

March 23, 1943.

W. JONES

2,314,402

REFRIGERATION

Filed June 20, 1940

2 Sheets-Sheet 1

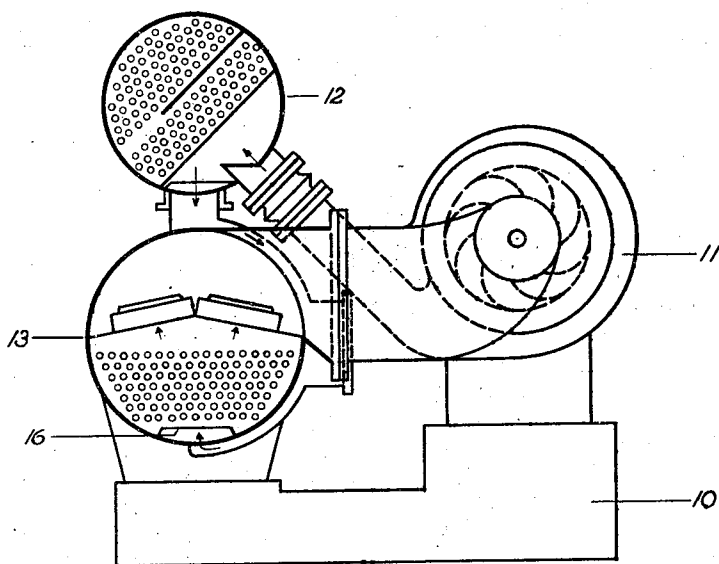


Fig. 1

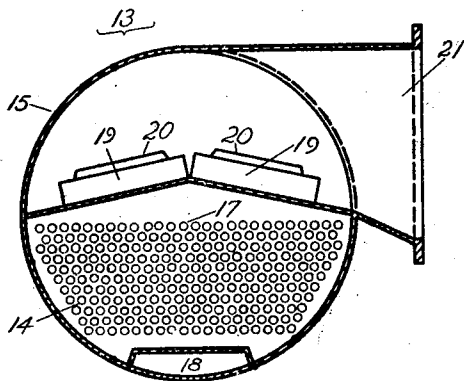


Fig. 2

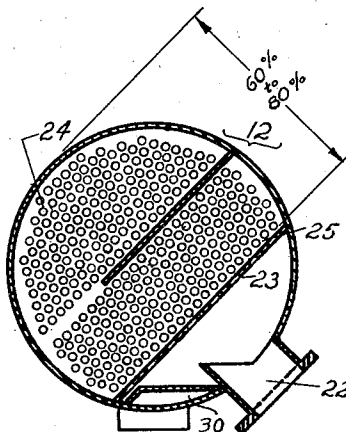


Fig. 3

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2 Sheets-Sheet 2

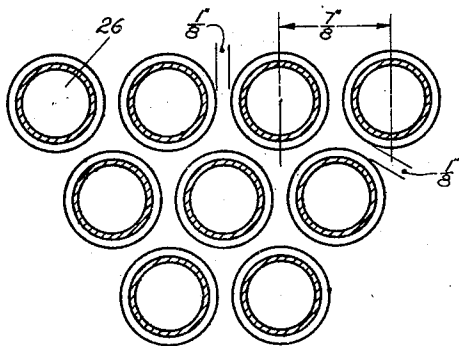


FIG. 4

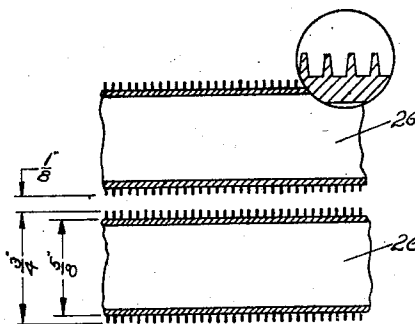


FIG. 5

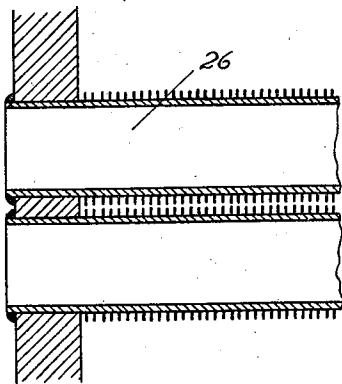


FIG. 6

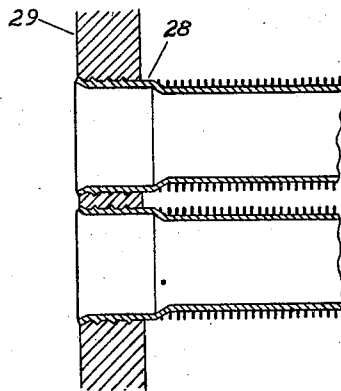


FIG. 7

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2,314,402

REFRIGERATION

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Application June 20, 1940, Serial No. 341,513

5 Claims. (Cl. 62—115)

This invention relates to refrigeration and more particularly to methods and means for increasing the efficiency and capacity of refrigeration systems by increasing the capacity and efficiency of evaporators or coolers and condensers employed in such systems.

