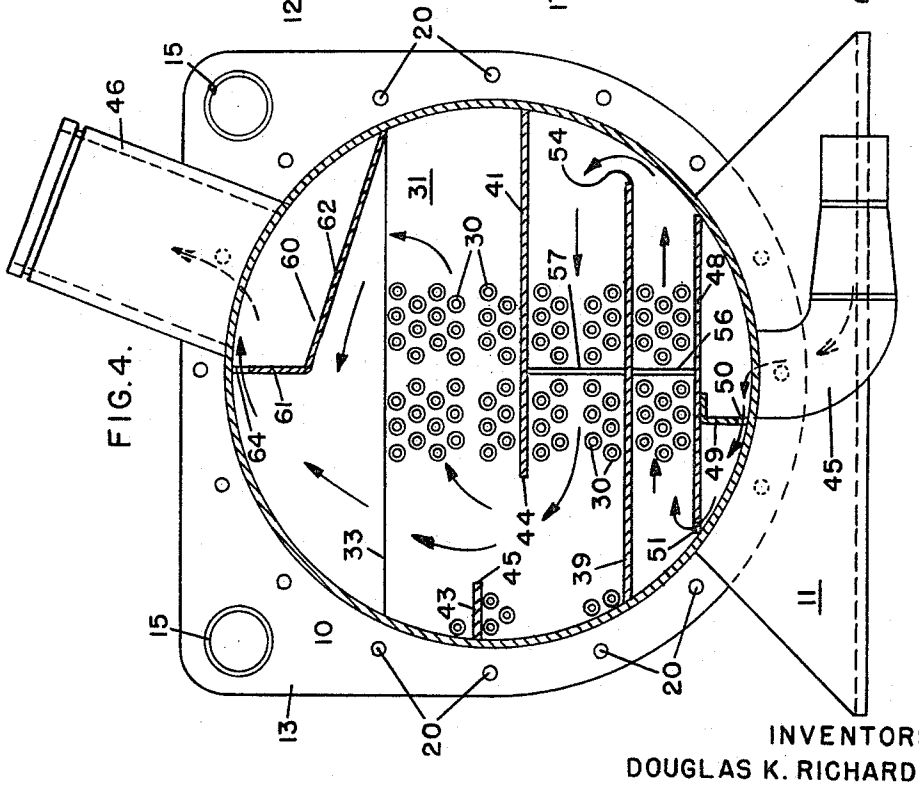
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Aug. 23, 1966 D. K. RICHARDSON ETAL 3,267,693

SHELL-AND-TUBE TYPE LIQUID CHILLERS

Filed June 29, 1965 3 Sheets-Sheet 2





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SHELL-AND-TUBE TYPE LIQUID CHILLERS

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FIG. 6.

