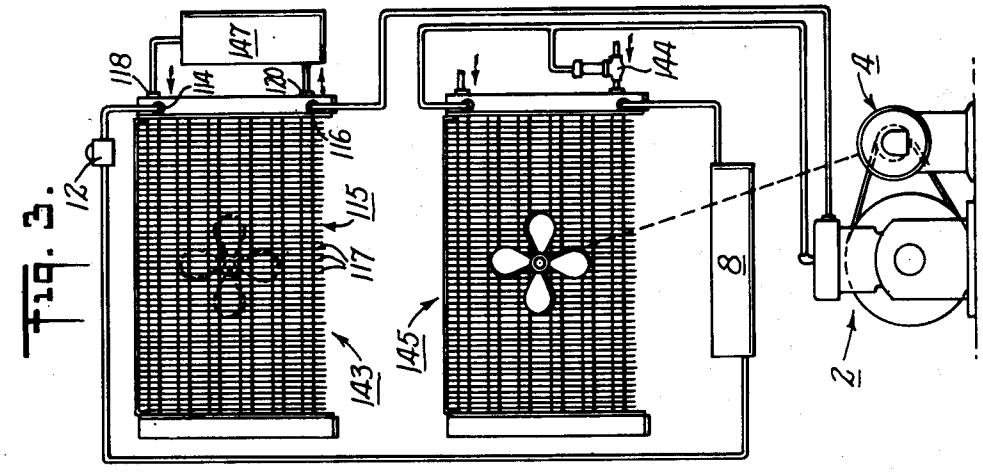
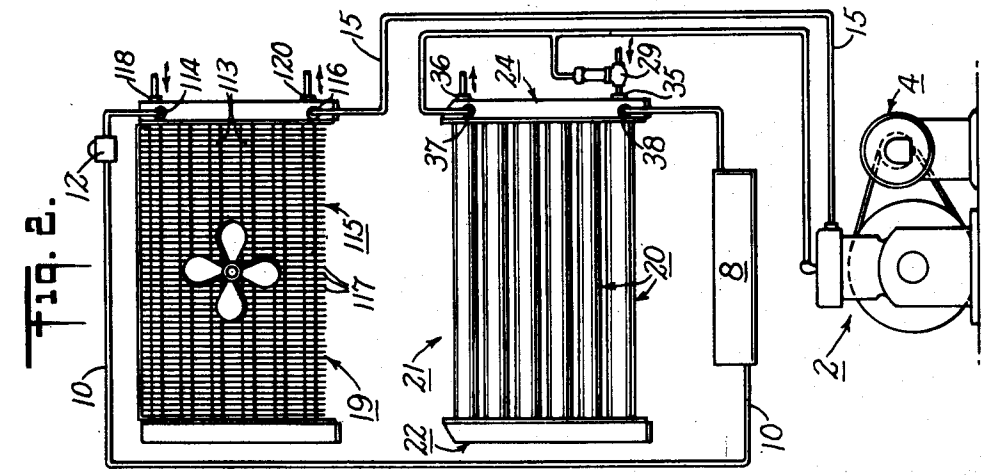
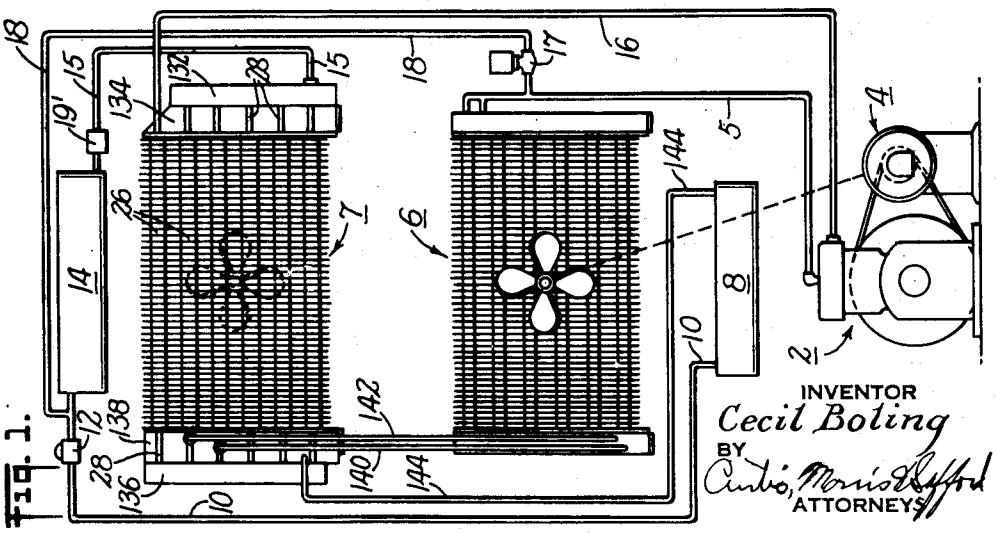
Nov. 10, 1953 C. BOLING 2,658,358

