May 13, 1952 L. L. ARBUCKLE 2,596,195

HEAT EXCHANGER FOR REFRIGERATING SYSTEMS

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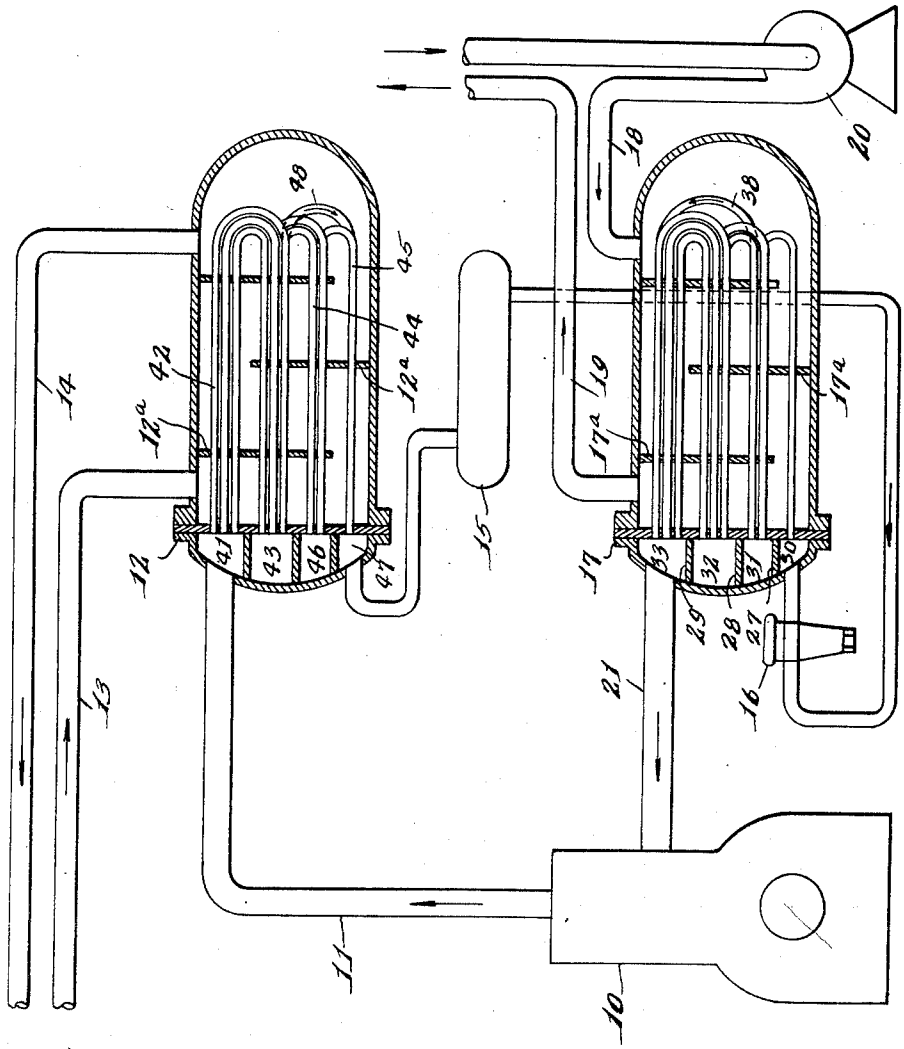


Fig. 1

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Fig. 2.