The problem, in connection with refrigeration machines, of providing adequate cooler and condenser surfaces, has in the past, presented numerous difficulties. While compressors have been satisfactorily developed for producing refrigerating effect measured in large tonnages, the art has not heretofore been able economically to keep pace with this compressor development, because of deficiency in cooler and condenser design and construction. In actual practice, it has been customary to provide a number of tubes within a shell, to be used either as a cooler or condenser. While differences in function caused different shell and tube structures to be employed, the essential difficulty was not overcome in that the use of plain tubes resulted in limiting the capacities or else caused the shell and tube structures to be inordinately large and expensive. While the art appreciated that tubes might be used with fins or extended surface, the use of Aerofin type tubes was not satisfactory since the spaces between tubes, and the spacing on tubes, within the limitations of the finning process, would not result in an efficient structure. Besides, the problem of removing such finned tubes from the shells had not been satisfactorily solved, since the tube ends when rolled to a diameter which exceeded the tube plus fin would have thin and weak walls often making them unfit for further use when removed from a shell. As a result, finned tubes have not been satisfactorily used in practice; while the use of plain tubes closely nested together has limited the efficiency and capacity of the refrigeration system in which they were employed.

Applicant has solved the problem by enabling the surface area in such coolers and condensers to be greatly increased without proportionately increasing the size of the cooler and condenser shells themselves. In addition, applicant has provided a surface ratio between the inside surface of a tube and the outside surface which, in combination with a novel method of stacking the tubes and in arranging the tubes in a predetermined section of a shell, results in a revolutionary increase in capacity never before achieved.

A feature of the invention covers the use of metal extruded from the surface of a tube to provide a desired configuration on the surface of the

tube. Such extrusion may be accomplished by apparatus disclosed, for example, in U. S. Patent 1,865,575. This not only results in a correct ratio between inside and outside tube surface, but also promotes exceedingly efficient heat exchange because the film resistances are reduced to a minimum. The extruded surfaces are comparatively small in height compared to the finned surfaces heretofore produced, for example, by the Aerofin process. Consequently, applicant efficiently utilizes tubes substantially of the same diameter as the plain tubes heretofore used and can nest them so closely together that the space in a shell is used to maximum advantage and efficiency in heat exchange greatly increased compared to that achieved with other types of tubes having equal inner or outer surface areas. No previous type of tubes have been built employing equivalent inner and outer surface areas in the same tube or having equivalent inner and outer surface ratios.

The use of such tubes of small diameter closely nested together not only reduces the size of coolers and condensers required to produce desired refrigerating effect, but consequently reduces the refrigerant charge required. The combination of closely packed tubes, following applicant's pattern of stacking and applicant's surface ratios, as well as applicant's specification of extruded surfaces, enables submergence losses to be held to a minimum, while at the same time permits a ratio between liquid and surging gas which promotes maximum effectiveness of heat exchange.

These and other advantages will be more apparent from the following detailed description of applicant's invention, setting forth his specification of shell and tube structures, to be read in connection with the accompanying drawings in which:

Fig. 1 illustrates diagrammatically a refrigeration system including cooler and condenser structures incorporating applicant's invention;

Fig. 2 is a sectional view of a cooler of the type used in the system of Fig. 1;

Fig. 3 is a sectional view of a condenser of the type used in the system of Fig. 1;

Fig. 4 is a fragmentary view in section of a series of tubes illustrating the manner of stacking of the tubes in the cooler and condenser structures of Figs. 1, 2 and 3;

Fig. 5 illustrates the interpositioning in a cooler or condenser structure of two adjacent tubes formed in accordance with applicant's invention;

Fig. 6 illustrates the interpositioning in a cooler or condenser structure of two adjacent tubes formed in accordance with applicant's invention,

in which the ends are directly soldered into a tube sheet; and

Fig. 7 illustrates two such tubes having belled ends rolled within a tube sheet.

Considering the drawings, similar designations referring to similar parts, numeral 10 illustrates a base on which are suitably mounted compressor 11, condenser 12 and evaporator or cooler 13.