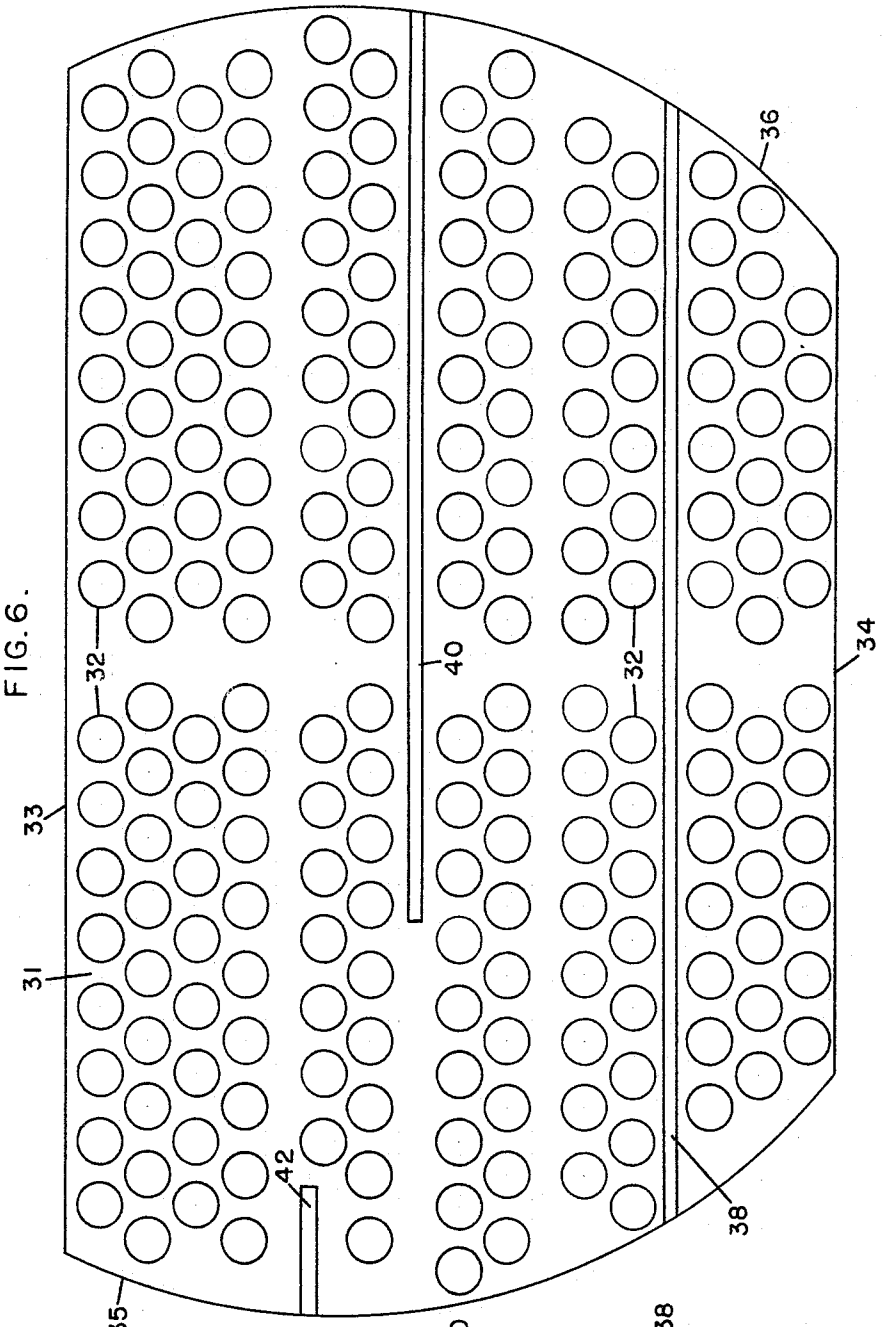
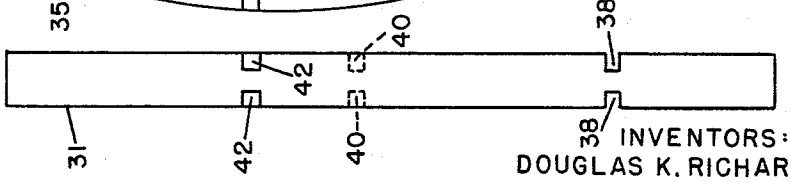


FIG. 7.



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SHELL-AND-TUBE TYPE LIQUID CHILLERS

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11 Claims. (Cl. 62—527)

This invention relates to shell-and-tube type liquid chillers.

In the usual flooded, shell-and-tube type liquid chiller, the liquid to be chilled is flowed through closely spaced, parallel tubes, with the refrigerant flowed in a single pass over the exterior surfaces of the tubes. In a shell-and-tube type liquid chiller embodying this invention, the liquid to be chilled is flowed through closely spaced, parallel tubes, but the refrigerant is flowed in a plurality of passes over the exterior surfaces of the tubes.