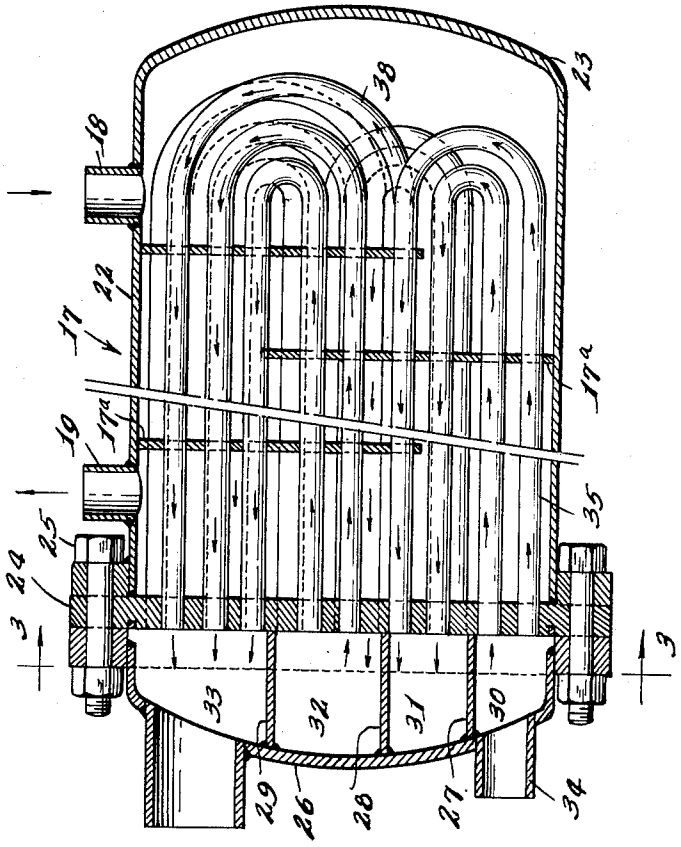
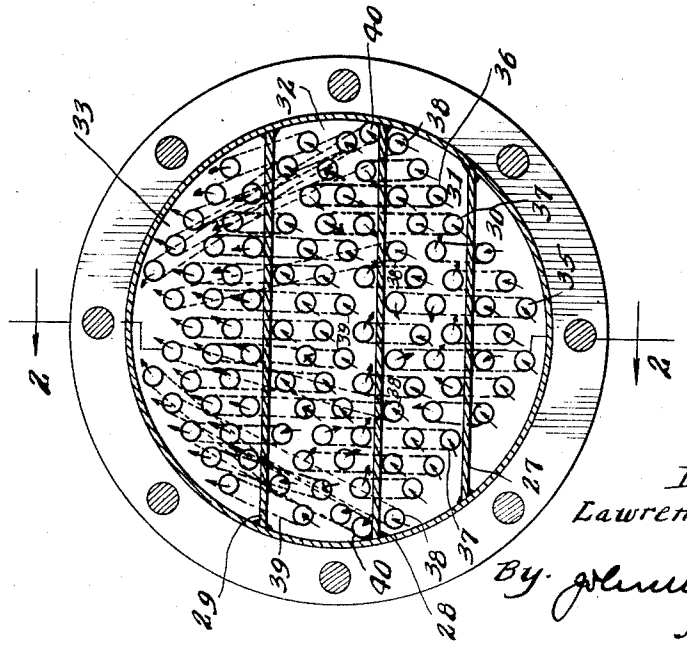


Fig. 3.



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Fig. 4.

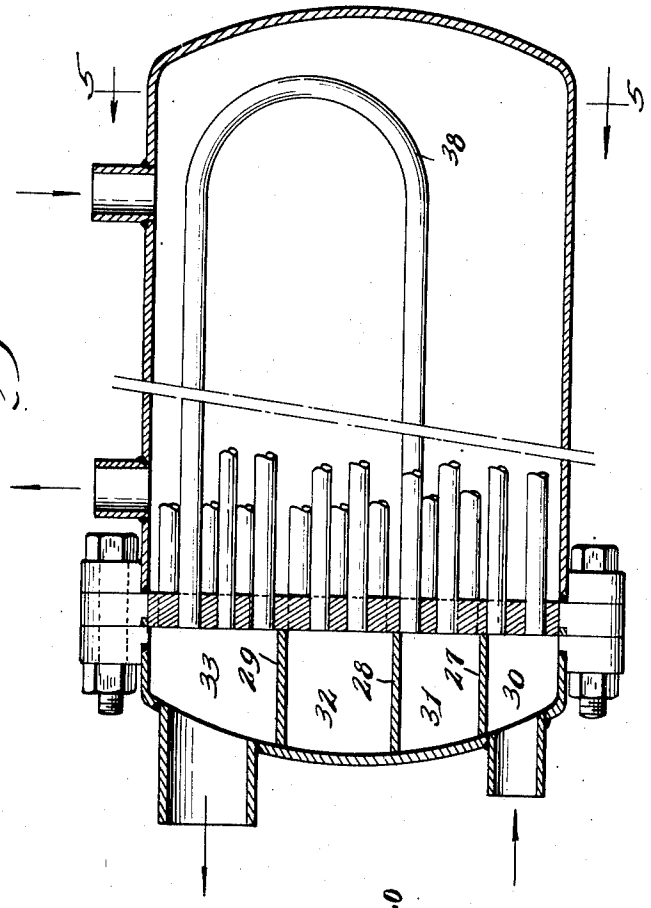
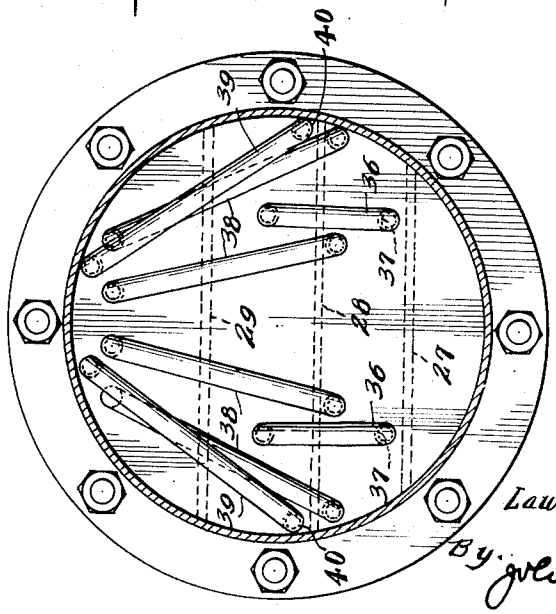


Fig. 5.