The compressor is driven by a suitable motor, turbine or other driving means, not shown, and serves to compress a suitable refrigerant, which is discharged to condenser 12 where the refrigerant is liquefied, and then delivered to cooler or evaporator 13 and finally returned to the compressor in the usual refrigeration cycle. Since such cycle is well understood by those skilled in the art, no detailed description of the construction of the compressor and associated elements is required to an understanding of the invention which relates primarily to the condenser and cooler structures.

Considering cooler 13, a plurality of tubes 14 are stacked or nested in the lower portion of shell 15. With tubes formed in accordance with applicant's invention, optimum results will be achieved if the tube nest in shell 15 extends from above refrigerant distributing plate 16 to an upper tube line 17 situated forty to fifty per cent of the height of the shell above the bottom thereof. In practice, refrigerant in liquid form enters distribution channel 18 and through spaced openings in the sides of channel plate 16 enters the shell proper. Under load conditions, the refrigerant becomes a turbulent mixture of gas and liquid due to the heat exchange between the liquid to be cooled within the tubes 14 and the refrigerant surrounding the tubes. The gas rising above the tube level line 17 passes through eliminators 19, where entrained liquid refrigerant is removed, then through perforated pressure equalization plates 20, and finally entering the compressor through suction intake 21.

The refrigerant gas, after compression, enters condenser 12 through conduit 22, is diverted by dispersion baffle 23 and then impinges against the outer surfaces of tubes 24, through which a suitable cooling fluid is circulated. With tubes formed in accordance with applicant's invention, optimum results will be achieved if the tube nest in shell 12 is positioned substantially as illustrated and lower tube line 25 is located a distance between 60-80% of the diameter of the shell from an extremity thereof. The baffle shown located within the tube bundle in the condenser extends about two-thirds of the distance across the shell and thereby serves to increase the velocity of the gas over a major part of the tube bundle by increasing the length of travel. The baffle provides a quiet zone thereabove, wherein the non-condensibles are collected. Since turbulence and velocity are at a minimum in this upper zone, the concentration of non-condensibles therein is facilitated and diffusion thereof mitigated.

The suction intake should be indicated by 21 instead of 20.

Baffle 30 shown at the bottom of the condenser serves to avoid bypassing of refrigerant from conduit 22.

The problem in the cooler and condenser is to promote heat exchange between the fluid in the tubes and the refrigerant surrounding the tubes at a maximum rate and with a maximum utilization of space and minimum refrigerant charge.

The rate of heat transfer through tubes 14 and

24 depends in great measure on the refrigerant film resistance. This resistance is radically reduced by applicant by providing a concentration of surface area on the outside of the tubes so that the ratio between outside tube surface area and inside tube surface area is in the neighborhood of 3.5. In addition, the stacking of tubes as illustrated in Figs. 2, 3 and 4 results in a concentration of heat exchange surface making for practical maximum efficiency. Applicant has found that his desired ratio of outside to inside tube surface area can best be obtained by using a tube with an outside diameter between $\frac{3}{8}$ " to 1" having extruded surfaces, preferably in the form of extruded fins eight to forty to the inch, said extruded fins being .020" to .125" in height. The tube ends are belled, preferably as described in copending application Serial No. 340,328 filed June 13, 1940, so that the tubes are removable from the evaporator and condenser shells. In one preferred form of the invention, applicant provides a series of tubes 26, whose nominal outside diameter is $\frac{5}{8}$ ". The thickness of the tube wall is .049". Each of the tubes has 16 fins to the inch, each fin being $\frac{1}{8}$ " in height making an overall outside diameter of $\frac{3}{4}$ ". The spacing between adjacent tubes is $\frac{1}{8}$ " so that the tubes are interpositioned on $\frac{7}{8}$ " centers. Each fin is about .020" thick at the bottom and about .010" thick at the top, although the limits of fin thickness at the bottom may be between .015" to .020" while the limits of fin thickness at the top may be between .007" to .010".

The dimensions, surface ratios, and manner of stacking tubes as aforesaid are particularly adapted for use with low pressure refrigerants having high specific densities. However, high pressure refrigerants will give advantageous results, under comparable operating conditions, as for example when used to produce low temperatures as in operations requiring below freezing conditions.

Applicant's arrangement of evaporator tubes, stacked as illustrated in Figs. 2 and 4, enables the refrigerant charge to be employed most effectively with submergence losses reduced to a minimum. By utilizing an area whose upper level is approximately 45% of the height of the evaporator shell, the tube bundle is reduced to a practical minimum which facilitates optimum turbulence and velocity of refrigerant over the tube surfaces. The escape of gas is very rapid and undesirable and unequal accumulations of gas, as might be the case with a tube bundle of greater height, are reduced to a minimum.

Of further importance, applicant's stacking as shown in Figs. 2 and 4 prevents excessive velocities of gas through the tube bundle which otherwise will wipe away liquid from the tube surface and reduce the heat transfer effect.

In other words, the stacking is an important factor in promoting necessary turbulence to produce maximum heat exchange with minimum submergence losses while limiting the velocity of the gas to prevent undesirable sweeping away of liquid refrigerant from the outside tube surfaces.

The same surface ratios, extruded fin construction and stacking arrangement result in exceedingly effective condenser action too, giving more than two and one-half times the rate of heat transfer compared to former condenser structures employed for equivalent uses. The utilization of tubes designed as aforesaid, in an area in the condenser shell approximately 60 to 80% of

the diametral height of the shell results in speedy condensation, with the production of a gas velocity sufficient in this case to wipe away non-condensable gases from the outer surfaces of the tubes.

While applicant's tubes 26 may be directly soldered within a tube sheet 29, and in this case the tubes could be interpositioned with the fins of adjacent tubes almost touching, applicant prefers to provide belled ends 28, to be rolled into tube sheet 29, to facilitate replacement of tubes, whereupon the spacing between fins of adjacent tubes would be $\frac{1}{8}$ ".

Since certain changes in carrying out the above method of operation and in the constructions set forth, which embody the invention may be made without departing from its scope, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a refrigeration system of the character described, an evaporator shell, a tube bundle within the evaporator shell, the tubes in said bundle having extrusions on the outer surface thereof, said extrusions being in the form of fins, the ratio between the outside tube surface area and inside tube surface area being more than three to one, the inside cross-sectional area of the evaporator shell in which said tube bundle is located being substantially forty to fifty percent of the total inside cross-sectional area, means for admitting liquid refrigerant at the bottom of the shell upwardly through the tube nest, and means above the tube nest for withdrawing evaporated refrigerant therefrom for delivery from the shell.

2. In a refrigeration system of the character described, a condenser shell, a tube bundle within the condenser shell, the tubes in said bundle having extrusions on the outer surface thereof, said extrusions being in the form of fins, the ratio between the outside tube surface area and inside tube surface area being more than three to one, the inside cross-sectional area of the condenser shell in which said tube bundle is located being over sixty percent of the total inside cross-sectional area, means at the bottom of the shell for removing condensed refrigerant from the shell, and an inlet arrangement proximate the bottom of the shell for admitting refrigerant in gaseous form for passage upwardly through the tube nest.

3. In a refrigeration system of the character described, a shell structure, a tube bundle within the structure, means for passing a fluid through the tubes, means for routing refrigerant in con-

tact with the outside surfaces of the tubes, each tube having extended surfaces in the form of fins extruded from and extending from the outside thereof, said surfaces extending approximately one sixteenth inch in height from the tube and forming an aggregate outside surface bearing a ratio with respect to the inside surface of the tube of over two to one, said tubes being interpositioned in stacks between an intake opening and a discharge opening whereby a low pressure refrigerant having a high specific density will be in turbulent condition substantially throughout the bundle and be substantially free of submergence losses.

4. In a refrigeration system of the character described, a shell structure, a tube bundle within the structure, means for permitting the passage of refrigerant upwardly in contact with the outside surfaces of the tubes, the tubes having extended surfaces in the form of fins extruded and extending from the outside thereof, said surfaces extending approximately one-sixteenth inch in height above the tube and forming an aggregate outside surface bearing a ratio with respect to the inside surface of the tube of approximately three to one, said tubes being stacked between an inlet adjacent the bottom of the shell and the top of the shell filling the greater part of the interior of the shell, the tubes being interpositioned in such manner that a low pressure refrigerant having a high specific density may have a velocity sufficiently high to sweep away non-condensable gases from the outside surfaces of the tubes in its passage upwardly through the tube bundle.

5. In a refrigeration system of the character described an evaporator shell, a condenser shell, a tube bundle in each of the shells, the tubes of said bundles having extended surfaces in the form of fins extruded and extending from the outside thereof, a charge of low pressure refrigerant having a high specific density within the system, individual inlet arrangements in combination respectively with said shells whereby liquid refrigerant will be admitted into the evaporator shell upwardly through the bundle therein and gaseous refrigerant will be admitted into the condenser shell upwardly through the bundle therein, said tubes each having a ratio between outside and inside surfaces thereof so that the system may operate at maximum efficiency when the tubes in the evaporator shell occupy substantially forty to fifty percent of the inside cross-sectional area of the evaporator shell and the tubes in the condenser shell occupy over sixty percent of the inside cross-sectional area of the condenser shell.

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