REFRIGERATION SYSTEM WITH MULTIPLE FLUID HEAT TRANSFER

Original Filed July 27, 1950 4 Sheets-Sheet 1







INVENTOR
Cecil Boling
BY
Curtis, Morris & Safford
ATTORNEYS

Nov. 10, 1953 C. BOLING 2,658,358

REFRIGERATION SYSTEM WITH MULTIPLE FLUID HEAT TRANSFER

Original Filed July 27, 1950 4 Sheets-Sheet 2

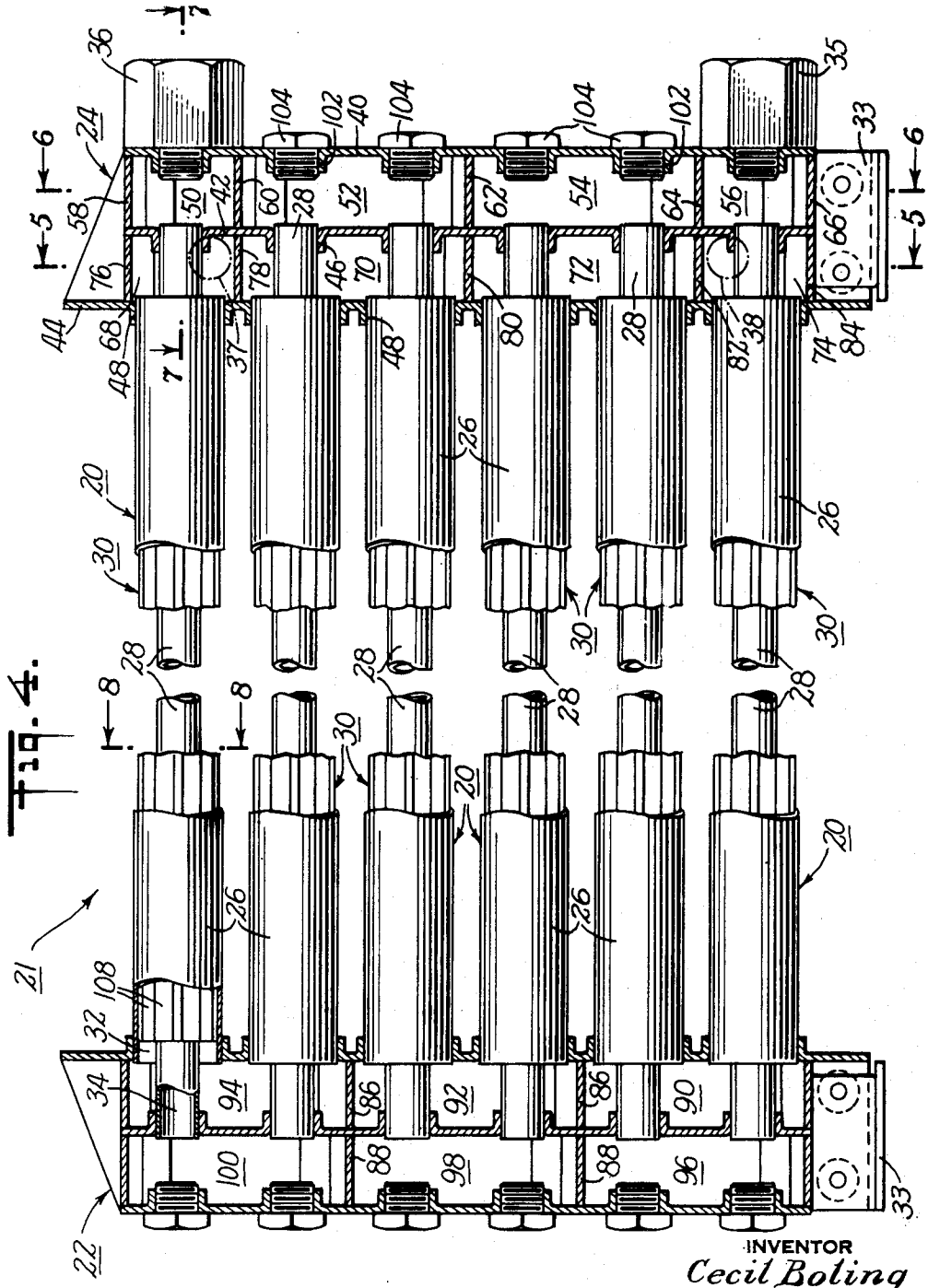


Fig. 4.

INVENTOR
Cecil Boling
BY
Curtis, Morris & Safford
ATTORNEYS

Nov. 10, 1953 C. BOLING 2,658,358

REFRIGERATION SYSTEM WITH MULTIPLE FLUID HEAT TRANSFER

Original Filed July 27, 1950 4 Sheets-Sheet 3

Fig. 5.

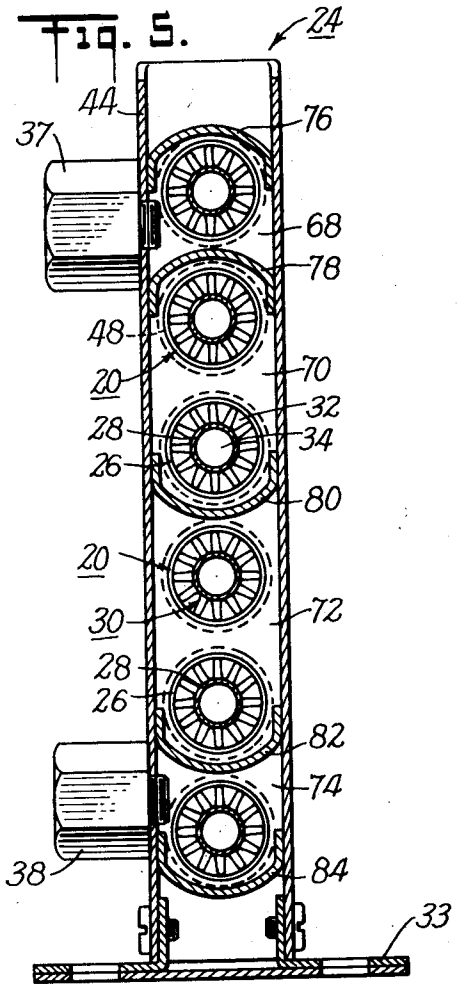


Fig. 6.

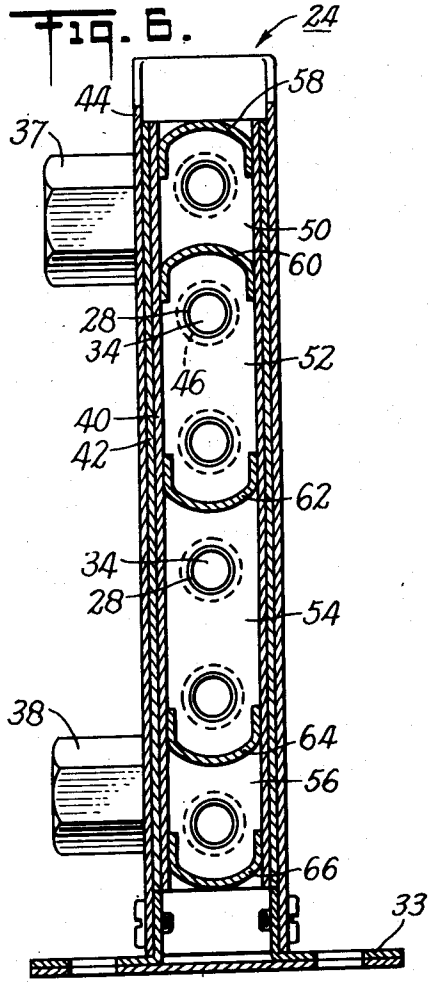


Fig. 7.

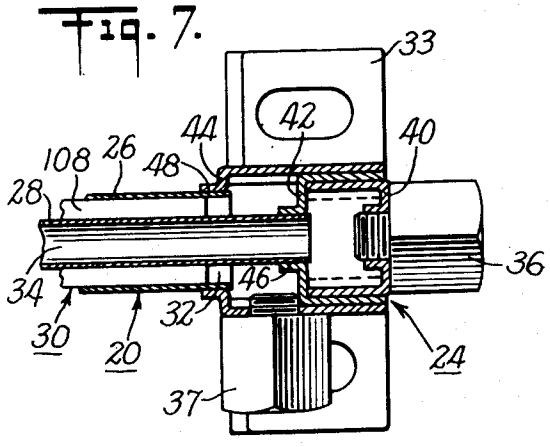
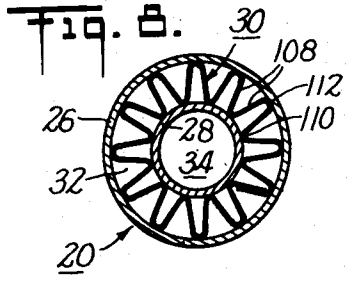


Fig. 8.



INVENTOR
Cecil Boling
BY
Curtis, Morris & Safford
ATTORNEYS

Nov. 10, 1953 C. BOLING 2,658,358

REFRIGERATION SYSTEM WITH MULTIPLE FLUID HEAT TRANSFER

Original Filed July 27, 1950 4 Sheets-Sheet 4

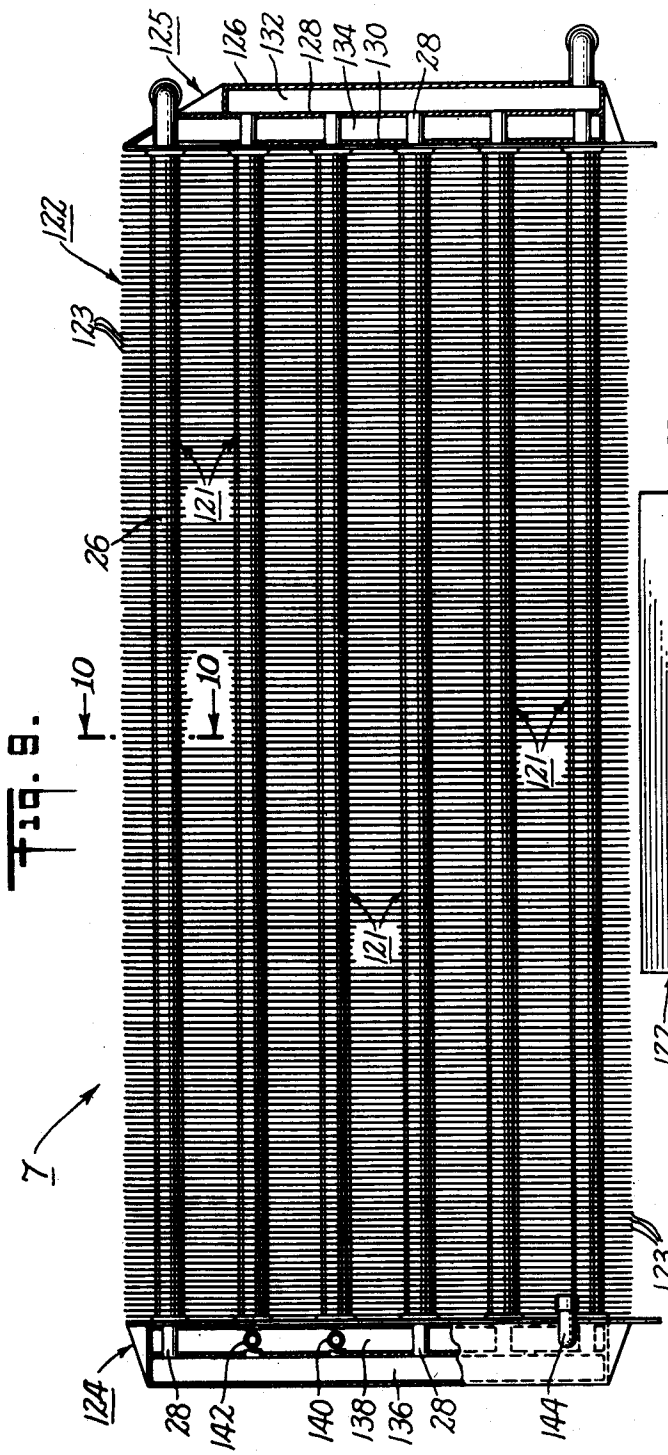


Fig. 9.

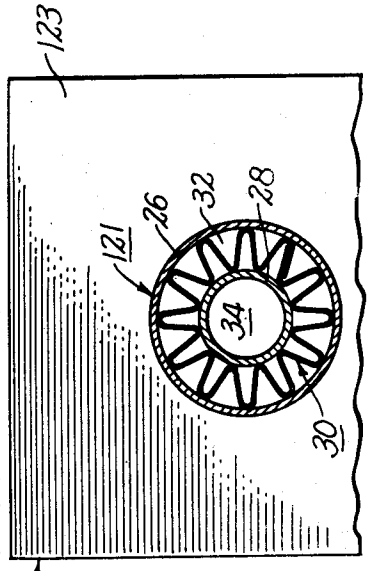


Fig. 10.

INVENTOR
Cecil Boling
BY
Curtis, Morris & Safford
ATTORNEYS

Patented Nov. 10, 1953 2,658,358

UNITED STATES PATENT OFFICE

2,658,358

REFRIGERATION SYSTEM WITH MULTIPLE FLUID HEAT TRANSFER

Cecil Boling, Brewster, N. Y., assignor to The Heat-X-Changer Co., Inc., Brewster, N. Y., a corporation of New York

Original application July 27, 1950, Serial No. 176,128, now Patent No. 2,611,587, dated September 22, 1952. Divided and this application November 14, 1951, Serial No. 256,204

7 Claims. (Cl. 62—117.55)

1

This invention relates to refrigeration and heat transfer or exchange equipment such as that which is used in refrigeration systems, with such equipment, and more in particular to improved refrigeration systems and heat exchange components such as condensers, evaporators and the like where one fluid is passed into heat exchange relationship with one or more other fluids. This application is a division of my copending application Serial No. 176,128, filed July 27, 1950, now Patent No. 2,611,587, September 23, 1952, and the claims of which are now restricted to the heat interchange tube and fin structure.

An object of this invention is to provide improved refrigeration systems wherein extremely efficient operation is obtained with equipment which is simple and sturdy in construction, inexpensive to manufacture and maintain, compact, light in weight and thoroughly dependable in use, and which is adaptable to meet many problems in different fields. Further objects are to provide improved heat exchange units having certain or all of the above desirable characteristics with particular attention being directed toward providing improved condensers, evaporators and the like. A further object is to provide heat exchange equipment which may be of more or less standardized design and construction and yet which is adaptable for use in solving many different problems which have been encountered in widely diversified fields. A still further object is to provide for the manufacture of equipment of the above character upon a mass production basis with the advantages and economies which may be obtained thereby. These and other objects will be in part obvious and in part pointed out below.

The invention accordingly consists in the features of construction, combinations of elements, arrangements of parts and in the several steps and relation and order of each of the same to one or more of the others, all as will be illustratively described herein, and the scope of the application of which will be indicated in the following claims.

In the drawings:

Figure 1 is a somewhat schematic representation of one embodiment of the invention;

Figures 2 and 3 are similar to Figure 1 but show other embodiments of the invention;

Figure 4 is an enlarged view with parts broken away of the condenser of the embodiment of Figure 2;

Figures 5 and 6 are vertical sections, respectively, on the lines 5—5 and 6—6 of Figure 4;

2

Figure 7 is a section on the line 7—7 of Figure 4;

Figure 8 is a further enlarged view on the line 8—8 of Figure 4;

Figure 9 is a view similar to Figure 4 but showing a heat transfer unit of the embodiment of Figure 1; and,

Figure 10 is a section on the line 10—10 of Figure 9.

Refrigeration systems generally include two or more heat transfer units wherein heat is transferred to or from a stream or streams of the refrigerating medium. Examples of such heat transfer units are: condensers, evaporators and heat interchangers where one stream of refrigerant is passed in heat transfer relationship with another or where a liquid or air is cooled or heated by a liquid or gas. With any particular refrigeration system the performance may be improved by increasing the rate of heat transfer at the heat transfer units. Thus, if there is a high rate of heat transfer at the condenser, a relatively large amount of refrigerant is condensed with a minimum amount of air or water and with a relatively small condenser. Similarly, the performance of the system is improved by increasing the rate of heat transfer to the refrigerant in the evaporator, thus, to promote uniform cooling throughout the evaporator zone and uniform and complete evaporation of the refrigerant.

Generally, the performance of an air cooled condenser varies over a relatively wide range in accordance with the ambient temperature as well as the load. That is, the rate at which heat is transferred from the condenser drops materially when the ambient temperature rises, and it has been accepted practice to design air cooled condensers for refrigeration systems with a relatively high excess load factor at normal or mean ambient temperatures solely to take care of the high loads at high ambient temperatures. Proposals have been made to provide both an air-cooled condenser and a water cooled condenser for a single refrigeration system or to utilize both air and water to cool a single condenser unit. With such arrangements most or all of the heat is passed to the air at light loads and at low ambient temperatures, but as the ambient temperature or the load rises, heat is passed to the water. However, it has been difficult to provide for the efficient transfer of heat to both air and water with condenser structure which is inexpensive to manufacture and thoroughly satisfactory in every respect.

A similar problem arises with evaporators

where it is desirable to provide a good heat transfer relationship between the refrigerant and air at the evaporator surfaces for the purpose of cooling the air, and also between a defrosting medium and the evaporator surfaces for the purpose of melting the frost free during a defrosting operation. Similarly, with a combination air cooling and heating system where a refrigeration system cools a building in summer and heating is provided in winter, it is desirable to provide a single heat transfer unit of minimum size and cost in each room which is the heat radiator in winter and the cooling or heat-absorbing unit in summer. In each of the systems referred to above, the present invention contemplates the provision of one or more heat transfer units, each of which is adapted to pass two or more fluids, i. e., liquids or gases, into efficient heat transfer relationship with each other or to pass selectively or simultaneously two such fluids into heat transfer relationship with air or the like.

Referring particularly to Figure 1 of the drawings wherein a refrigeration system is shown somewhat schematically, a compressor 2 is driven by a motor 4 and is automatically controlled so that it compresses refrigerant and delivers it through a hot gas line 5 to a primary condenser 6 and thence to a secondary condenser 7. The refrigerant is condensed in the condensers and the liquid refrigerant goes to a receiver 8 and thence through a liquid line 10 and an expansion valve 12 to an evaporator 14. The refrigerant evaporates in the evaporator and flows through a line 15 which has a throttle valve 19 therein which does not interfere with the flow of the refrigerant gas during the refrigeration cycle. The refrigerant then passes through a heat exchange passageway in the secondary condenser 7, and a line 16 to the compressor.

During normal operation frost accumulates on evaporator 14 and the evaporator is defrosted by passing hot gas from the compressor directly to the evaporator so that it does not flow through the condensers. Accordingly, the system is provided with a valve 17 in a bypass line 18, and this valve is opened to connect the hot gas line 5 through line 18 to the inlet of evaporator 14; the hot gas heats the evaporator and the ice is melted free. The rise in pressure causes the throttle valve 19' to close and throttle the flow of refrigerant as it returns from the evaporator to the compressor through line 15 to the heat exchange passageway in the secondary condenser 7 and thence to the compressor through line 16. This causes the refrigerant to condense in the evaporator and it is evaporated in the secondary condenser 7 so that the secondary condenser is also a re-evaporator.

In the embodiment of Figure 2 the system represented is similar to that of Figure 1 except that: a special evaporator 19 is provided; a condenser 21 of modified form replaces the condensers 6 and 7; and, the bypass line 18 and valves 17 and 19 are omitted. In this embodiment the defrosting operation is carried on by passing a hot liquid through a separate passageway in the evaporator to perform the defrosting operation. Consequently, no hot gas is passed to the evaporator, and it is unnecessary to provide for the re-evaporation of refrigerant passing to the compressor.

Condenser 21 is of a special construction which constitutes an important phase of the invention and now will be described more in detail. This condenser is shown in Figures 4 to 8 and comprises a set of six horizontal multiple-passageway condenser tube assemblies 20 (Figure 4) rigidly mounted and interconnected at their ends by a pair of header assemblies 22 and 24. Each of the condenser tube assemblies 20 comprises an outer tube 26 and an inner tube 28 (see also Figure 8), having an internal, radially-compressed, fin assembly 30 positioned in the annular space 32 between the two tubes. In each tube assembly the refrigerant from the compressor passes through the space 32 which acts as a condensing passageway where the gas is cooled thereby to condense it to a liquid.

Cooling water is flowed through the passageway 34 in each inner tube 28 so that cooling of the refrigerant gas is obtained as a result of heat passing through the inner tube wall to the water. The flow of water is controlled by a metering valve 29 which is connected through a pressure tube to the compressed or hot gas line from the compressor and permits water to flow through the condenser at a rate sufficient to keep the pressure of the compressed gas within desirable limits.

The header assemblies 22 and 24 (Figure 4) provide rigid support for the condenser tube assemblies and are in turn supported at the bottom (see also Figures 5 and 6) by a pair of sheet metal mounting brackets 33 which are clamped in place on the base of the machine by bolts (not shown). The header assemblies provide fluid connections whereby the various passageways 32 are connected in series; and, at the same time, all of the passageways 34 are connected in series. Accordingly, header assembly 24 is provided at the bottom with a water inlet fitting 35, and at the top with a water outlet fitting 36; and (see Figure 5), there is at the top a refrigerant inlet fitting 37 and at the bottom a refrigerant outlet fitting 38.

Header assembly 24 is formed by two interengaged vertical channels 40 and 42 (see Figure 7) and a third enclosing channel 44. Channels 40 and 42 form the header passageways for the inner tubes 28 while channels 42 and 44 form the header passageways for the annular passageways 32 in tubes 26. Accordingly, channel 42 is provided with a set of flanged openings 46 which receive the ends of tubes 28 and channel 44 is provided with concentrically positioned flanged openings 48 which similarly receive the ends of tube 26. Referring to Figure 6, the space between channels 40 and 42 is divided into four header passageways 50, 52, 54 and 56 by five arch-like transverse walls 58, 60, 62, 64 and 66 which are positioned as shown in Figure 6 and provide horizontal blocks or walls between the respective header passageways. The header passageways 50 and 56 are open respectively to the ends of the top and bottom tubes 28 while each of passageways 52 and 54 is open to the ends of a pair of the centrally positioned tubes 28 (see also Figure 4). Referring to Figure 5, the header passageways 68, 70, 72 and 74 between channels 42 and 44 are similarly formed by arch-like transverse walls 76, 78, 80, 82 and 84. The top and bottom passageways 68 and 70 are connected respectively to the annular passageways 32 in the top and bottom tube assemblies while the passageways 70 and 72 are each connected to a pair of the centrally positioned passageways 32.

Referring to the left-hand portion of Figure 4, header 22 is substantially identical in construction with header 24 except that arch-like transverse walls 86 and 88 are positioned to provide: header passageways 90, 92 and 94 which connect the annular passageways 32 in the lower pair of tubes, the central pair of tubes, and the

top pair of tubes, respectively; and header passageways 96, 98 and 100 which connect the ends of the lower pair of tubes 28, the central pair of these tubes, and the top pair of these tubes, respectively. It is thus seen that the water inlet fitting 35 is connected to a water passageway which extends through passageway 56, the lower tube 28, passageway 96, the next tube 28, passageway 54, the next tube 28, passageway 98, the next tube 28, passageway 52, the next tube 28, passageway 100, the top tube 28, and thence through passageway 50 to the water outlet fitting 36. A similar refrigerant circuit is provided from the refrigerant inlet fitting 37 at the top and through passageways 68, 32, 94, 32, 70, 32, 92, 32, 72, 32, 90, 32, and 74 to the refrigerant outlet fitting 38. Each of the channels 40 is provided with a set of flanged openings 102 which are respectively in alignment with the ends of tubes 28 and each of these openings is threaded; and the water inlet and outlet fittings are threaded into the top and bottom of these openings 102 and the other of these openings are closed by a screw cap 104. Thus, the water circuit may be readily cleaned by removing these fittings and screw caps, and by inserting a spiral tube cleaner.

The various elements of the header assemblies are connected to each other and to tubes 26 and 28 by a soldering operation. Thus, during manufacture the elements are assembled in a jig, and the headers are then heated and soldered. Upon cooling the entire unit is held together as a unitary structure, and the joints and seams are sealed.

The fin assembly 30 is of the type disclosed in my copending application Serial No. 17,899, filed March 30, 1948, now Patent No. 2,611,585 September 23, 1952, and is characterized by being formed of sheet metal which is somewhat corrugated so that fins are provided extending longitudinally of the tubes. Referring particularly to Figure 8, each of the fin assemblies 30 comprises a single piece of sheet metal which is of substantially the exact length as tube 28 and is corrugated to form an even number of substantially flat radial fin portions 108 which, except at the edges of the sheet, are connected each with the next two. The fin portions are connected adjacent tube 28 by a relatively sharp angle bend 110 and adjacent tube 26 by a rounded bend 112. This gives a good heat transfer relationship with both tubes, and gives structural advantages. During construction of the apparatus, the fin assembly 30 and the inner tube 28 are slid into tube 26, and tube 28 is then expanded so that it presses radially outwardly upon the fin assembly 30. Thus, each of the fin portions 108 is compressed radially so that one edge is pressed at a bend 110 against the outer surface of tube 28 and the other edge is pressed at a bend 112 against the inner surface of tube 26. With this construction the fin assembly is expansible so that it is pushed by the inner tube outwardly against the outer tube, but can not be compressed to any great extent radially and, therefore, the fin assembly is placed under radial compression by the expansion of tube 28. Thus, the fin assembly has good heat transfer relationship with both of the tubes and also with the refrigerant flowing through the passageway 32 between the tubes. Furthermore, the refrigerant flow through this passageway is relatively unobstructed because the fins extend longitudinally of the passageway.

In Figure 2 the evaporator 19 is substantially identical in construction with the condenser 21, except that each of the tube assemblies has on its outer tube 113 a fin assembly of the tube 115 formed by square sheet metal fins 117. These fins 117 are put in place on each tube 113 prior to assembly with its internal fin assembly 30 and its inside tube 28, and the tube 113 is expanded to hold the fins 117 in place and to give a good heat transfer relationship. The refrigerant passes from the receiver 8 through line 10 and expansion valve 12 to the refrigerant inlet fitting 114. It then flows through the series of evaporator passageways identical with passageways 32 to the refrigerant outlet fitting 116 from which it returns through line 15 to the compressor. An inlet fitting 118 identical with fitting 36 on the condenser provides an inlet connection for a defrosting liquid which may be an aqueous solution or another liquid which is heated.

Thus, when frost accumulates on the evaporator the refrigeration operation is discontinued and heated defrosting liquid is supplied to fitting 118. This liquid flows through the passageway corresponding to the water passageway in the condenser and it is discharged at the bottom of the evaporator, through a fitting 120. The heat from the defrosting liquid passes through the walls of tubes 28 and thence through the fin assemblies 30 to the outer tubes 26. This heats the outer tubes and the fins so that the accumulated frost or ice is melted free. It is thus seen that the evaporator surfaces are in good heat transfer relationship with the inside tubes 28 and, therefore, the defrosting operation is carried on efficiently. This good heat transfer relationship exists by virtue of the fin assemblies 30 being held under radial compression so that each fin assembly is in tight contact with the outer surface of its inner tube and the inner surface of its outer tube.

Referring now again to Figure 1, it was stated above that the secondary condenser 7 is of special construction and provides a heat transfer passageway for the return refrigerant. Referring to Figure 9, this condenser 7 is in many respects identical with condenser 21 of Figure 2. There are six tube assemblies 121, each of which is constructed in the same manner as tube assemblies 20 of Figure 2 but the outer tube 26 carries a fin assembly 122 formed by fins 123 which are identical with the fins 117 on the evaporator of Figure 2. The headers 124 and 125 are quite similar to the corresponding headers 22 and 24 of Figure 2 and differ only in that certain of the partitions or transverse walls are omitted and the right-hand header 125 is cut away at the top.

Header 125 is formed by a set of interengaged channels 126, 128 and 130 and there is a single passageway 132 at the right between channels 126 and 128 which is open to the right-hand ends of all of the tubes 28, except for the top tube. There is also a single passageway 134 between channels 128 and 130 which is open to the annular finned passageways 32 between the concentric tubes 26 and 28 of the respective tube assemblies. Header 124 is similar to header 125 except that its channels extend to the top of the condenser and provide a single passageway 136 which is open to the left-hand ends of all of the tubes 28 and a passageway 138 which is open to the left-hand ends of all of the passageways 32.

It has been pointed out above that (see also Figure 1) the compressed gas flows from the compressor to the primary condenser 6 which, in actual construction, is mounted at the side of

the secondary condenser 7 and a single fan passes air through the two condensers. The refrigerant from the primary condenser passes through two tubes 140 and 142 to the upper portion of passageway 138 at the left-hand end of the secondary condenser and, as indicated, this passageway is open to the left-hand end of all of the annular finned passageways 32 in the various tube assemblies. The bottom of this passageway 138 is connected through a line 144 to the receiver and, therfore, the condensed refrigerant from the primary condenser flows through the lines 140 and 142 into passageway 138 and down this passageway and through line 144 to the receiver with minimum resistance to flow. However, any refrigerant gas which is not condensed in the primary condenser 6 separates from the liquid refrigerant in passageway 138 and flows into the various passageways 32 where heat is passed from it by the internal fin assemblies 30 and also by contact with the outer tubes 26.

The internal fin assemblies 30 are compressed as a result of the expansion of the internal tubes 28 during assembly and the external fins 123 are in good heat transfer relationship with their tube surfaces. Thus, the heat from the refrigerant gas passes efficiently to the fins 123 and thence to the air. The right-hand ends of the passageways 32 are also interconnected by the passageway 134 and liquid refrigerant flows from passageway 134 to the left to passageway 138; therefore, no liquid is trapped in any of the passageways. Thus, an efficient condensing action is performed by the secondary condenser.

The secondary condenser is also a re-evaporator and the refrigerant returns through it from the evaporator to the compressor. This return re-evaporator passageway is formed by the inside tubes 28 and the interconnecting passageways 132 and 136. Line 15 is connected to the bottom of passageway 132 at the right-hand side of the unit and the top tube 28 has its right-hand end connected to line 16 which extends to the intake port of the compressor. As indicated above, passageway 132 is connected to the right-hand end of all of tubes 28 except the top one and the left-hand passageway 136 is connected to all of the tubes 28. Thus, the refrigerant flowing from line 15 into passageway 132 flows freely to the left through the five lower tubes 28 and into passageway 136. From passageway 136 the refrigerant flows to the right through the top tube 28 which is of sufficient size to carry the refrigerant without objectionable pressure drop. Thus, the refrigerant returning from the evaporator to the compressor during the refrigeration cycle is passed into heat exchange relationship with refrigerant on the "high side." This not only insures that no drops or "slugs" of liquid refrigerant will reach the compressor in the return line but it also improves the performance of the system.

During the defrosting cycle the flow from the evaporator to the compressor is unchanged and, as indicated, hot gas flows through line 18 directly to the evaporator where it melts ice or frost free. During this operation refrigerant is condensed in the evaporator and this flows through line 15 and valve 19', which then provides a pressure drop to passageway 132 and thence through the lower five tubes 28 to passageway 136. The liquid refrigerant tends to flow through the lower tubes while the upper tubes tend to remain free for gas and vapor. Heat, however, is passed to the refrigerant through the walls of tubes 28 from the respective fin assemblies 30. These fin assemblies are in good heat exchange relationship with the outer tubes 26 and the external fins 123. Therefore, heat is absorbed by the fins 123 and passed by the internal fin assemblies to the refrigerant in the inner tubes 28. The unit therefore acts as an efficient re-evaporator and insures the evaporation of all liquid refrigerant which flows from the evaporator. The five tubes 28 operate in parallel and, as indicated, they offer minimum resistance to the refrigerant flow. The top tube 28 prevents "slopping over" which might occur under some conditions of operation if line 16 were connected to passageway 136. Under some circumstances there may be one or more additional tubes connected in parallel with the top tube or a more extended series arrangement may be provided so that the refrigerant follows a longer path.

In the embodiment of Figure 3 an arrangement is shown schematically wherein a single heat transfer unit 143 acts as an evaporator in the summer to cool the air in a room, for example, and acts as a heat radiator in the winter to heat the room. The unit 143 is identical with evaporator 19 of Figure 2 and the parts are correspondingly numbered. However, when the unit is acting as an evaporator its surface temperature is above freezing and therefore frost does not form and it is unnecessary to defrost it.

For purposes of heating in winter the inner tubes 28 of unit 143 are connected to a heating medium, illustratively, steam supplied from a remote boiler 147. The condensing unit of Figure 3 is identical with that of Figure 2 except that an air and water cooled condenser 145 is provided which is identical in structure with evaporators 19 and 143. In condenser 145 the inner tube circuit, formed by tubes 28 connected in series, acts as a water circuit for the condenser cooling water the same as in Figure 1 and therefore water is supplied to this inner tube circuit through a valve 144 identical with valve 29 of Figure 2. However, each of the condenser tube assemblies is provided with external fins as in Figure 1, and under low load conditions and at low ambient temperatures, the cooling effect of the fins is sufficient to condense all of the refrigerant. Under such circumstances, valve 144 remains closed and there is no water flow because the pressure of the hot gas does not rise. However, at high loads and when the ambient temperature rises the "high side" pressure rises indicating that the condenser is not condensing all of the refrigerant; this opens valve 144 and permits water to flow through the condenser so that there is auxiliary cooling. With this arrangement it has been found that the unit can be designed for normal operation as a solely air cooled unit; and yet peak and abnormal loads need not be taken into consideration insofar as the air cooling surface is concerned because such loads are handled with the assistance of water cooling. This arrangement is of particular advantage under circumstances where the free use of water is objectionable and where maximum efficiency is important.

With the embodiment of Figure 3 the refrigeration system operates to cool the air during warm weather in accordance with the normal refrigeration cycle of operation. During such operation the inner tubes carry no heating or cooling medium. However, they perform the function referred to previously of providing the high heat transfer relationship between the fin structures

and the outer tubes and thence with the air. When cooling is no longer required the refrigeration system is turned off and, if desirable, heating may be effected immediately by merely supplying the heating medium such as steam to the inner tube circuit. The steam or other heating medium such as hot water flows through the inner tube circuit and the heat is transferred through the walls of tubes **28** and thence through the internal fin assemblies to the outer tubes **26** where it is transferred to the air. It is thus seen that the refrigeration system and the heating system utilizes the same heat transfer structures and yet the cooling fluid and heating fluid circuits are not interconnected. In Figure 3 the schematic representation is of a system having one heat transfer unit **143**, although it should be clearly understood that such a system would normally include several, if not many, such units.

With the condenser **146** it should be noted that maximum performance is obtainable with a minimum sized condenser because the compressed internal fin assemblies make it possible to provide a high rate of heat transfer with the air as well as with the water. Similarly, in the heat transfer unit **143** high heat transfer is provided between the refrigerant and the air in the summer and also between the steam and the air in the winter. Thus, a single heat transfer unit of minimum size may be provided with a single air circulating and mounting structure. Under some circumstances hot water or other hot fluid may be used as the heating medium and the fins may be omitted if the external surface is sufficient otherwise. Generally, the heat transfer units of the type herein disclosed are provided with fans when there is to be a heat transfer relationship with air. Thus, in the embodiments shown, fans are used whenever the tube assemblies are provided with external fins.

With the various heat transfer units herein disclosed it will be appreciated that the header structures may be modified to obtain either full parallel or full series flow, or there may be combined parallel and series flow. For example, with a condenser the inner tubes may be connected to operate with adjacent pairs in parallel or all of them may be in parallel. Similarly, the passageways **32** may be connected so that two or three are in parallel. The particular internal fin structure gives minimum pressure drop through the passageways **32** even though there is rapid flow. The pressure drop is, of course, reduced if parallel flow is provided, although under some circumstances, it is desirable to provide an extended series flow.

The arrangement of providing the internal fin structures **30** with U-bends of greater mean radius at the outer tubes than at the inner tubes is an important feature of construction. This characteristic of the fin structures is obtained by corrugating sheet metal with alternate wide and narrow U-bends. Thus, in actual production, a strip of sheet metal having a width or transverse dimension which is exactly that desired as the length of the fin assembly is placed in a fin-forming machine. This fin-forming machine has a sheet holder adjacent a forming zone at which the sheet is clamped originally with a leading edge projecting into the zone. Two forming strips of different widths are positioned on the opposite sides of the projecting leading edge of the sheet and they are moved edgewise into engagement with the opposite sides of the sheet. The engagement of the two forming strips is along zones spaced slightly from each other and the movement of the forming strips is continued so that the sheet is formed into two corrugations. One of the corrugations is narrower than the other because its forming strip is narrower and one U-bend is also narrower than the other.

The forming strips are then withdrawn and then the sheet is advanced and the operation is then repeated until there is a sufficient number of corrugations for a fin assembly **30**. The fin assembly is then curved into annular form and the edges are interlocked as shown. An inner tube **28** and a fin assembly **30** is then inserted into a tube **26** and in this embodiment the inner tube **28** is expanded. The expansion is sufficient to press the fin assembly **30** outwardly against the inner wall of tube **26** and each corrugation or fin portion is placed under compression. Under some circumstances the outer tube may be deformed to a smaller size to obtain this compressed condition of the fins. The internal fin assembly is deformable so that its mean radius may be changed readily or it may even be deformed to a non-annular shape so as to conform to the exact radial dimensions of the space provided for it. Such deforming changes the total angles of the various U-bends but the radially extending fin portions are not bent materially. Thus, the fin assembly will still withstand substantial radial compression which, in any event, is made sufficient to insure the desired heat transfer relationship with the confining walls. This high heat transfer relationship is thus obtainable without the use of solders or other bonding metals or auxiliary structures. In the illustrative embodiments, tubes **26** and **28** and internal fin assemblies **30** are copper, although it is understood that other metals may be used when desirable.

As many possible embodiments may be made of the mechanical features of the above invention and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matter hereinabove set forth, or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a refrigeration system of the character described wherein refrigerant is passed to an evaporator in liquid phase and returns in gas phase, the combination with the other components of said system of a heat transfer unit connected in flow series in the refrigerant circuit which comprises, a bank of parallel tube assemblies each of which is formed by an inner tube and an outer tube which are concentrically positioned to provide an annular space therebetween and an annular fin assembly formed by sheet metal which has been corrugated with each corrugation forming a fin portion which extends somewhat radially and bridges said annular space, said fin assembly having the characteristic that it is deformable but is capable of withstanding radial compression, said tubes being of such relative size as a result of one of them being deformed after assembly that said fin assembly is compressed within said annular space whereby it exerts substantial pressure upon the outer surface of the inner tube and the inner surface of the outer tube, and a pair of headers for said tube assemblies and providing fluid connections to said annular spaces thereof and also to the inner tubes thereof, each of said header assem-

blies including a first wall portion which provides rigid mounting means for the various outer tubes and a second wall means which provides mounting means for the various inner tubes.

2. Apparatus as described in claim 1 wherein said heat transfer unit is a condenser and re-evaporator unit wherein, said header assemblies comprise means connecting a plurality of said inner tubes in parallel whereby refrigerant flowing from the evaporator is provided with a plurality of parallel paths of flow, and which includes external fin assemblies mounted respectively on said tube assemblies.

3. Apparatus as described in claim 2 wherein said refrigeration system includes a primary condenser and said heat transfer units acts as a secondary condenser, and wherein said header assemblies connect all of said annular spaces of the tube assemblies in parallel relationship.

4. Apparatus as described in claim 1 wherein each of said annular fin assemblies has its corrugations connected by relatively narrow U-bends adjacent the inner tube with which it is associated and connected by substantially wider U-bends adjacent the outer tube with which it is associated.

5. Apparatus as described in claim 1 wherein said annular spaces in said tube assemblies comprise the evaporator for the system, and wherein heat is supplied to the unit through the central passageway through said tubes.

6. In a refrigeration system of the character described wherein refrigerant is compressed and is condensed after which it is returned to the compressor, the combination with the compressor and the evaporator of, a condenser and re-evaporator unit connected in flow series in the refrigerant circuit, said unit including a plurality of tube assemblies each of which is formed by a pair of concentrically positioned tubes having a condensing passageway therebetween and a radially compressed fin assembly positioned within the condensing passageway and having good heat transfer relationships with the two tubes by virtue of the compressed condition of the fin assembly, said unit including a pair of header assemblies which include means connecting one or more of the inner tubes of the tube assemblies in series relationship in the return path of the refrigerant flowing from the evaporator to the compressor whereby liquid refrigerant which flows from the evaporator is re-evaporated by heat passing to it through said fin assembly, each

of said header assemblies including first wall means which provide rigid mounting means for the inner tubes and second wall means which provide rigid mounting means for the outer tubes.

7. In a refrigeration system of the character described wherein refrigerant is compressed and is condensed, and is then passed to an evaporator where it is evaporated, after which it is returned to the compressor, and wherein frost or the like tends to accumulate on exposed surfaces of the evaporator which frost or the like must be removed by a defrosting operation, the combination with the compressor and the other components of the system of an evaporator formed by a plurality of tube assemblies and a pair of headers providing mounting means for said tube assemblies and providing for fluid flow therethrough, each of said tube assemblies comprising a pair of concentrically positioned tubes of different radii and having an annular passageway therebetween and a central passageway through the smaller diameter tube, said assembly also having a radially compressed fin assembly positioned within said annular passageway and having good heat transfer relationships with the two tubes by virtue of the compressed condition of the fin assembly, each of said headers being formed by a structure providing header connections with said annular passageways for one fluid circuit and header connections with said central passageways for another fluid circuit, one of said fluid circuits providing the evaporator for said refrigerator system, and the other of said fluid circuits providing for the introduction of a heated fluid to perform the defrosting operation.

CECIL BOLING.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
35,496	Montgomery	June 3, 1862
184,085	Kittredge	Nov. 7, 1876
237,515	Gould	Feb. 8, 1881
660,292	Durr	Oct. 23, 1900
1,270,198	Parkhurst	June 18, 1918
1,584,772	Hyde	May 18, 1926
2,004,389	Jones	July 11, 1935
2,206,826	Hopper	July 2, 1940
2,324,395	Hoop	July 13, 1943
2,351,140	McCloy	June 13, 1944
2,430,538	Leeson	Nov. 18, 1947