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Fig. 6.

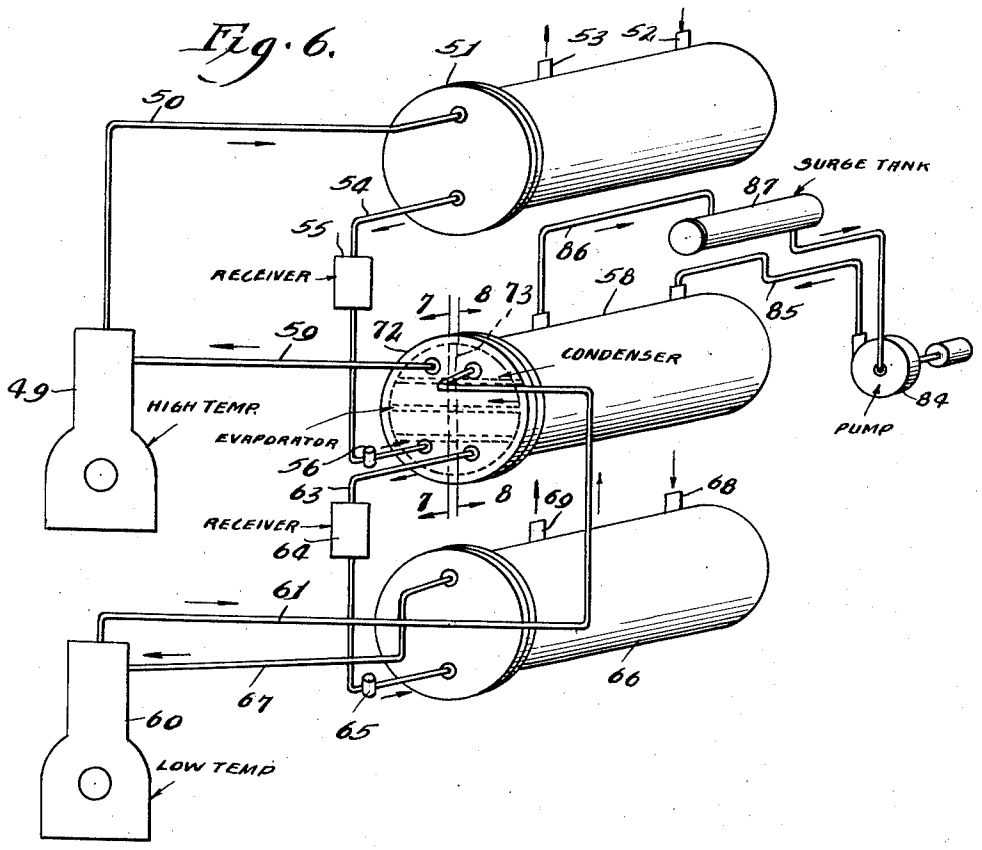


Fig. 8.

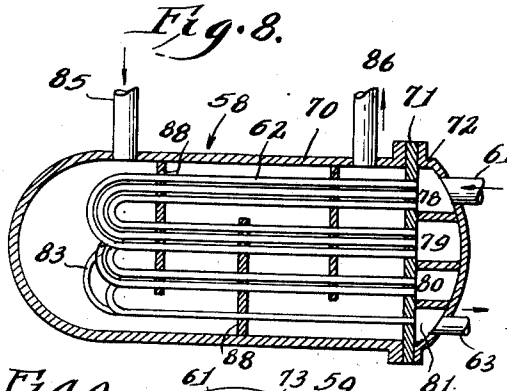


Fig. 7.

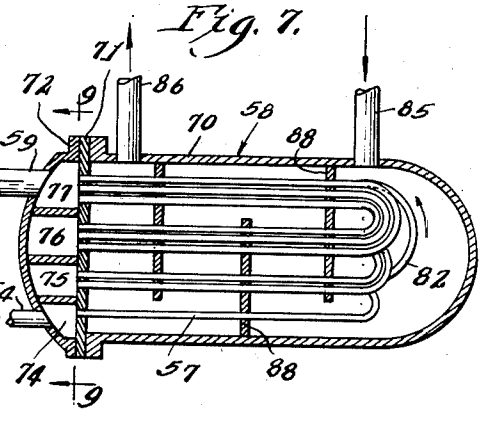
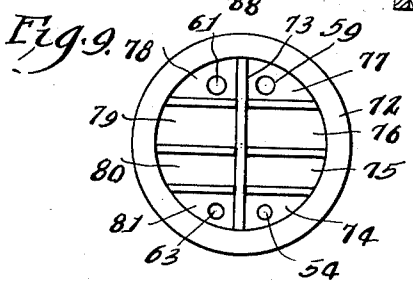


Fig. 9.