In one embodiment of this invention, a refrigerant inlet is provided at the longitudinal center of the bottom of a horizontally extending shell, and a refrigerant gas outlet is provided at the longitudinal center of the top of the shell. Baffles are used to cause the entering refrigerant to flow over the exterior surfaces of the tubes in a plurality of horizontal and vertical passes along the entire lengths of the tubes between the refrigerant inlet and outlet. The liquid to be chilled is caused by manifolds at the ends of the tubes to flow through the tubes in the desired number of passes.

An advantage of this invention is that the velocity of the boiling refrigerant is greatly increased over that in conventional chillers, enabling a substantially smaller refrigerant charge to be used; increasing refrigerant side heat transfer, and reducing the amount of refrigerant side surface or the number of tubes required. The size and cost of the chiller is reduced.

An object of his invention is to increase the velocity of the boiling refrigerant in a shell-and-tube type liquid chiller.

Another object of this invention is to reduce the refrigerant charge in a shell-and-tube type liquid chiller.

Another object of this invention is to reduce the size and cost of a shell-and-tube type liquid chiller.

This invention will now be described with reference to the annexed drawings, of which:

FIG. 1 is a fragmentary side view of a liquid chiller embodying this invention, with baffle sheets and tube support sheets shown by dashed lines;

FIG. 2 is a view, with a portion removed, of the left end of FIG. 1;

FIG. 3 is a view, with a portion removed, of the right end of FIG. 1;

FIG. 4 is an enlarged section along the lines 4—4 of FIG. 1, with some of the tubes omitted;

FIG. 5 is a view along the lines 5—5 of FIG. 1, on an enlarged scale, with some of the tubes omitted;

FIG. 6 is a greatly enlarged side view of one of the tub support sheets used, and

FIG. 7 is an end view of FIG. 6.

A horizontally extending, cylindrical shell **10** is supported on base members **11**. A tube sheet **12** extends across and is welded to the right end of the shell **10**, and a similar tube sheet **13** extends across and is welded to the left end of the shell **10**. The tube sheets **12** and **13** have circular holes **14** and **15** respectively in their upper corners for receiving hoist supports. A circular head ring **16** is attached by bolts **17** to the tube sheet **12**, with a gasket **18** between the sheet **12** and the ring **16**. A similar circular head ring **19** is attached by bolts **20** to the tube sheet **13**, with a gasket **21** between the sheet **13** and the ring **19**. The ring **16** has welded thereto

a manifold **23** which has a diametral, vertically extending baffle sheet **24** extending across the space within the manifold **23**. The manifold **23** has another baffle sheet **25** extending horizontally from the center of the sheet **24** across the space within the manifold **23**. The manifold **23** has a liquid inlet **26** between the sheet **25** and the lower half of the sheet **24**, and has a liquid outlet **27** between the sheet **25** and the upper half of the sheet **24**. The ring **19** has welded thereto a manifold **28** which has a diametral, horizontally extending, baffle sheet **29** extending across the space within the manifold **28**.

The tube sheets **12** and **13** contain circular openings into which extend the ends of copper tubes **30** which extend horizontally the length of the shell **10**. The tubes **30** are supported between the tube sheets **12** and **13** by spaced apart, vertically extending, tube support sheets **31** which have circular openings **32** through which the tubes **30** extend. The sheets **31** have horizontally extending tops **33** and bottoms **34**, and have ends **35** and **36** curved to contact the inner surface of the shell **10** between its top and bottom. The sheets **31** have slots **38** extending part way therethrough from opposite sides thereof for receiving the ends of baffle sheets **39** (FIGS. 1 and 4). The sheets **31** also have slots **40** extending part way therethrough from opposite sides thereof for receiving the ends of baffle sheets **41**. The sheets **31** also have slots **42** extending part way therethrough from opposite sides thereof for receiving the ends of baffle sheets **43**.

