Aug. 6, 1940. O. W. GREENE 2,210,031

REFRIGERATING APPARATUS AND METHOD

Filed Aug. 28, 1936 4 Sheets-Sheet 1

Fig. 1

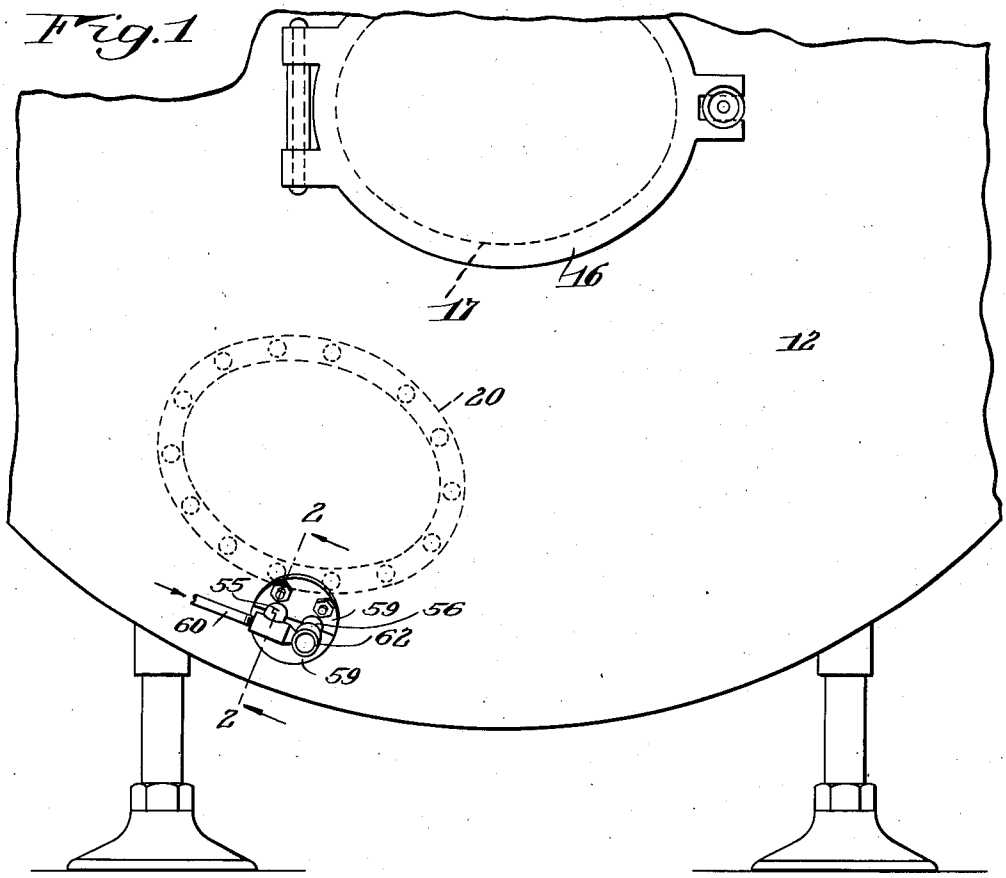


Fig. 2

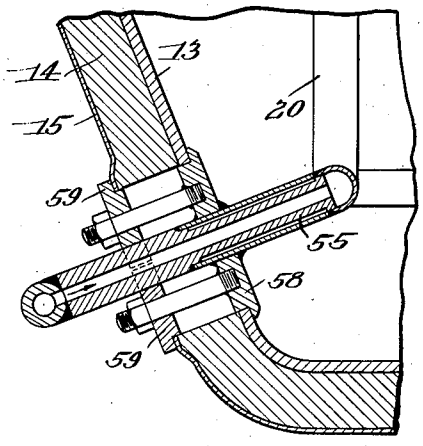
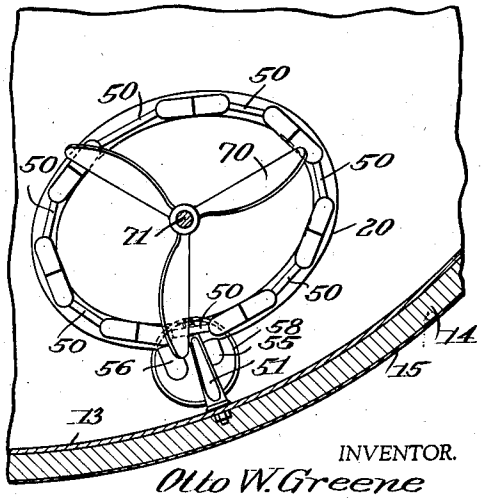


Fig. 4



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REFRIGERATING APPARATUS AND METHOD

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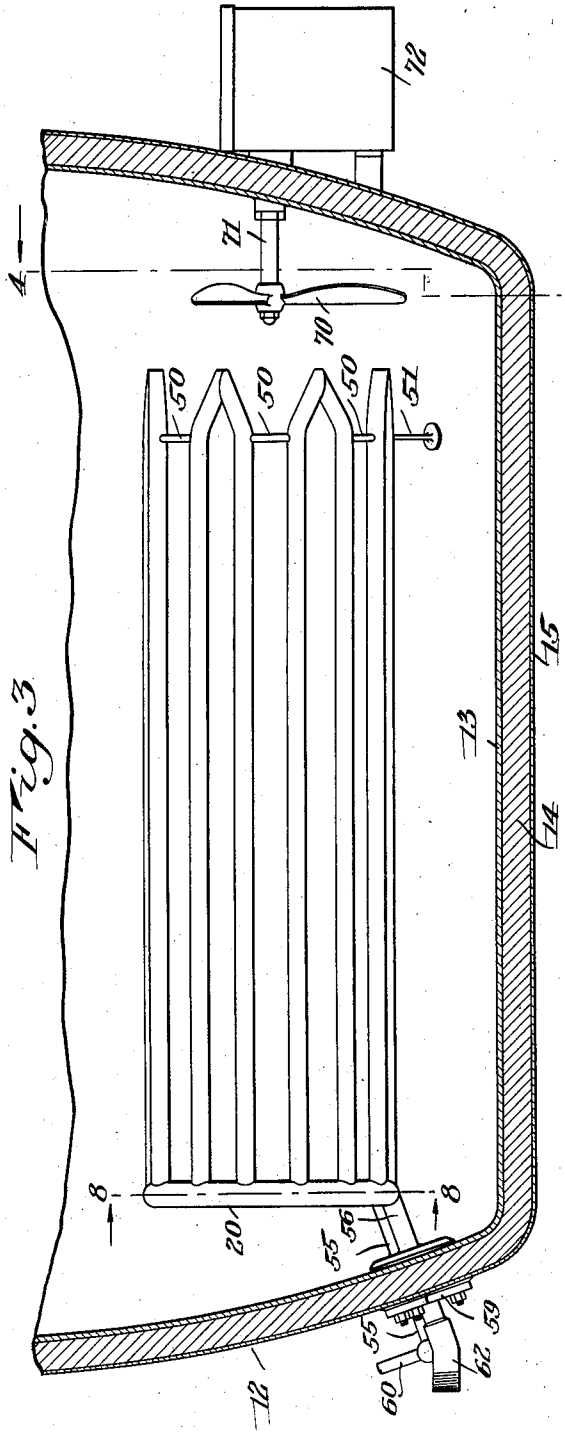