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UNITED STATES PATENT OFFICE

2,596,195

HEAT EXCHANGER FOR REFRIGERATING SYSTEMS

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Application April 24, 1947, Serial No. 743,667

9 Claims. (Cl. 62—126)

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My invention relates to heat exchangers for refrigerating systems, such as evaporators and condensers, and more particularly to novel arrangements thereof which are reflected in more efficient heat transfer and the prevention of oil trapping.

In the operation of such units and more particularly those in which the refrigerant, both vapor and liquid phase, flows through tubes in heat exchange to a selected fluid, serious problems in efficient heat transfer are encountered. For example, in the condenser, the high pressure vapor gradually changes state and is discharged as a high pressure liquid, while in the evaporator, the latter liquid, after passage through the usual expansion valve, gradually changes state to a saturated vapor. During these changes, the volume per pound of the refrigerant decreases in the condenser and increases in the evaporator. Since the tubes in the several passes of these units customarily have equal cross-sectional areas, attempts to solve the heat transfer problem created by the change in the volume-weight ratio have usually consisted in arranging the tubes so that the capacity of the tube groups in the successive passes in the direction of flow of the refrigerant decreases in the condenser and increases in the evaporator. This result is accomplished by varying the number of tubes in each pass and this arrangement is characterized by important operating advantages over that type of heat exchanger in which the number of tubes in each pass is approximately the same.

Oil trapping also presents a problem in the operation of such systems. A certain amount of lubricating oil is discharged from the compressor along with the refrigerant, then in the vapor stage, and after being cooled and liquified in the condenser, the refrigerant and oil passes to the evaporator. As a result of the vaporization of the refrigerant in the evaporator, the oil tends to accumulate in the latter unit. This accumulation is objectionable for a number of reasons, including foaming in the evaporator with consequent wet compression in the compressor, a raising of the boiling point with certain refrigerants and an accompanying adverse effect on the heat exchange, and a depletion of the oil charge that should be normally retained in the compressor. Attempted solutions of this problem have involved the use of oil traps on the discharge side of the compressor, or of distilling processes, continuous or batch type, in which the heat for operating the still is derived either from warm liquid leaving the condenser, or from hot gas discharged

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by the compressor, but these methods have not proved entirely successful.

It is therefore one object of my invention to provide a heat exchanger which may be arranged either as a condenser or evaporator for refrigerating systems and in which heat transfer efficiency is increased and resistance to flow of the refrigerant is decreased by relating the capacity of the tubes in the successive passes in the direction of flow of the refrigerant to the change in the volume-weight ratio of this substance, and in which a portion of the refrigerant whose capacity for heat exchange has been exhausted is discharged from the unit without being required to traverse all of the passes thereof.

A further object is to provide a heat exchanger of the character indicated in which the tubes connecting the successive chambers or plenums thereof are arranged to maintain a reasonable, average velocity of the refrigerant through the unit and to prevent oil trapping in the chambers.

A further object is to provide a heat exchanger incorporating the above features which is particularly adapted for inclusion in the so-called cascade or split system of refrigeration and wherein, in a two stage system, for example, the evaporator of the first stage and the condenser of the second stage are placed in heat exchanging relation to a common fluid in a single shell.

These and further objects of the invention will be set forth in the following specification, reference being had to the accompanying drawings, and the novel means by which said objects are effectuated will be definitely pointed out in the claims.

In the drawings:

Fig. 1 is a schematic view, partly in section, of a typical refrigerating system in which the condenser and evaporator include the improved features.

Fig. 2 is an enlarged, sectional elevation of the evaporator taken along the line 2—2 in Fig. 3.

Fig. 3 is a section along the line 3—3 in Fig. 2 showing the tube distribution to the several chambers of the evaporator.

Fig. 4 is a sectional view, similar to Fig. 2, showing the short circuiting of certain tubes around an intermediate pass direct to the outlet chamber of the evaporator, the remaining tubes being shown fragmentarily.

Fig. 5 is a section along the line 5—5 in Fig. 4 and showing in addition the disposition of the tubes for preventing oil trapping.

Fig. 6 is a diagrammatic layout of a two stage, split or cascade system of refrigeration in which

the first stage evaporator and the second stage condenser are mounted in an intermediate shell in heat exchanging relation to a common fluid.

Figs. 7 and 8 are vertical, longitudinal sections of the intermediate shell taken along the lines 7—7 and 8—8, respectively, in Fig. 6.

Fig. 9 is an interior, end view of the header in the intermediate heat exchanger, as taken along the line 9—9 in Fig. 7.