A refrigerant inlet tube **45** connects with the interior of the shell **10** at the longitudinal center of its bottom. A refrigerant gas outlet tube **46** connects with the interior of the shell **10** at the longitudinal center of its top, substantially opposite the inlet tube **45**. A refrigerant inlet baffle assembly consists of a horizontally extending baffle sheet which extends along and under the bottoms **34** of the tube support sheets **31**, the length of the shell **10** and across the lower portion of the interior of the shell, and also consists of a baffle sheet **49** which extends vertically from the bottom of the sheet **48** to the bottom of the shell **10** in alignment with the left edge (FIG. 4) of the inlet tube **45** where it connects with the interior of the shell. The baffle sheet **49** also extends the length of the shell, and has longitudinally spaced apart notches **50** in its bottom edge. The baffle sheet **48** has longitudinally spaced apart notches **51** in its left edge (FIG. 4), which are staggered with respect to and are larger than the notches **50**.

Horizontally extending baffle sheets **39** collectively extend the length of the shell **10** except where they are spaced apart at tube support sheets **31**, across the interior of the shell above the baffle sheet **48**. The baffle sheets **39** extend from their left edges (FIG. 4) about 90% of the way across the interior of the shell **10** leaving spaces between their right edges and the adjacent inner surface of the shell for refrigerant to flow. Both ends of each baffle sheet **39** except the two end ones extend into slots **38** in the sheets **31** as do the inner ends of the end sheets **39**. Baffle sheets **41** extend horizontally above the sheets **39**, collectively the length of the shell **10** except where they are spaced at the tube support sheets **31**, and extend from their right edges (FIG. 4) about two-thirds of the way across the interior of the shell **10**, leaving spaces between their left edges **44** and the adjacent side of the interior of the shell for refrigerant to flow. Both ends of the baffle sheets **41** except the two end ones extend into slots **40** in the tube support sheets **31**, as do the inner ends of the end baffle sheets **41**. Baffle sheets **43** extend horizontally above the sheets **41**, collectively the length of the shell **10** except where they are spaced apart at the tube support sheets **31**, and extend from their left edges (FIG. 4) about one-ninth of the way across the inter of the shell,

leaving spaces between their right edges 55 and the edges 44 of the sheets 41 for refrigerant to flow. Both ends of the baffle sheets 43 except the two end ones extend into slots 42 in the tube support sheets 31 as do the inner ends of the end baffle sheets 43. The tube support sheets 31 thus also support the baffle sheets 39, 41 and 43.

Narrow strips 56 extend vertically between and in contact with the baffle sheets 48 and 39 at their transverse centers at the ends of the shell 10. Similar strips 57 aligned with the strips 56 extend between and in contact with the sheets 39 and 41. The strips 56 and 57 support the ends of the end ones of the baffle sheets 41.

A suction baffle assembly consists of a baffle sheet 60 having a portion 61 extending vertically from the shell 10 along the longitudinal center of the latter adjacent to the left edge (FIG. 4) of the gas outlet tube 46 where it connects with the interior of the shell 10 above the top row of tubes 30, and having a portion 62 which extends from the lower end of the portion 61 at an angle of about 110° to the inner surface of the upper portion of the shell 10. The sheet portions 61 and 62 extend the length of the shell 10, and the sheet portion 61 has longitudinally spaced apart notches 64 in its upper edge.

With reference to FIG. 4, the left and right edges of the baffle sheets 48 and 39, the right edge of the baffle sheet 41, the left edge of the baffle sheet 43, the top edge of the baffle sheet portion 61, and the right edge of the baffle sheet portion 62 are welded to the inner surface of the shell 10.