Fig. 3

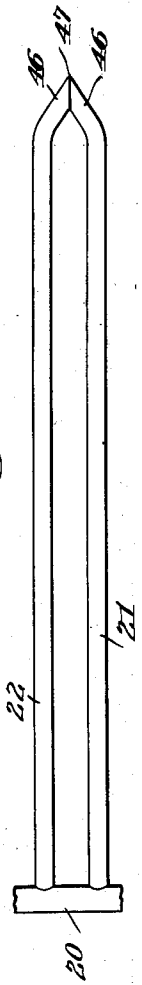


Fig. 5

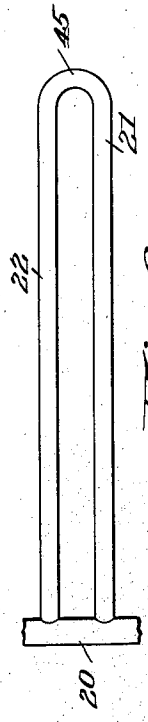


Fig. 6

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REFRIGERATING APPARATUS AND METHOD

Filed Aug. 28, 1936 4 Sheets-Sheet 3

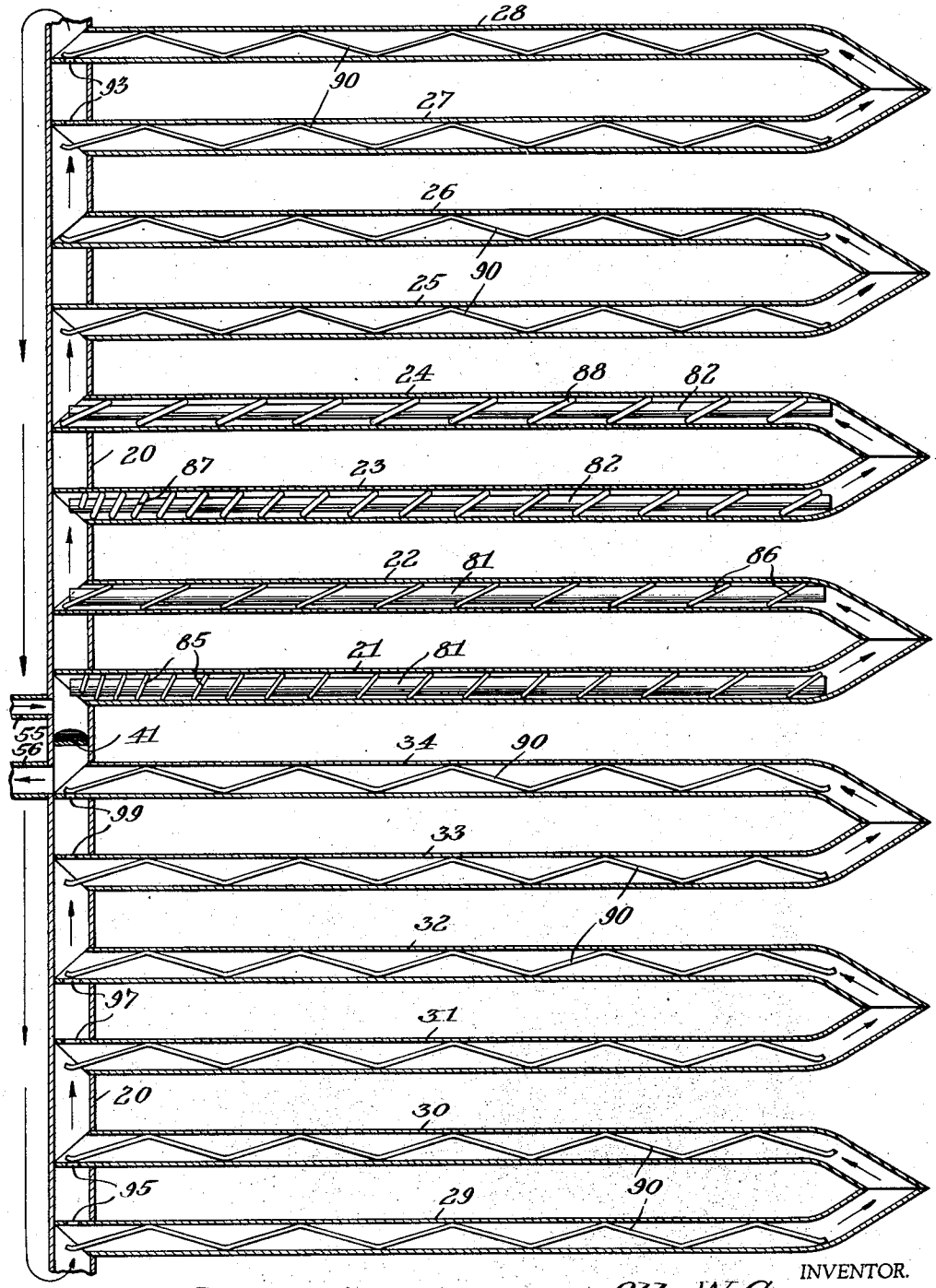


Fig. 7

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REFRIGERATING APPARATUS AND METHOD

Filed Aug. 28, 1936 4 Sheets-Sheet 4

Fig. 8

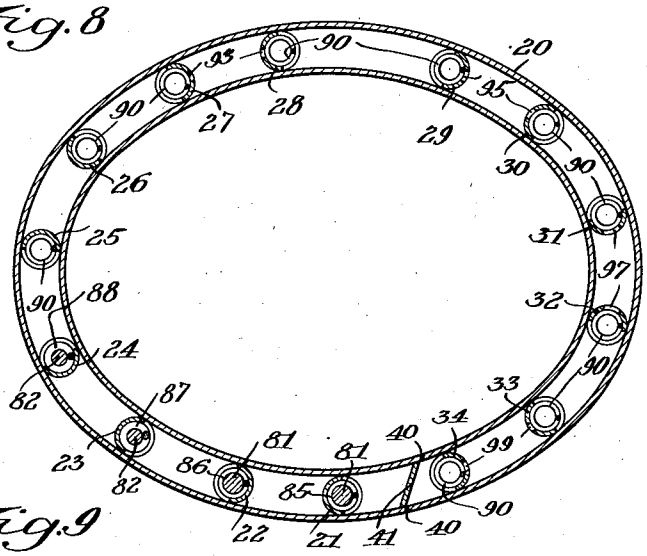
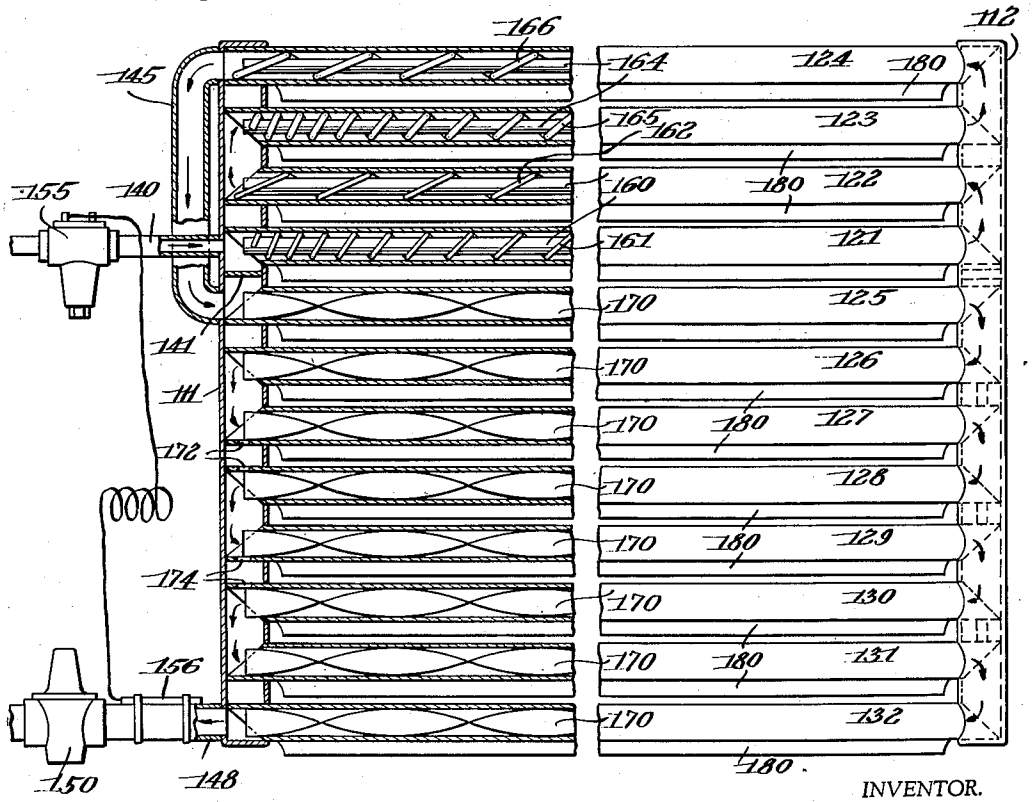


Fig. 9



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Patented Aug. 6, 1940 2,210,031

UNITED STATES PATENT OFFICE

2,210,031

REFRIGERATING APPARATUS AND METHOD

Otto W. Greene, Elyria, Ohio, assignor to The Pfaudler Co., Rochester, N. Y., a corporation of New York

Application August 28, 1936, Serial No. 98,332

14 Claims. (Cl. 62—126)

This invention relates to a method of and apparatus for refrigeration.

An object of the invention is the provision of generally improved and more satisfactory cooling apparatus of the above mentioned type.

Another object is the provision of cooling apparatus so designed and constructed that the cooling fluid will be moved effectively through the passageway or conduit in which it is placed.

Another object is the provision of a passageway or conduit for the cooling fluid, so designed and constructed that substantially the entire inner surface of such passageway or conduit will be kept continuously covered with unvaporized cooling liquid.

Still another object is the provision of a passageway or conduit for the cooling fluid so designed as to have a cross sectional area increasing in the direction of flow of the fluid in rough proportion to the increase in volume of the fluid caused by passage of part thereof from liquid phase to vapor phase.

Still another object is the provision of a passageway or conduit for the cooling fluid, so designed that any substantial bodies of liquid passing therethrough will be atomized or broken up into a spray of particles at certain points in the passageway.

A further object of the invention is the provision of cooling apparatus so constructed that it may be cleaned with great ease so as to be especially suitable for use in connection with food products, where sanitation is important.

A further object is the provision of cooling apparatus so designed that expansion and contraction stresses resulting from temperature changes may be readily accommodated without causing leakage at joints or other damage to the parts.

A still further object is the provision of cooling apparatus so designed and constructed that it may be readily placed within a closed tank or container through a relatively small manhole.

My invention further contemplates a method of increasing the efficiency of a cooling coil by causing the refrigerant, particularly that portion of the refrigerant in liquid phase, to flow at high velocity in intimate contact with the walls of the coil.

To these and other ends the invention resides in certain improvements and combinations of parts, all as will be hereinafter more fully described, the novel features being pointed out in the claims at the end of the specification.

In the drawings:

Fig. 1 is an end view of a fragment of a tank equipped with one form of cooling apparatus according to the present invention;

Fig. 2 is a section taken substantially on the line 2—2 of Fig. 1;

Fig. 3 is a vertical section taken longitudinally through the tank of Fig. 1;

Fig. 4 is a vertical section taken substantially on the line 4—4 of Fig. 3;

Fig. 5 is a view of one form of conduit which may be used in the cooling apparatus;

Fig. 6 is a similar view of an alternative form of conduit;

Fig. 7 is a developed diagrammatic view of the conduits through which the cooling fluid flows, in one form of construction;

Fig. 8 is a vertical section through the header to which certain other conduit sections are connected, this section being taken substantially on the line 8—8 of Fig. 3, and

Fig. 9 is a vertical section through an alternative form of apparatus.

The same reference numerals throughout the several views indicate the same parts.

The present invention may be embodied in apparatus of the surface cooling type, providing a cooling surface over which the milk or other liquid to be cooled may flow, such a construction being illustrated in Fig. 9, or it may be embodied preferably in apparatus of the immersion type, in which the conduits, passageways or coils carrying the cooling fluid are immersed in a body of the liquid to be cooled, which body of liquid is held in a suitable tank or container. This preferred form of construction is indicated in Figs. 1 to 8 inclusive, to which reference will now be made.

The tank or container for holding the liquid to be cooled is indicated in general at 12, and may comprise an inner metallic wall 13 covered by a layer 14 of insulating material and an outer jacket 15 of thin sheet metal or other suitable material. A manhole cover 16 closes a manhole 17 of standard or usual size. Preferably, but not necessarily, the tank or container is of generally cylindrical shape, with its axis arranged approximately horizontally, as shown, and the manhole is in one end wall of the tank.

Within this tank is an immersion cooling unit comprising a header section 20 and a series of conduit sections 21 to 34 inclusive, forming loops or passes. The header section 20 may be straight, curved, or of any other desired shape, but in the

preferred form of the invention this header is formed of a tube bent to a somewhat elliptical outline as indicated in Figures 1, 4 and 8, with the ends of the tube joined to each other at 40 as by welding or the like. The partition 41 is preferably secured in the tube, as by welding, adjacent the joint 40, and the inlet is just to one side of this partition and the outlet just to the other side thereof, so that the cooling fluid entering at the inlet must flow around the entire elliptical outline of the header before reaching the outlet.

The conduit sections 21 to 34 inclusive may extend from the header section 20 to a second header section, or they may simply be connected to each other in pairs or formed integrally with each other so as to constitute return bends or coil sections. For instance, as shown in Fig. 6, two of the adjacent conduit sections 21 and 22 may be formed integrally with each other or formed of two sections welded to each other to provide an approximately semi-circular connecting bend 45 at the ends of the sections 21 and 22 remote from the header 20. Such a semi-circular return bend is quite satisfactory in many instances, but for greatest efficiency within the cooling unit, and for least resistance to flow of liquid past the cooling unit, it is preferred to use sharp angular connections instead of the semi-circular bends shown in Fig. 6. Such sharp angular connections are indicated in Figures 3 and 5. Each two adjacent conduit sections 21 and 22 constituting one pair of sections are connected to each other at their outer ends, remote from the header 20, by bending the ends angularly toward each other as indicated at 46, and welding them to each other at the joint 47, so that where the two sections meet they make an acute angle bend, changing the direction of flow abruptly by substantially more than ninety degrees. Thus any concentrated masses of liquid passing through the tubes or conduit sections at relatively high velocity are broken up into a spray, or somewhat atomized when they hit these sharp angular corners. Moreover, the sharp angle presented exteriorly of the tubes reduces the resistance to flow of surrounding liquid in a direction along the tubes.

The tubes extend substantially parallel to each other throughout the major portions of their length, as shown in Fig. 3, and their ends opposite to the header 20 are supported by posts 50 welded or otherwise suitably secured to the tubes, and connecting each tube of one pair or pass to the adjacent tube of the next pair or pass. These posts 50 are of small cross section and relatively flexible, so that expansion or contraction of the tubes caused by differences in temperature will simply bend the posts 50 without distorting the tuhes themselves. A post 51 secured to the tank wall 13 and extending inwardly therefrom is connected to one of the members 50, as shown especially in Figs. 3 and 4, to support one end of the tube assembly or cooling unit in spaced relation to the tank. This post 51 is relatively broad in a direction transverse to the length of the cooling unit, as seen from Fig. 4, so as to have substantial resistance to deformation in this direction. In the direction of the length of the cooling unit, however, the post 51 is relatively thin as seen from Fig. 3, so that it offers only slight resistance to bending by forces exerted in a direction lengthwise of the cooling unit. Thus expansion and contraction of the cooling unit in a lengthwise direction does not damage the unit or the tank, since the post 51 simply bends to accommodate the relative movement between the tank and the end of the cooling unit.

The opposite ends of the tubes or conduit sections 21 to 34, inclusive, or left hand ends when viewed as in Figs. 3 and 7, may be joined to the header 20 in any suitable manner. Preferably all of the tubes 21 to 34 are of the same external diameter, and the header 20 is formed of a tube having an internal diameter substantially equal to the external diameter of the tubes. The ends of the tubes 21 to 34 extend through openings in the header tube 20 and project into the header, and are cut obliquely at approximately forty-five degrees, so that they form partitions in the header as shown. The tubes are preferably welded to the header where they enter it.

An inlet conduit 55 and an outlet conduit 56 extend from the header, at points on opposite sides of the partition 41, out through a small opening in the end wall of the tank 13. A plate 58, surrounding the conduits 55 and 56 and welded to them to form a fluid tight joint therewith, forms a closure for the tank opening and a support for supporting the inlet and outlet conduits which, in turn, form the support for the header 20 and its end of the whole cooling unit. Two plates 59 are fitted around the conduits 55 and 56 externally of the tank, and bolts connected to the plate 58 extend through the plates 59 and have nuts bearing against the plates 59, to draw the plate 58 firmly into fluid-tight engagement with the tank. A volatile or low-boiling refrigerating liquid of any suitable kind, such as ammonia, methylchloride, sulphur dioxide, Freon, etc., is supplied to the inlet conduit 55 through a conduit 60 (Fig. 1), and after flowing through the cooling unit, the refrigerant, now mainly a vapor, but possibly including some liquid, comes out through the outlet conduit 56 and its external outlet connection 62.

Any number of tubes or conduit sections may be employed, to provide any number of loops or passes in the cooling unit, depending upon the required cooling capacity and other characteristics desired. The inlet and outlet connections may be at any desired points with respect to the several tubes. In the embodiment here illustrated as a preferred example of the invention, fourteen tubes or conduit sections are employed, connected in pairs to provide seven loops or passes. Each tube is preferably straight, except for the bend at at one end where it is connected to the other tube of the same pair, and the tubes are all substantially parallel to each other and to the axis of the tank, which is substantially horizontal. In the preferred example, the inlet and outlet are near the low point of the elliptical header 20, and so placed that the refrigerant flows up hill through about the first three loops and intervening header portions, then flows downwardly through the remainder of the loops and intervening header portions, to the outlet.

It will be readily seen from Fig. 7 that the ends of the tubes which project into the header 20 form partitions therein in such manner as to force the refrigerant to flow successively through the several loops or passes, and they prevent the refrigerant from flowing directly around the header, except to the limited extent permitted by certain by-pass openings which will be further described below. Thus the refrigerant, entering the header 20 through the inlet 55, flows through the tube 21 to the remote end

thereof, then back through the tube 22 to the header, then along the header a short distance to the open end of the tube 23, along this tube to the remote end thereof, back to the header through the tube 24, and so on, passing successively through the tubes 25 to 34, inclusive, in the direction of the arrows in Fig. 7, finally emerging from the header through the outlet 56.

Preferably an agitator 70 (Figs. 3 and 4), of the impeller or propeller type is mounted within the tank 13 on a shaft 71 extending through the end wall of the tank remote from the header 20, and is driven by a suitable motor and gearing within the housing 72. In the preferred form, the shaft 71 is alined substantially with the long axis of the cooling unit through the center of the elliptical cross section thereof, so that when the agitator is in operation it tends to force a stream of the liquid within the tank lengthwise through the cooling unit. The cooling unit offers only slight resistance to the flow of the liquid in this direction, since the flow is lengthwise of the tubes not across them, and this resistance is still further reduced if the sharp angular connections 46, 47 between the two tubes of each pass are used, as indicated in Figs. 3 and 5, rather than the return bends of Fig. 6. Hence extremely satisfactory and rapid cooling results from this arrangement, with the expenditure of a relatively low amount of power for agitation.

The elliptical outline of the header 20 is preferably slightly smaller than the similar elliptical outline of the manhole 17. At no point do any of the tubes 21 to 34, inclusive, as a group have any cross sectional outline larger than the elliptical outline of the header 20. Hence the entire tube assembly and header may be inserted endwise into the tank in completely assembled condition through the standard manhole 17. After the unit is inserted, it is placed in proper position with the inlet and outlet connections 55 and 56 extending through the small connection hole in the tank, and with the plate 58, which has been previously welded to the connections 55 and 56, in position to close this opening, as shown in Fig. 2. Then the outer plates 59 are put in position at the outer end of the connection hole, and the nuts are applied to and tightened on the bolts previously secured to the plate 58. The supporting post 51 is connected to the cooling unit to support the end thereof remote from the header 20, and the necessary conduit connections are made, externally of the tank, to the inlet and outlet of the unit, and this completes the installation of the cooling apparatus. It is seen that only a slight amount of work is required within the tank, and no parts whatever have to be assembled within the tank except the connection of the supporting post 51 to the tank and to the cooling unit, all other assembling operations being done exteriorly of the tank.

Another feature of the present invention is that the cooling unit is not mounted directly along the center line of the tank, but is mounted a little to one side of a vertical plane passing through the longitudinal axis of the tank, as indicated in Fig. 1. Hence, when it is necessary to clean the interior of the tank and the exterior of the cooling unit, a man may enter the tank, and may stand directly on the lowest part of the bottom thereof at the point where this bottom is approximately level, instead of being forced to stand on the more sloping part of the bottom, to one side of the central plane, as would be the case if the cooling unit were mounted directly along the central plane. Moreover, the tubes 28 and 29 are preferably spaced from each other a little farther apart than the other tubes, as indicated in Figs. 1, 4, and 8, to allow ample room between those tubes so that a person standing within the tank may insert a brush or other suitable implement through the space between these tubes to clean those sides of the tubes which are faced toward the center of the elliptical assembly.

Another important feature of the present invention is the interior construction of the tubes or conduits of the cooling unit. In cooling units of the type which obtain the cooling effect by boiling or volatilizing a liquid refrigerant, it has heretofore been generally believed that there should be only a very slight difference between the inlet pressure and the outlet pressure in order to obtain greatest efficiency. According to the present invention, however, greater efficiency may be attained if greater pressure differences are used, and if the internal construction of the passageway, tubes, or conduits is such that the refrigerant passes through them with relatively high velocity and keeps the inner surfaces of the tubes or passageways substantially completely or very largely covered by a film of unvaporized refrigerant in liquid phase. It is highly desirable to have relatively high velocity of flow even at or near the inlet end of the cooling unit. Yet, if the tubes forming the passageway or conduit be made sufficiently small to obtain the desired velocity of flow in the first part of the cooling unit, it is apparent that, with the conventional construction, tubes of the same size would be much too small at a further advanced point in the cooling unit, where the volume of refrigerant was much greater due to passage of a portion thereof from liquid phase to vapor phase. As formation of vapor continues, and the volume of the refrigerant very greatly increases, the velocity of flow would rise to excessive heights, if the cross sectional size of the passageway remained constant. Or, if the tubes were made large enough to accommodate the required volume of refrigerant at the outlet end of the unit, tubes of this same size would be much too large near the inlet end of the unit, resulting in sluggish and inefficient flow in this part of the unit.

One way of overcoming this difficulty, according to the present invention, is to provide successive tube sections of increasing size. Such an arrangement is not preferred under most circumstances, however, because usually it is desirable to have the various tubes of the cooling unit all of the same or approximately the same external diameter.

Hence, according to the preferred form of the present invention, the first few tubes are provided with what may be termed fillers inside the tubes, to reduce the cross sectional area of the passageway area available for flow of the refrigerant. For example, the two tubes 21 and 22 of the first pass or loop are provided with rods 81 of an external diameter slightly smaller than the internal diameter of these tubes. The next two tubes 23 and 24 constituting the second pass, are provided with rods 82 slightly smaller than the rods 81 so that a somewhat greater cross sectional area is available for flow of the refrigerant. The desired tapering effect, or increasing cross section of flow passage-

way, may be obtained even more smoothly and satisfactorily by winding these rods 81 and 82 with spirally arranged wires of gradually increasing pitch. Around the rod 81 in the tube 21 is wound a wire 85 of such size that it touches, or substantially touches, the inner wall of the tube 21. Thus the refrigerant cannot flow directly along the tube, but must flow spirally around and around the annular space between the rod and the tube, along the passageway defined by the wire. As shown plainly in Fig. 7, the wire starts off with a relatively small pitch, and this pitch gradually increases throughout the length of the rod 81, so that the cross sectional area of the passageway defined by the wire gradually increases throughout the length of this tube. Similarly, a wire 86 wound around the rod 81 of the tube 22 starts with a pitch about equal to the final pitch of the wire 85 at the discharge end of the tube 21, and the wire 86 gradually increases in pitch in the direction of flow, so that the cross sectional area of the flow passageway is gradually increased throughout the length of the second tube 22.

In the third tube 23, since the rod 82 is smaller, a larger wire 87 is used in order to fill the space between the rod and the tube. This wire 87 starts out with a relatively small pitch as shown in the drawings, which pitch gradually increases in the direction of flow. The wire 88 around the rod 82 in the tube 24 likewise has a pitch increasing in the direction of flow.

The wires 85, 86, 87, and 88 may be welded either continuously or at spaced intervals to the rods on which they are wound, before the rods are inserted in the ends of the tubes. Then the rods with the wires wound on them are put in the ends of the tubes before the tubes are set into and welded to the header 20.

This same construction, using smaller and smaller rods in the successive loops or passes, and wires of increasing pitch wound around the rods in each loop, may be used throughout all or any desired number of the loops or passes. If used throughout substantially all of the loops, however, this construction would usually result in tubes of undesirably large diameter, whereas it is usually preferred to employ tubes of relatively small diameter, which are much less expensive, especially when made of high priced materials such as stainless steel. Hence, in the preferred embodiment, the rod and spiral wire construction is employed only in the first two loops or passes of a total of seven loops, and a different construction is provided in the remaining loops.

The tubes 25 and 26 of the third pass or loop are preferably provided with deflecting means or baffle means to give the fluid a somewhat swirling or rotary action within the tubes as it flows along them, but without substantially decreasing the cross sectional area of the flow passageway. This baffle means or deflecting means is preferably in the form of a wire or small rod 90 wound spirally or helically and lying against the inner surface of the tube or conduit, to form, in effect, a spiral or helical ridge or fin projecting inwardly from the inner surface. This ridge or fin does not substantially decrease the available cross sectional area for flow of fluid through the tube, but it does offer just enough resistance to the flow of the fluid so that the fluid is caused to rotate or swirl in a spiral manner as it flows longitudinally through the conduit. Thus, as the refrigerant flows through the conduit, that part of the refrigerant which is in vapor phase, swirling around and around the inner circumference of the conduit, carries along with it that part of the refrigerant which is in liquid phase, keeping substantially the entire inner surface of the conduit coated with a film of liquid at all times. Were this deflecting baffle means not provided, the liquid refrigerant might run along the bottom part of the tube or conduit and only gas or vapor with substantially no liquid might be in contact with the upper part of the walls of the tube, with consequent reduction in efficiency.

The deflecting or baffle means might also be in the form of a strip of sheet metal or the like twisted spirally and placed within the tube or conduit, such spirally twisted strips being indicated in the alternative construction shown in Fig. 9 of the drawings. Usually, however, it is preferred to use a spirally extending wire or small rod, rather than a spirally twisted strip, because the wire or rod does not reduce the cross sectional area of the conduit to quite so great an extent, and does not increase the frictional resistance to flow to quite such an extent.

All of the tubes 25 to 34 inclusive of the remaining passes are preferably provided with spirally or helically arranged baffle or deflecting means such as above described, preferably in the form of the above mentioned spiral wire or small rod, although some may be of the spirally twisted strip form and others may be of wire or small rod form, if desired. For instance, if it is preferred to reduce the cross sectional area of the conduits of the third pass to some extent, but not to so great an extent as by the use of a filler rod 82, then the tubes or conduits of the third pass could be provided with the spirally twisted strips above mentioned, while the conduits or tubes of the fourth and succeeding passes could be of slightly greater effective cross sectional area by providing them with the wire or small rod form of baffle or deflector.

Because of the larger cross sectional area of the conduits 25 and 26 compared to the effective flow area of the conduit 24, the refrigerant will flow substantially slower through the first part of the conduit 25 than through the conduit 24, gradually increasing its rate of flow through the conduits 25 and 26 as additional liquid boils away and forms an increased volume of vapor. At the end of the third pass, that is, at the left hand end of the tube 26 when viewed as in Fig. 7, the velocity of flow has preferably been brought up to about the velocity obtaining at the end of the tube 24.

The velocity of flow will be further increased in the next or fourth pass made up of the conduits 27 and 28, and in each succeeding pass, due to boiling off of additional refrigerant from liquid phase to vapor phase, unless means is provided for counteracting this tendency of the velocity to increase. Such means may or may not be provided, depending on the results desired. When such means is desired, it may take the place of by-pass openings across the ends of the passes so that more or less of the refrigerant will be bypassed along the header 20 instead of flowing through the full length of each pass.

Such by-pass openings across the fourth loop or pass formed of the tubes 27 and 28, are shown at 93 in Fig. 7. These openings 93 are formed in the partition-like ends of the tubes 27 and 28 within the header 20, so that part of the refrigerant may pass through the opening 93 in the tube 27, thence a short distance along the header 20, and through the opening 93 in the next tube

28, to meet the other portion of refrigerant which has flowed around the full length of the pass 27—28.

Similar by-pass openings 95 may be formed in the tubes 29 and 30 of the fifth pass, and similar openings 97 may be formed in the ends of the tube 31 and 32 of the sixth pass.

The sizes of the respective by-pass openings will depend upon the conditions desired. If it is preferred to have the velocities of flow at the ends of the fourth, fifth, and sixth passes approximately equal to each other and approximately equal to the velocity of flow at the end of the third pass, then the respective by-pass openings 93, 95, and 97 should be of such sizes as to by-pass just enough of the refrigerant to compensate for the increasing volume of refrigerant through these respective passes. If it is desired to have the velocity of flow decrease progressively, so that it is slower at the end of the sixth pass than at the end of the fifth, and slower at the end of the fifth than at the end of the fourth, etc., then the by-pass openings would be still larger than the sizes required to compensate for the increasing volumes of refrigerant. Such a decrease in velocity from one pass to another is seldom desired.

If it is desired to have the velocity of flow increase somewhat from the end of one pass to the end of the next, so that at the end of the fourth pass the velocity is greater than at the end of the third pass, and at the end of the fifth pass greater than at the end of the fourth, etc., then the by-pass openings either would be omitted entirely, as is frequently permissible, especially in small cooling units, or would be made somewhat smaller than the size required to compensate fully for the increasing volume of refrigerant. The judgment of the designing engineer, rather than any set rule or formula, should be the guide in determining whether or not to use any by-passes, and in determining the sizes of the by-passes to be used. If by-passes are used, the determination of the sizes of the by-pass openings must take into account the greater friction caused by flow throughout the entire length of one pass or loop, than the friction of flow through the much shorter by-pass path across the end of the pass or loop.

With a cooling unit having passes or loops of one certain size and length, it is found that by-pass openings having a cross sectional area about 15% of the total cross sectional area of the pass or loop will approximately compensate for the increase in velocity which would otherwise be caused by boiling off of refrigerant within that pass or loop. With this particular size of pass, the by-pass openings 93 might have an area of about 15% of the area of the tubes 27 and 28, the by-pass openings 95 might have an area of about 30% of such tube area, and the by-pass openings 97 might have an area of about 45% of such tube area, and the velocity of flow in the latter part of the tube 32, just before reaching the header 20, would then be about equal to the velocity of flow at the end of the tube 26. These same areas of by-pass openings would give different results, however, with tubes of different length or characteristics, and hence they must be taken merely as an illustration of one particular embodiment of the invention, rather than as a limitation or as a definite guide for constructing other embodiments.

By-pass openings 99 may also be provided, if desired, through the ends of the tubes 33 and 34, constituting the last or seventh pass or loop. The sizes of these by-pass openings would again depend upon the judgment of the designing engineer and the results which he wishes to obtain. Frequently it is preferred to use no by-pass at all across the last loop, even through by-passes may be used across some of the preceding loops, because a by-pass across the last loop will frequently allow some liquid refrigerant to pass through this by-pass, so that the refrigerant will not be completely vaporized in the unit. Greater efficiency of vaporation would be attained, therefore, by using no by-pass across the last loop. But this greater efficiency of vaporation would be at the expense of perhaps slightly less efficiency of cooling, because there would be greater back pressure if no by-pass were provided, with consequent slower velocity of flow through the unit. Frequently it is desirable to use a relatively small by-pass across the last loop or pass, smaller than the size which would theoretically be used at this point, in order to increase somewhat the rate of flow without letting too much liquid refrigerant pass through the by-pass. If no by-pass is used, practically all of the remaining liquid refrigerant will usually be vaporized in the last pass.

With the foregoing construction a highly satisfactory cooling unit is provided. The high rate of flow in comparison to the very sluggish flow of refrigerant through conventional cooling units greatly increases the cooling capacity by raising the rate at which heat may be transferred through the conduit or tube walls to the refrigerant. A high rate of flow has the further and important advantage that the liquid refrigerant is carried along with the gas or vapor by reason of the rapid movement of the latter so that the liquid does not form concentrated masses nor remain stagnant in the lowest part of the system, but is positively forced or carried along at all times. If any oil becomes mixed with the refrigerant, it does not collect and remain in the system, blanking off the heat exchanging area thereof and reducing the efficiency of the cooler, but the oil, like the liquid refrigerant, is carried along through the apparatus by the rapid flow of gas or vapor.

Due to the spiral or helical construction, both around the filler rods 81 and 82 and around the inner surfaces of those conduits or tubes which do not have filler rods, the rapidly flowing gas swirls around in such manner that the liquid refrigerant is constantly carried over the entire inner surface of the tubes, at the top sides as well as bottom sides thereof, so that a layer of liquid refrigerant coats substantially the entire inner surface of the tubes at all times, promoting a maximum degree of cooling. The spiral or swirling action helps to keep the liquid broken up into more or less of a spray of small particles, but if any substantial masses or concentrations of the liquid should form, notwithstanding the swirling action, these bodies of liquid would be quickly broken up into a spray, or into much smaller bodies, by the sharp corners or bends with which they would come into violent contact. The sharp corners formed at the junction of the two tubes at their ends remote from the header are particularly efficacious in breaking up bodies of liquid, and the right angle bends formed by the junction of the header and the tubes also are very helpful in breaking up bodies of liquid.

While the velocity of flow may vary to a considerable extent depending upon the judgment of the designing engineer, it is believed preferable in most cases that the velocity of flow should be not less than about 200 feet per minute, and pref-

erably about 400 feet per minute, in the first tube of the first pass or loop, and this should be raised to a vapor speed of not less than about 2000 feet per minute and preferably a speed of about 3600 feet per minute at the end of the last tube of the last loop.

As previously stated, the inlet and outlet connections of the header 20 are arranged so that through about the first three loops or passes the refrigerant flows in an uphill direction, and thereafter the refrigerant flows in a downhill direction. This is advantageous because, with this arrangement, some of the unvaporized or liquid refrigerant will be constantly running forward through the by-passes 93, 95, and 97 to supply adequate liquid refrigerant to the last few passes.

The outlet of the cooling unit is preferably connected to a back pressure valve set for a pressure of about forty-five pounds to the square inch. The inlet is provided with either a hand operated or automatically operated inlet valve arranged to give maximum cooling capacity. Usually the refrigerant will be supplied under a pressure of, say ninety to one hundred and fifty pounds to the square inch. The above mentioned pressures and velocities are those found most satisfactory when ammonia is used as the refrigerant, and some readjustment of pressures and velocities may be desirable if other volatile refrigerants are used, such as methylchloride, sulphur dioxide, Freon, etc.

The preferred embodiment illustrated by way of example in Figs. 1 to 8, inclusive, is an embodiment in which the cooling unit is intended to be immersed in the milk, water, or other liquid which is to be cooled. As previously stated, the principles of the present invention may be applied equally well to a cooler of the surface type rather than the immersion type, and such a surface cooler may be of the form illustrated by way of example in Fig. 9. Here, two substantially vertical headers 111 and 112 are employed. Any desired number of tubes or conduits may be used, twelve being here shown, numbered from 121 to 132 inclusive. Each of these tubes extends approximately horizontally and has one end connected to one header and the other end connected to the other header. As in the previous embodiment, the connection may conveniently be made by providing holes in the headers of the proper size to receive the tubes, the exterior diameters of the tubes being approximately equal to the internal diameters of the headers. The ends of the tubes projecting into the headers, are cut diagonally, as shown, so that these projecting ends of the tubes form partitions in the headers.

The refrigerant may pass through the various tubes in any desired order, but preferably starts at a tube somewhat below the top of the unit, flows upwardly to the top, and then downwardly through the remaining tubes. For example, the inlet 140 may enter the header 111 near the end of the tube 121, which is the fourth tube from the top. A partition 141 in the header 111 just below the inlet prevents the refrigerant from escaping downwardly in the header, while the end of the tube 121 itself forms a partition preventing the refrigerant from escaping upwardly. Hence the refrigerant must flow into and through the tube 121. From the right hand end of the tube 121, when viewed as in Fig. 9, the refrigerant flows into the header 112, up this header a short distance into the right hand end of the tube 122, then leftwardly along the tube 122 to the header 111, upwardly through this header to the left hand end of the tube 123, and along this tube 123 to the header 112. Here, the refrigerant again passes upwardly through a short section of the header 112, enters the right hand end of the top tube 124, and flows leftwardly through it, this time not to the header 111, but to the end of a conduit 145 which conveys the refrigerant downwardly to a point in the header 111 just below the partition 141. Here, the refrigerant enters the end of the tube 125, which is the next tube below the tube 121. Then the refrigerant flows through the tube 125 to the header 112, down through this header to the next tube 126, leftwardly through the tube 126 to the header 111, and so on successively through the tubes 127 to 132, finally issuing from the left hand end of the tube 132 into the bottom of the header 111, and then into the outlet connection 148. This outlet connection is provided with a suitable back pressure valve 150 and the inlet connection 140 is provided with an inlet valve 155 which may be controlled automatically by a temperature control including the heat responsive element 156 adjacent the outlet 148.

The interior construction of the tubes in this form of cooler may be the same, or substantially the same as that previously described in connection with the previous embodiment. For example, the first two tubes 121 and 122 may both be provided with filler rods 160 around which wires 161 and 162 are wound spirally or helically, with gradually increasing pitch, in a manner similar to the wires 85 and 86 in the previous embodiment. The next two tubes 123 and 124 may be provided with smaller filler rods 164, wound with larger wires 165 and 166 of gradually increasing pitch similar to the wires 87 and 88 previously described. The other tubes 125 to 132, inclusive, may omit the filler rods, but preferably are provided with baffle means or deflecting means for causing spiral or rotary swirling of the refrigerant passing through these tubes. This baffle or deflecting means may be in the form of a spirally wound wire or small rod like the wires or rods 90 in the previous embodiment, or may be in the form of spirally twisted strips 170.

As before, by-pass means may or may not be employed, according to the judgment of the designing engineer. If by-passes are desired, there may be a by-pass 172 between the tubes 127 and 128, and a by-pass 174 between the tubes 129 and 130.

The milk, water, or other liquid to be cooled may be caused to flow over all or any suitable part of the surface of the tubes 121 to 132 inclusive. For instance, a tank or hopper may discharge liquid onto the top of the uppermost tube 124, and after the liquid has flowed down the sides of the tube a fin 180 depending from the bottom edge of the tube may direct the liquid onto the top of the next lower tube 123. Similar fins 180 may be provided on the bottom edges of each of the tubes so that the liquid to be cooled flows in succession from each tube down its fin into the top of the tube below, the cooled liquid finally being caught in a suitable receptacle or trough beneath the bottom of the last tube 132.

This surface type of cooling unit may be either open or enclosed in a suitable housing. Its internal operation is substantially the same as that previously described in connection with the first embodiment.

While certain embodiments of the invention have been disclosed, it is to be understood that

the inventive idea may be carried out in a number of ways. This application is therefore not to be limited to the precise details described, but is intended to cover all variations and modifications thereof falling within the spirit of the invention or the scope of the appended claims.

I claim:

1. Refrigerating apparatus comprising conduit means forming a passageway for flow of a refrigerating agent having a tendency to pass from liquid phase to gaseous phase as heat is absorbed, said passageway having filler means therein of less cross sectional area than the area of said passageway, deflecting means arranged generally spirally around said filler means, and means for supplying a refrigerating agent at least partially in liquid phase to said passageway at one end thereof at a pressure substantially higher than that existing at the other end of said passageway so that said refrigerating agent will flow rapidly along said passageway and that part thereof which remains in liquid phase will be deflected during its flow, by said deflecting means, so as to spread over substantially the entire perimeter of said passageway.

2. Refrigerating apparatus for use with a refrigerating agent having a tendency to pass from liquid phase to gaseous phase as heat is absorbed, said apparatus comprising means forming a circuitous passageway having a plurality of convolutions through which said refrigerating agent flows, means for supplying said refrigerating agent at least partly in liquid phase to one end of said passageway at a pressure sufficiently higher than that existing at the other end of said passageway so that said agent will flow relatively rapidly through said passageway, and by-pass means of restricted cross sectional area for by-passing a portion of said refrigerating agent in liquid phase past one of said convolutions so that it may be effective to pass into vapor phase and absorb heat in a subsequent convolution.

3. Refrigerating apparatus for use with a refrigerating agent having a tendency to pass from liquid phase to gaseous phase as heat is absorbed, said apparatus comprising means forming a circuitous passageway having a plurality of convolutions through which said refrigerating agent flows, means for supplying refrigerating agent at least partly in liquid phase to one end of said passageway at a pressure sufficiently higher than that existing at the other end of said passageway so that said agent will flow relatively rapidly through said passageway, by-pass means of one cross sectional area for by-passing a portion of said refrigerating agent partly in liquid phase past one of said convolutions, and by-pass means of a substantially different cross sectional area for by-passing a portion of said refrigating agent partly in liquid phase past another of said convolutions so that the portion of the by-passed agent which is in liquid phase may be effective to pass into vapor phase and absorb heat in a subsequent convolution beyond the one past which it is by-passed.

4. The combination with a liquid container, of conduit means within said container for carrying fluid in heat exchanging relationship to liquid in said container, said conduit means including a plurality of sections arranged approximately parallel to each other and grouped around a central free space, and propeller agitating means within said container and beyond one end of said grouped sections and approximately alined with said central free space to tend to drive liquid within said container in a general direction through said free space and along said conduit sections.

5. The combination with a container, of an elongated fluid coil within said container, said coil having header means adjacent one end thereof, fluid supply means extending from said header means through a wall of said container and serving also to support one end of said coil, and supporting bracket means adjacent the opposite end of said coil from said header means and connecting said opposite end of said coil to a wall of said container to support said opposite end of said coil, said bracket means being relatively flexible in a direction lengthwise of said coil and relatively inflexible in a direction transversely of said coil.

6. The combination with a container having an approximately cylindrical portion arranged with its axis approximately horizontal, of elongated coil means mounted within said container adjacent the bottom thereof and with the long dimension of said coil means extending approximately parallel to said axis, said coil means being formed of a plurality of conduit sections extending approximately parallel to each other through the major portion of the length of said coil means and grouped around a central free space, at least two of said conduit sections being laterally spaced sufficiently far from each other so that lateral access may be readily obtained to said central space for cleaning those exterior surfaces of said conduit sections which are faced toward said central space, said coil means being offset laterally from a vertical plane passing through said axis so that a person may, without substantial interference from said coil means, stand within said container at the lowest point of the bottom thereof to clean said container or said coil means.

7. Cooling means comprising a series of conduit sections extending substantially horizontally and arranged one above another in a substantially vertical plane, means for supplying a cooling agent to one end of one of said sections at an intermediate height in the series of sections, means connecting that section to the sections above it so that the supplied cooling agent flows successively through that section and the sections above it to the topmost section, means connecting the discharge end of the topmost section to one end of the section next beneath the one to which the cooling agent was initially supplied, and means for connecting said next beneath section to the sections below it so that said cooling agent will flow from said topmost section to said section next beneath the one to which the cooling agent was initially supplied and successively through all of the sections below it down to the lowermost section.

8. In refrigerating apparatus wherein a refrigerant is circulated through a refrigeration circuit having a high pressure and low pressure side, a conduit constituting part of the low pressure side of said circuit into which the refrigerant is passed from the high pressure side, means for vaporizing a portion of the refrigerant adjacent the inlet end of the conduit to cool the refrigerant in liquid phase down substantially to the vaporization point at the pressure of the inlet end, said conduit having a substantially uniform external size throughout a portion of its length, means in said conduit cooperating with the walls thereof to form a channel of a cross-sectional area increasing in the direction of flow throughout said same portion of the length of the conduit, and means for flowing the refrigerant

through the conduit at high velocity throughout substantially its entire length.

9. In refrigerating apparatus wherein a refrigerant is circulated through a refrigeration circuit having a high pressure and low pressure side, a conduit constituting part of the low pressure side of said circuit into which the refrigerant is passed from the high pressure side, means for vaporizing a portion of the refrigerant adjacent the inlet end of the conduit to cool the refrigerant in liquid phase down substantially to the vaporization point at the pressure of the inlet end, said conduit having a substantially uniform external size throughout a portion of its length, means in said conduit cooperating with the walls thereof to form a channel of a cross-sectional area increasing in the direction of flow throughout said same portion of the length of the conduit, means for flowing the refrigerant through the conduit at high velocity throughout substantially its entire length, and means in said conduit for causing the refrigerant to flow therethrough in intimate contact with substantially the entire inner wall thereof throughout said same portion of the length of the conduit.

10. In refrigerating apparatus wherein a refrigerant is circulated through a refrigeration circuit having a high pressure and low pressure side, a conduit constituting part of the low pressure side of said circuit into which the refrigerant is passed from the high pressure side, means for vaporizing a portion of the refrigerant adjacent the inlet end of the conduit to cool the refrigerant in liquid phase down substantially to the vaporization point at the pressure of the inlet end, said conduit having a substantially uniform external size throughout a portion of its length, means in said conduit cooperating with the walls thereof to form a channel of a cross-sectional area increasing in the direction of flow throughout said same portion of the length of the conduit, means for flowing the refrigerant through the conduit at high velocity throughout substantially its entire length, and means in said conduit for causing the refrigerant in liquid phase to flow through said same portion of the length of the conduit with a whirling motion in intimate contact with substantially the entire inner wall thereof.

11. In refrigerating apparatus wherein a refrigerant is circulated through a refrigeration circuit having a high pressure and a low pressure side, a conduit constituting part of the low pressure side of said circuit into which the refrigerant is passed from the high pressure side, means for vaporizing a portion of the refrigerant adjacent the inlet end of the conduit to cool the refrigerant in liquid phase down substantially to the vaporization point at the pressure of the inlet end, said conduit having two tubular portions through which the refrigerant successively flows, both of said portions being of the same cross-sectional dimensions, filler means of substantially different cross-sectional dimensions within said two portions cooperating with the walls thereof to form channels, the filler means in the second portion being of substantially smaller cross-sectional dimensions than the filler means of the first portion to allow a larger cross-sectional space for flow of said refrigerant through said second portion than through said first portion, deflecting means extending generally spirally around the filler means in at least one of said portions, and means for flowing the refrigerant through the conduit at high velocity throughout substantially its entire length.

12. Cooling apparatus comprising a coil for flow of a cooling agent therethrough, said coil including a generally ring-shaped header tube having a series of openings therein, a series of tubes extending laterally with respect to said header tube and being approximately parallel to each other and grouped around a central free space, each of said tubes having an end extending into said header tube through one of said openings and forming a substantially fluid tight connection with said header tube around the opening through which the tube extends, and means operatively connecting said tubes to each other in pairs at points remote from said header tube.

13. The method of operating a refrigerating system having a section of a cooling coil, said method including the steps of maintaining the refrigerant under a substantial pressure to maintain the refrigerant in liquid phase, passing the refrigerant into said coil section with an appreciable drop in pressure to thereby vaporize a portion of the refrigerant and cool the refrigerant in liquid phase to substantially its vaporization point at the pressure of the inlet end of the coil section, restricting the cross-sectional area of the stream of the refrigerant at the inlet end of the coil section so that a relatively rapid rate of flow is maintained at said inlet end to thereby avoid stagnant pools of refrigerant adjacent said inlet end, maintaining such a high rate of flow of refrigerant throughout the coil section as to prevent the formation of stagnant pools of liquid refrigerant therein, causing the liquid component of the stream to flow through a large portion of the coil section in contact with substantially the full circumference of the inner wall of such portion, and increasing the cross-sectional area of the stream substantially uniformly and progressively in the directional flow throughout a substantial length of said section as the volume of refrigerant in vapor phase increases.

14. The method of operating a refrigerating system having a section of a cooling coil, said method including the steps of maintaining the refrigerant under a substantial pressure to maintain the refrigerant in liquid phase, passing the refrigerant into said coil section with an appreciable drop in pressure to thereby vaporize a portion of the refrigerant and cool the refrigerant in liquid phase to substantially its vaporization point at the pressure of the inlet end of the coil section, maintaining such a high rate of flow of refrigerant throughout the coil section as to prevent the formation of stagnant pools of liquid refrigerant therein, causing the liquid stream of refrigerant to flow through at least a portion of the coil section at said high rate with a whirling motion so that the portion of the stream of refrigerant in liquid phase is maintained adjacent substantially the full circumference of the inner side walls of the coil in intimate contact therewith by centrifugal action, and increasing the cross-sectional area of the stream substantially uniformly and progressively in the directional flow throughout a substantial length of said section as the volume of refrigerant in vapor phase increases.

OTTO W. GREENE.