Referring to Fig. 1 of the drawings, the numeral 10 designates a typical, refrigerating system, compressor whose discharge side is connected by a pipe 11 to the inlet chamber of a condenser 12. Refrigerant liquified in the condenser by cooling water entering and leaving through pipes 13 and 14, respectively, flows through a receiver 15 and expansion valve 16 to the inlet chamber of an evaporator 17. The fluid to be refrigerated enters and leaves the evaporator through pipes 18 and 19, respectively, and may be circulated continuously by a pump 20. Saturated vapor discharged by the evaporator 17 returns through a pipe 21 to the compressor 10 to resume the cycle. Suitably arranged baffles 12a and 17a are provided in the condenser 12 and evaporator 17 to cause the cooling water and the fluid to be refrigerated, all respectively, to pursue a sinuous path in flowing through the indicated units.

So far as described, the system follows standard practice. The distinction resides in certain structural features of the condenser and evaporator which are intended to improve heat transfer efficiency and to prevent oil trapping. Since in their essential functional aspects and having regard to the nature of the invention, the condenser constitutes a reversal of the evaporator, attention will be directed to the latter for a disclosure of details.

Referring to Figs. 2, 3 and 4, the evaporator 17 is preferably arranged so that all of the chambers which provide communicating connection between the several passes are located at the same end of the unit. It comprises a shell 22 which may be cylindrical in cross section or otherwise shaped and which is closed at one end and open at the opposite end. A tube sheet 24 is bridged across and secured to the open end of the shell and clamped against the outer surface of the sheet 24, as by bolts 25, is a header 26. The space between the header and the tube sheet is divided by spaced walls 27, 28 and 29 into chambers 30, 31, 32 and 33 disposed, respectively, from the bottom to the top of the header. The low pressure, liquid refrigerant after passing through the expansion valve flows through the connection 34 into the chamber 30 which is the inlet for the evaporator. The chamber 33 constitutes the outlet of the unit, while the chambers 31 and 32 are intermediate in nature.

Due to the fact that a single tube sheet is employed, the tubes which are grouped to form passes through the evaporator are reversely bent to form U-tubes so that the ends of all the tubes are mounted in the one sheet. Generally speaking, the branches of the respective tubes lie in the same vertical plane, except where a contrary condition is dictated by the shape of the evaporator shell 22, with the ends of the lower and upper branches serving as inlets and outlets, respectively, for the flowing refrigerant. All tubes have the same cross section.

Specifically, and beginning with the inlet chamber 30, the branches of a plurality of U-tubes 35 have their ends mounted in the tube sheet 24, the lower and upper branches having their ends, respectively, communicating with the chambers 30 and 31. These tubes constitute the first pass whereby refrigerant flows from the chamber 30 to the chamber 31. The distribution of the branch ends in the two chambers is clearly shown in Fig. 3 and flow direction of the refrigerant into and out of these ends, as well as other branch ends presently described, is indicated by arrows.

The second pass through the evaporator is provided by a plurality of U-tubes 36 whose lower and upper branch ends communicate, respectively, with the chambers 31 and 32. The branch ends of the tubes 36 which communicate with the chamber 31 may be distributed in any desired manner across that portion of the tube sheet 24 included between the walls 27 and 28 in relation to the ends of the upper branches of the tubes 35 so that full use is made of the included part of the tube sheet, but in any case, it is preferred that some of the lower branch ends of the tubes 36 be disposed closely adjacent the wall 27 to prevent oil trapping in the chamber 31. Two such ends are indicated by the numeral 37 in Figs. 3 and 5, namely, the outermost ends of the row of tube ends which are positioned just above the wall 27, the intermediate ends of this row forming parts of the upper branches of the tubes 35.

Also mounted in the tube sheet 24 between the walls 27 and 28 are the ends of lower branches of U-tubes 38 (see Figs. 3 and 5). These ends are well distributed across the indicated part of the tube sheet and close to the wall 28 so that they lie in the upper part of the chamber 31 for a purpose presently explained. The tubes 38, however, bypass the chamber 32 inasmuch as the upper branches thereof terminate in the outlet chamber 33 (see Figs. 3, 4 and 5).

Communication between the chambers 32 and 33 which constitutes the third pass through the evaporator is provided by a plurality of U-tubes 39, some of which are inclined, as shown in Fig. 3, due to the shape of the shell. The lower branches of the tubes 39 communicate with the chamber 32 and the upper branches with the chamber 33. Preferably, certain of the ends of the lower branches of the tubes 39 are located close to the wall 28 to prevent oil trapping in the chamber 32 and two such ends are indicated by the numeral 40 in Figs. 3 and 5, being the outermost ends of the row of tube ends which lie just above the wall 28.

In the operation of the evaporator, the low pressure, liquid refrigerant enters the inlet chamber 30 and flows through the successive passes, changing state in the usual manner from a liquid to a saturated vapor at constant pressure in which condition it leaves the outlet chamber 33 en route to the compressor. Heat transfer efficiency is increased by properly relating the capacity of the successive passes to the changes in the volume-weight ratio of the refrigerant which, in the case of the evaporator, means that the capacity of the tubes in the successive passes increases in the direction of refrigerant flow. This construction insures a more complete evaporation in the shortest possible time, increases the efficiency of heat transfer, and maintains a reasonable, average velocity of the refrigerant through the evaporator which, in conjunction with the location of the inlet ends 37 and 40 of the U-tubes 36 and 39, respectively, prevents oil trapping in the chambers 31 and 32.