Operation

A liquid, such as water, to be chilled is supplied under pressure into the liquid inlet 26, and flows in four passes through the tubes 30, the first pass being through the tubes 30 having ends between the baffle sheets 24 and 25 in the manifold 23, in the 3 to 6 o'clock quadrant (FIG. 3), into the manifold 28, the second pass being through the tubes 30 having ends below the baffle sheet 29 in the manifold 28, in the 6 to 9 o'clock quadrant (FIG. 2), the third pass being through the tubes 30 having ends have the baffle sheet 29 in the manifold 28, in the 9 to 12 o'clock quadrant (FIG. 2), and the fourth pass being through the tubes 30 having ends between the baffle sheets 24 and 25 in the manifold 23, in the 12 to 3 o'clock quadrant (FIG. 3). Other numbers of passes could be provided.

Refrigerant from an expansion device which is not shown, is supplied through the inlet tube 45 into the interior of the shell 10 at the center of its bottom. The refrigerant then flows as shown by the dashed arrows on FIG. 1 and the solid-line arrows on FIG. 4, through the refrigerant distribution notches in the baffle sheet 49, both ways from the center of the bottom of the shell 10, then flows through the refrigerant distribution notches 51 in the baffle sheets 48, over the rows of tubes which are between the baffle sheets 48 and 39 along the entire lengths of such tubes, then flows through the spaces between edges 54 of the baffle sheets 39 and the adjacent inner surface of the shell 10, over the rows of tubes 30 between the baffle sheets 39 and 41 along the entire lengths of such tubes, then through the spaces between the edges 44 of the baffle sheets 41 and the edges 45 of the baffle sheets 43 over the uppermost rows of tubes 30 along their entire lengths, and then through the notches 64 in the baffle sheet portion 61 into the gas outlet tube 46. The notches 49 and 51 are staggered with respect to each other in order to double the refrigerant distribution effect into the first pass across the tubes 30 between the baffle sheets 39 and 48.

The refrigerant liquid evaporates as it passes through the chiller, and becomes gas, the velocity of which is greatly increased through being forced to flow through constructed passages in a plurality of horizontal and vertical passes across the tubes 30.

What is claimed is:

1. A liquid chiller comprising a substantially horizontally extending shell having liquid manifolds at its ends, a plurality of vertically spaced apart rows of substantially horizontally extending, closely spaced tubes extending within said shell substantially the length of said shell and connecting at their ends with the spaces within said manifolds, one of said manifolds having a liquid inlet, one of said manifolds having a liquid outlet, said shell having a refrigerant inlet in its bottom, and having a refrigerant gas outlet in its top, a plurality of vertically spaced apart, substantially horizontally extending baffle sheets within and extending substantially the length of said shell between said refrigerant inlet and outlet, and means including said baffle sheets for causing refrigerant to flow from said refrigerant inlet to said refrigerant outlet in a plurality of substantially horizontal and substantially vertical passes over the exterior surfaces of said tubes.

2. A liquid chiller as claimed in claim 1 in which there is provided a baffle sheet extending substantially vertically from the lowermost of said sheets to the inner surface of said shell alongside said refrigerant inlet, and having longitudinally spaced apart, constricted refrigerant flow passages therein.

3. A liquid chiller as claimed in claim 2 in which there is provided a baffle sheet within said shell extending across said refrigerant outlet substantially the length of said shell, and having longitudinally spaced apart, constricted refrigerant flow passages therein.

4. A liquid chiller as claimed in claim 1 in which there is provided a baffle sheet within said shell extending across said refrigerant outlet and substantially the length of said shell, and having longitudinally spaced apart, constricted refrigerant flow passages therein.

5. A liquid chiller comprising a substantially horizontally extending shell having liquid manifolds at its ends, a plurality of vertically spaced apart rows of substantially horizontally extending, closely spaced tubes extending within said shell substantially the length of said shell, and connecting at their ends with the spaces within said manifolds, one of said manifolds having a liquid inlet, one of said manifolds having a liquid outlet, said shell having a refrigerant inlet in its bottom and having a refrigerant gas outlet in its top, a first, substantially horizontally extending baffle sheet extending substantially the length of said shell with its edges in contact with the inner surface of said shell below the lowermost of said rows of tubes, one of said edges having longitudinally spaced apart, constricted refrigerant distribution notches, and a second baffle sheet extending substantially vertically downwardly from said first sheet to the inner surface of said shell adjacent to said refrigerant inlet, said second sheet extending substantially the length of said shell and having longitudinally spaced apart, constricted refrigerant distribution notches in its bottom edge.