In the particular arrangement shown, there are nine, seventeen and twenty-six outlets lead-

ing from the chambers 30, 31 and 32, respectively, or inlets to the respective sets of U-tubes, thus providing an approximate arithmetical progression in the capacities of the successive passes. This construction is suggestive only since operating conditions will not only determine the number of passes, but the number of tubes in each pass.

An important feature of the invention resides in the short circuiting of the chamber 32 by the tubes 38 which thus bypass the pass connecting the chambers 31 and 32. As already noted, the inlet ends of these tubes are located in the upper portion of the chamber 31 and hence are positioned to bleed from this chamber fully saturated vapors which have expended their heat transfer value and deliver them direct to the outlet chamber 33. This construction also serves to decrease flow resistance through the evaporator and increases the effective heat transfer surface. It will be understood that the short circuiting of only one pass as illustrated is by way of example only and that variations in the design may be adopted as determined by operating conditions to include the bypassing of more than one pass.

The principles outlined above may be applied in reverse to the condenser 12, and the application thereof is schematically shown in Fig. 1. The compressed, superheated vapor enters the inlet or top chamber 41 of the condenser and flows through the first pass indicated by the numeral 42 to the first, intermediate chamber 43 and thereafter successively through passes 44 and 45 to the second, intermediate and outlet chambers 46 and 47, respectively. As diagrammatically illustrated, the capacities of the successive passes decrease in the direction of flow, the precise capacity relation between the passes being dictated by operating conditions, including the change in the volume-weight ratio of the refrigerant while passing through the condenser. The chamber 46 and hence the pass connecting the chambers 43 and 46 are short circuited by tubes 48 whose inlet ends are positioned close to the bottom of the chamber 43. This arrangement enables the tubes 48 to bleed off surplus, saturated liquid refrigerant direct to the outlet or bottom chamber 47, thus reducing friction and increasing effective heat transfer surface.

In Figs. 6 to 9, inclusive, are illustrated the application of a heat exchanger embodying the above principles to a two stage, cascade or split system of refrigeration which enables temperatures of 0° F. and below to be attained in the evaporator of the second stage. Referring to Fig. 6 which schematically shows such a system, the numeral 49 designates a compressor in the high temperature stage which is connected by a pipe 50 to the inlet chamber of a condenser 51 whose internal construction is preferably identical with the condenser 12 shown in Fig. 1. Cooling water for the condenser 51 is supplied and evacuated through pipes 52 and 53, respectively, and the liquified refrigerant is discharged through a pipe 54 which includes a receiver 55 and an expansion valve 56 to an evaporator 57 (see Fig. 7) whose tubular passes are mounted in the left half of a heat exchanger 58, as shown in Fig. 6, and which will be more particularly described hereinafter. Saturated vapor discharged by the evaporator 57 is returned to the compressor 49 through a pipe 59 to resume the cycle.

In the low temperature stage, a compressor 60 discharges refrigerant through a pipe 61 to a condenser 62 (see Fig. 8) whose tubular passes occupy the other half of the heat exchanger 58 and the refrigerant liquified in the condenser 62 then flows through a pipe 63 which includes a receiver 64 and an expansion valve 65 to the inlet chamber of an evaporator 66 whose interior construction is preferably like the evaporator 17 illustrated in Fig. 1. Saturated vapor from the evaporator 66 returns through a pipe 67 to the compressor 60 to resume the cycle, and the fluid being refrigerated enters and leaves the shell of the evaporator 66 through pipes 68 and 69, respectively.

The major improvement in the above system resides in the heat exchanger 58 in that the evaporator 57 and the condenser 62 are enclosed in the same shell and arranged for heat exchange with a brine which bathes the tubular passes of the evaporator and condenser. Specifically, the heat exchanger 58 comprises a shell 70 which is closed at one end and open at the other end. A tube sheet 71 is bridged across the open end of the shell 70 and is clamped thereagainst by a header 72 secured to the shell in any approved manner. The interior of the header is centrally divided by a vertical wall 73 which abuts the tube sheet and from the right side of the wall 73, as viewed in Fig. 9, extend a plurality of horizontal, vertically spaced septa which divide the right half of the header into chambers 74, 75, 76 and 77, reading from bottom to top of the header. Similarly arranged septa extend from the opposite side of the wall 73 which divide the left half of the header 72, also as viewed in Fig. 9, into chambers 78, 79, 80 and 81, reading from top to bottom of the header.

The arrangement shown in Fig. 7 constitutes the left half of the heat exchanger 58, as viewed in Fig. 6, and the chambers 74, 75, 76 and 77 are connected by tubular passes forming the evaporator 57, the chamber 74 acting as the inlet and therefore communicating with the pipe 54, and the chamber 77 serving as the outlet and communicating with the pipe 59. The passes in the evaporator 57 are arranged in the same manner and for the same reasons as indicated for the evaporator 17, i. e., the capacity of the tubes in the successive passes increases in the direction of refrigerant flow and the tubes are further arranged to prevent oil trapping in the chambers 75 and 76. Bypassing of the chamber 76 is effected by tubes generally indicated by the numeral 82 in Fig. 7, thus bleeding fully saturated vapors which have expended their heat value from the chamber 75 direct to the outlet chamber 77.

Similarly, the arrangement shown in Fig. 8 constitutes the right half of the heat exchanger 58, as viewed in Fig. 6, and the chambers 78, 79, 80 and 81 are connected by tubular passes forming the condenser 62, the chamber 78 acting as the inlet and therefore communicating with the pipe 61, and the chamber 81 serving as the outlet and communicating with the pipe 63. The passes in the condenser 62 are arranged in the same manner and for the same reasons as indicated for the condenser 12, i. e., the capacity of the tubes in the successive passes decreases in the direction of refrigerant flow and the tubes are further arranged to prevent oil trapping in the chambers 79 and 80. Bypassing of the chamber 80 to thus bleed saturated, liquid refrigerant from the chamber 79 direct to the outlet chamber 81 is accomplished by tubes generally indicated by the numeral 83 in Fig. 8.

It is understood that the tubular passes of the evaporator **57** and the condenser **62** are only schematically illustrated in Figs. 7 and 8, respectively. In detail, the construction of the evaporator **57** would be comparable to the evaporator **17**, as illustrated in Figs. 2 to 5, inclusive, and the same construction substantially in reverse would be employed for the condenser **62**.

Heat exchange between the evaporator **57** and condenser **62** is effected by circulating a low freezing point brine, such as calcium chloride, through the shell **70**, the brine absorbing heat from the condenser **62** and being cooled by the evaporator **57**. Specifically, this result is accomplished by a closed, circulating system including a pump **84**, a supply pipe **85** connecting the pump to one end of the shell **70**, and a return pipe **86** which may include a surge tank **87** connecting the other end of the shell to the pump. Baffles **88** are provided in the shell **70** to insure adequate heat transfer by causing the brine to follow a sinuous path in flowing through the shell and over the passes of the evaporator and condenser.

In operation the arrangement shown in Fig. 6 functions in the characteristic manner of a cascade or split system to provide the desired temperature in the fluid being refrigerated in the evaporator **66**, it being understood that suitable refrigerants would be selected for the two stages in accordance with known practice to secure the desired end result in the evaporator **66**. In split systems as presently employed, the evaporator **57** and the condenser **62** are enclosed in separate shells which are circulatorily connected by a pipe system including a pump. It will be obvious, therefore, that my improved arrangement not only embodies the efficiency advantages of present systems, but, in addition, certain pronounced economies in the way of equipment and space savings. By mounting the evaporator **57** and condenser **62** as indicated, applicant requires only a single shell for these units in a two stage system and so is enabled to effect a material reduction in the amount of pipe, pipe connections, insulation and space otherwise required. These savings have particular value on shipboard where space and weight factors are important. It will be understood that the conception of enclosing evaporating and condensing units in a single shell is not restricted to a two stage, split system, but is also applicable to such a system which incorporates a greater number of stages.

Since the generic conception embodied in the heat exchanger **58** resides in having separate tubular units enclosed within a single shell and bathed by a common liquid which has heat exchange relation with the units, the invention is not restricted to the particular construction exemplified by the exchanger **58**. The same idea can be applied to a so-called dual evaporator in which a single shell, similar to the shell **70** and having a header similar to the header **72**, would enclose separate evaporators, each similar to the evaporator **57** and each included in a separate refrigeration circuit. In this case, the twin evaporators would be bathed by the fluid to be refrigerated.

I claim:

1. A heat exchanger for a refrigerating system comprising, a plurality of horizontal refrigerant tubes arranged in groups constituting passes whose respective capacities in the direction of refrigerant flow are related to the changes in the volume-weight ratio of the refrigerant to maintain a predetermined velocity of refrigerant flow, inlet and outlet chambers communicating with the first and last passes, respectively, intermediate chambers connecting the outlet and inlet ends of successive, intermediate passes, and other tubes discharging into the outlet chamber and providing a bypass of at least one intermediate pass for evacuating refrigerant whose heat transfer value has been exhausted, the inlet ends of said other tubes communicating with that part of the associated chamber in which the last named refrigerant portion tends to collect.

2. A heat exchanger for a refrigerating system comprising, a plurality of horizontal refrigerant tubes arranged in groups constituting passes whose respective capacities in the direction of refrigerant flow are related to the changes in the volume-weight ratio of the refrigerant to maintain a predetermined velocity of refrigerant flow, inlet and outlet chambers communicating with the first and last passes, respectively, intermediate chambers connecting the outlet and inlet ends of successive, intermediate passes, the inlets of certain of the tubes connecting an intermediate chamber with the next chamber in the direction of flow being disposed immediately adjacent the bottom of that intermediate chamber from which the refrigerant is withdrawn to prevent oil trapping, and other tubes discharging into the outlet chamber and providing a bypass of at least one intermediate pass for evacuating refrigerant whose heat transfer value has been exhausted, the inlet ends of said other tubes communicating with that part of the associated chamber in which the last named refrigerant portion tends to collect.

3. An evaporator for a refrigerating system comprising, a plurality of horizontal refrigerant tubes arranged in groups constituting passes whose respective capacities successively increase in the direction of refrigerant flow to accommodate changes in the volume-weight ratio of the refrigerant whereby a predetermined velocity of refrigerant flow is maintained, inlet and outlet chambers communicating with the first and last passes, respectively, intermediate chambers connecting the outlet and inlet ends of successive, intermediate passes, and other tubes discharging into the outlet chamber and providing a bypass of at least one intermediate pass for evacuating refrigerant whose heat transfer value has been exhausted, the inlet ends of said other tubes communicating with the upper part of the associated chamber.

4. An evaporator for a refrigerating system comprising, a plurality of horizontal refrigerant tubes arranged in groups constituting passes whose respective capacities successively increase in the direction of refrigerant flow to accommodate changes in the volume-weight ratio of the refrigerant whereby a predetermined velocity of refrigerant flow is maintained, inlet and outlet chambers communicating with the first and last passes, respectively, intermediate chambers connecting the outlet and inlet ends of successive, intermediate passes, the inlets of certain of the tubes connecting an intermediate chamber with the next chamber in the direction of flow being disposed immediately adjacent the bottom of that intermediate chamber from which the refrigerant is withdrawn to prevent oil trapping, and other tubes discharging into the outlet chamber and providing a bypass of at least one intermediate pass for evacuating refrigerant whose heat trans-

fer value has been exhausted, the inlet ends of said other tubes communicating with the upper part of the associated chamber.

5. A condenser for a refrigerating system comprising, a plurality of horizontal refrigerant tubes arranged in groups constituting passes whose respective capacities successively decrease in the direction of refrigerant flow to accommodate changes in the volume-weight ratio of the refrigerant whereby a predetermined velocity of refrigerant flow is maintained, inlet and outlet chambers communicating with the first and last passes, respectively, intermediate chambers connecting the outlet and inlet ends of successive, intermediate passes, and other tubes discharging into the outlet chamber and providing a bypass of at least one intermediate pass for evacuating condensed refrigerant, the inlet ends of said other tubes communicating with the lower part of the associated chamber.

6. A condenser for a refrigerating system comprising, a plurality of horizontal refrigerant tubes including groups arranged in a succession of passes, an inlet chamber, a plurality of intermediate chambers and an outlet chamber series flow connected by the passes, and a group including other tubes connecting the outlet chamber with one of the intermediate chambers in bypassing relation to another intermediate chamber for evacuating condensed refrigerant, the inlet ends of said other tubes communicating with the lower part of the associated chamber.

7. A cascade type, refrigerating system having first and second stages, a heat exchanger arranged to occupy an intermediate position between the stages and including a shell, an evaporator and a condenser each having tubular passes extending within the shell, the evaporator being externally connected to the first stage and the condenser being externally connected to the second stage, and means for flowing a brine through the shell in heat exchange relation to the evaporator and condenser.

8. A heat exchanger for refrigerating systems

comprising, a plurality of horizontal refrigerant tubes arranged in groups constituting passes whose respective capacities in the direction of refrigerant flow are related to the changes in the volume-weight ratio of the refrigerant to maintain a predetermined velocity of refrigerant flow, inlet and outlet chambers communicating with the first and last passes, respectively, and an intermediate chamber connecting the inlet and outlet ends of successive, intermediate passes, the inlets of certain of the tubes connecting the intermediate chamber with the outlet chamber being disposed immediately adjacent the bottom of the intermediate chamber to prevent oil trapping.

9. An evaporator for a refrigerating system comprising, a plurality of horizontal refrigerant tubes arranged in groups constituting passes whose respective capacities successively increase in the direction of refrigerant flow to accommodate changes in the volume-weight ratio of the refrigerant whereby a predetermined velocity of refrigerant flow is maintained, inlet and outlet chambers communicating with the first and last passes, respectively, and an intermediate chamber connecting the inlet and outlet ends of successive, intermediate passes, the inlets of certain of the tubes connecting the intermediate chamber with the outlet chamber being disposed immediately adjacent the bottom of the intermediate chamber to prevent oil trapping.

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