6. A liquid chiller as claimed in claim 5 in which there is provided a baffle sheet within said shell extending across said refrigerant outlet and substantially the length of said shell, with its edges in contact with the inner surface of said shell, and having longitudinally spaced apart, constricted refrigerant flow notches in one of its said edges.

7. A liquid chiller as claimed in claim 5 in which said notches in said bottom edge of said second sheet are staggered with respect to said notches in said one ends of said first sheet.

8. A liquid chiller as claimed in claim 5 in which there is provided within said said shell a plurality of longitudinally spaced apart, substantially vertically extending, tube support sheets through which said tubes extend, said support sheets having similar, substantially horizontally extending upper slots extending part way therethrough in opposite sides thereof, said support sheets having similar, substantially horizontally extending lower slots extending part way therethrough in opposite sides thereof, in which there is provided a first plurality of aligned, substantially

horizontally extending, baffle sheets between adjacent ones of said rows of tubes and having ends in said lower slots, and in which there is provided a second plurality of aligned, substantially horizontally extending, baffle sheets between adjacent ones of said rows of tubes and having ends in said upper slots, said sheets of said first plurality having edges in contact with the inner surface of said shell above said edge of said first sheet which has notches therein, and having their other edges aligned and spaced from the facing inner surface of said shell, said sheets of said second plurality having edges in contact with the inner surface of said shell above where said other edges of said sheets of said first plurality are spaced from the inner surface of said shell, and having their other edges aligned and spaced further from the facing inner surface of said shell than said other edges of said sheets of said first plurality.

9. A liquid chiller as claimed in claim **8** in which there is provided a baffle sheet within said shell extending substantially the length of said shell and extending across said refrigerant outlet, with its edges in contact with the inner surface of said shell, and having longitudinally spaced apart, constricted refrigerant flow notches in one of its edges.

10. A liquid chiller as claimed in claim **9** in which said support sheets have other similar, substantially horizontally extending slots extending part way therethrough in opposite sides thereof above said upper slots, and in which there is provided a third plurality of baffle sheets between adjacent ones of said rows of tubes and having ends in said other slots, said sheets of said third plurality having edges in contact the inner surface of said shell

above where said edges of said sheets of said first plurality are in contact with said inner surface of said shell, and extending across the interior of said shell a distance substantially less than the distance said sheets of said second plurality extend across the interior of said shell.

11. A liquid chiller as claimed in claim **8** in which said support sheets have other similar, substantially horizontally extending slots extending part way therethrough in opposite sides thereof above said upper slots, and in which there is provided a third plurality of baffle sheets between adjacent ones of said rows of tubes and having ends in said other slots, said sheets of said third plurality having edges in contact with the inner surface of said shell above where said edges of said sheets of said first plurality are in contact with the inner surface of said shell, and extending across the interior of said shell a distance substantially less than the distance said sheets of said second plurality extend across the interior of said shell.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,267,693 August 23, 1966

Douglas K. Richardson et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 11, after "top," insert -- and --; column 4, lines 14 and 15, strike out "and means including said baffle sheets for" and insert instead -- two alternate ones of said sheets having corresponding edges contacting the inner surface of one side of said shell with spaces provided adjacent to their opposite edges for the upward flow of refrigerant, and another one of said sheets between said alternate ones having an edge contacting the inner surface of the opposite side of said shell with space provided adjacent to its opposite edge for the upward flow of refrigerant, said sheets and said spaces --; line 63, for "ends" read -- edge --.

Signed and sealed this 26th day of September 1967.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents