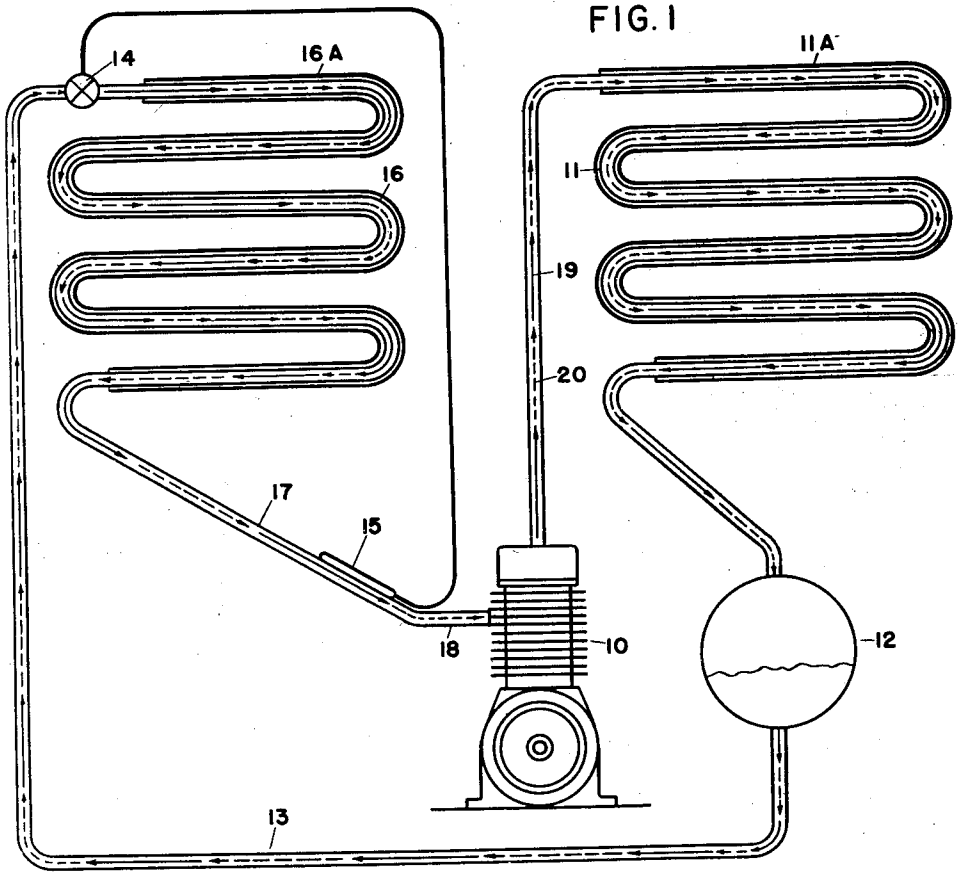
Dec. 27, 1949 C. M. ASHLEY 2,492,725

MIXED REFRIGERANT SYSTEM

Filed April 9, 1945

FIG. 1



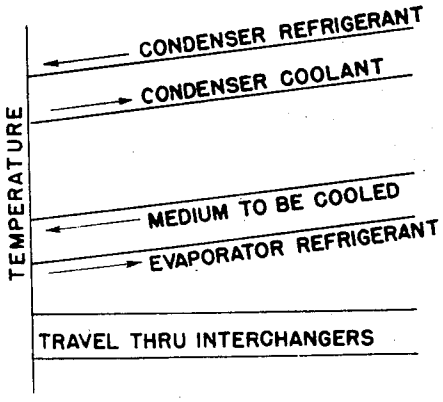


FIG. 2

INVENTOR.
Carlyle M. Ashley
BY Thurston Bird
Attorney

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MIXED REFRIGERANT SYSTEM

Carlyle M. Ashley, Fayetteville, N. Y., assignor to Carrier Corporation, Syracuse, N. Y., a corporation of Delaware

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6 Claims. (Cl. 62—115)

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This invention relates to refrigeration, and more particularly to the use in a refrigeration cycle of a plurality of refrigerants having different boiling points which are miscible with each other in liquid form.

Prior to the instant invention, refrigeration systems have usually been charged with a single refrigerant having a relatively high boiling point, or a single refrigerant having a relatively low boiling point and the heat exchangers incorporated in such systems, (condensers and evaporators), have been designed to meet the requirements of the refrigerant used.

Some prior refrigeration systems have been designed to employ two refrigerants having different boiling points and so arranged that one of the refrigerants evaporates in one evaporator while the other refrigerant evaporates in a separate evaporator so that the two evaporators may serve two spaces at two different temperature levels.

It is an object of the invention to provide a novel refrigeration system utilizing a plurality of miscible volatile refrigerants having different boiling points in such manner that the heat exchange surfaces incorporated in the system are utilized more efficiently.

It is a further object of the invention to provide a novel refrigeration system including an evaporator adapted to utilize a plurality of miscible refrigerants having different boiling points whereby the heat exchange surface of the evaporator will be utilized more efficiently.

It is a further object of the invention to provide a novel refrigeration system wherein a plurality of miscible refrigerants of different boiling points will be efficiently condensed with substantially maximum effective use of the heat exchange surface of the condenser forming part of the system.

In general, applicant teaches the effective use in a system of refrigeration of a plurality of miscible refrigerants having different boiling points (vapor pressures), wherein the refrigerant vapor and the refrigerant liquid flow together in parallel relationship. Thus, in condensing such a refrigerant mixture, initial condensation, which occurs at a relatively high temperature, will result in formation of condensate rich in the component of higher boiling point and poor in the component of lower boiling point. As the condensing action proceeds with the coolant in counterflow or cross-flow relationship providing progressively lower temperatures, successively smaller increments of the component

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of higher boiling point and progressively larger increments of the component of lower boiling point will be produced in the condensate. Finally, with condensation at the minimum temperature, a maximum concentration of the component of lower boiling point will be found in the condensate with the maximum concentration of the component of higher boiling point theretofore largely condensed at higher temperatures.

Such a process involves no irreversible loss of thermal head since the vapor and the corresponding liquid phase are at each point in contact. There is a progressive interchange of the two components between the vapor and liquid phase which proceeds apace with the condensing action to maintain the vapor and liquid in equilibrium.

The process is reversible. In the evaporator, the first vapor produced is rich in the components of lower boiling point and as the refrigerant mixture progresses through the evaporator, with the medium to be cooled progressively being higher in temperature, less of the component of lower boiling point and more of the component of higher boiling point will vaporize. Proximate the discharge end of the evaporator, the component of lower boiling point will have been largely vaporized and the vaporization of the component of higher boiling point, in maximum volume, will take place. The liquid at each point is in equilibrium with the vapor, (the component of low boiling point having a high vapor pressure and high volatility with the component of high boiling point having a low vapor pressure and low volatility).

The nature and advantages of the invention will be apparent from the following description taken in conjunction with the accompanying drawing, wherein:

Fig. 1 is a schematic view of a refrigeration system in accordance with the invention; and

Fig. 2 is a chart of "temperatures" plotted against a "travel through the interchanger" of condenser refrigerant, condenser coolant, medium to be cooled, and evaporator refrigerant.

Referring to the drawings, the charge, comprising a plurality of miscible refrigerants having different boiling points, as for example two refrigerants of the halogen series CCl_2F_2 and $CHClF_2$ is compressed by the compressor 10 and passed upwardly to the top coil of the condenser 11. The components of the multiple refrigerant as they are condensed pass downwardly through the condenser 11 into the liquid receiver 12. From the liquid receiver the multiple refrigerant of

miscible components passes in the direction of the arrows within the conduit or feed line 13, through the expansion valve 14, controlled by the thermal bulb 15, which is in contact with the discharge line 17 leading from the evaporator 16, and thence into the suction 18 and back to compressor 10. The solid line arrows 19 designate one of the components of the multiple refrigerant which component has a known boiling point at a given pressure. The dotted line arrow 20 designates a second component of the multiple refrigerant, which component has a different boiling point at the same given pressure. The components 19 and 20 are miscible with each other. The component refrigerants which are used in the refrigeration system, may be selected from refrigerants which are known to be miscible with each other and known to have different boiling points at a given pressure. The invention is not limited to any two or more refrigerants. While the schematic drawing discloses the use of two refrigerants, it is to be understood that it is contemplated that more than two refrigerants may be used.

It is contemplated, in accordance with the invention, that the coolant for the condenser 11 will in general be passed in counterflow relation to the passage of the multiple refrigerant through the condenser 11. The coolant may be a gas, such as air, or a liquid, such as water. In the case of water, for example, the flow of condenser coolant may be through a tube 11a of larger diameter and concentric with the condenser tube. In the case of air cooling, a fan will be employed at one end of a casing in which the condenser is housed. In either case, as is well known, substantially a counter-flow or, in some cases, a cross-flow relationship will be provided to secure most effective heat exchange.

The medium to be refrigerated or cooled will also be passed substantially in counterflow or, in some cases, in crossflow relationship to the flow of refrigerant through evaporator 16 in the same general manner as that described in connection with the coolant for the condenser. That is, the medium to be refrigerated may be passed in true counterflow relationship to the passage of the refrigerant through the evaporator tubes, for example, in the case of water, through a tube 16a of larger diameter, or it may be passed generally in counterflow relationship to the evaporator by passing the medium to be cooled upwardly and transversely of the tubes of the evaporator which carry the refrigerant generally downwardly therethrough.

Bearing in mind that a counterflow relationship exists between the condenser and its coolant, the relatively low temperature coolant will first contact the bottom tube of the condenser which contains a multiple refrigerant also of relatively low temperature. When the coolant reaches the top tube of the condenser, it will be relatively warm and, correspondingly, the multiple refrigerant within the top tube will be in gaseous form.

As the multiple refrigerant passes downwardly thru the condenser, it begins to liquefy and the liquid so formed is rich in the refrigerant component of higher boiling point (or condensing point). As the multiple refrigerant continues further downwardly through the condenser and contacts ascending coolant of relatively low temperature, greater amounts of the refrigerant component of lower boiling point (or condensing point) will liquefy until the lowest tube of the condenser is reached when all of the refrigerant component of lower boiling point is condensed. The various refrigerant components liquefy together throughout the process and the liquid at any time during passage of the refrigerant through the condenser differs only in the concentration of the various components, that is, being relatively weak or rich in any given component. The mean temperatures of the multiple refrigerant within the condenser, as well as the temperatures of the condenser coolant as it travels through the condenser, correspond to the two parallel sloping lines at the top of the chart in Fig. 2. As the two lines tend to be parallel when a proper choice of the components of the multiple refrigerant is made in relation to temperature difference, it will be apparent that there is a substantially constant temperature differential between the condensing refrigerants and the coolant indicating that the condenser surface is being utilized at even efficiency and with optimum effective use of the surface throughout its length. If a single refrigerant were utilized in the same condenser with the same counterflow relationship, the refrigerant would condense at a substantially constant temperature and the line marked "condenser refrigerant" on the chart in Fig. 2 would be horizontal as long as some substantial amount of refrigerant remained to be condensed; and hence the curve would not be parallel to the line corresponding to the condenser coolant temperature. Further, the condenser coolant temperature would tend to slope upwardly more sharply so that the temperature differential between the coolant and the refrigerant would be greater at the bottom of the condenser than at the top. Accordingly, when a single refrigerant is used, the temperature differential cannot be the same throughout the length of the condenser and, accordingly, only a portion or small fraction of the condenser can be operated at high efficiency insofar as heat exchange is concerned while the remainder of the condenser surface is operated at progressively decreasing efficiency.

The principle of operation described in connection with the condenser is similarly true in connection with the operation of the evaporator 16. As the medium to be cooled is passed in counterflow relationship with the multiple refrigerant, the relatively warm medium first contacts the lowest tube of the evaporator which is relatively warm and when the medium reaches the top tube of the evaporator, it is relatively cool as is also the refrigerant in the top tube of the evaporator. As the refrigerant passes downwardly through the tubes of the evaporator, the component refrigerant of lower boiling point is evaporated in greater proportion than the component refrigerant of higher boiling point is evaporated. In other words, the various refrigerant components evaporate together but the component of lower boiling point is evaporated in greater amount so that the first vapor produced is rich in the component of lower boiling point, leaving the liquid weak therein but rich in the component of higher boiling point. As the multiple refrigerant continues through the evaporator greater amounts of the component of higher boiling point evaporate so that the concentration of the various components of the vapor is constantly changing. The evaporation in greater proportion of the refrigerant of lower boiling point (the more volatile refrigerant) prevents the refrigerant of higher boiling point from volatilizing prematurely in great quantities and, accordingly, the temperatures of the medium to be cooled and the refrig-

erant, as they pass in counterflow relationship, provide substantially a constant temperature differential between the medium to be cooled and the mean temperature of the refrigerant. This is shown in the chart of Fig. 2 by the two lower sloping parallel lines. This indicates that the effective surface of the evaporator throughout its length is being utilized at relatively high efficiency as compared to a system utilizing a single refrigerant which volatilizes substantially at constant temperature, so that the temperature differential at the bottom of the evaporator where the medium to be cooled is introduced, is great and the temperature differential at the top of the evaporator, where the medium to be cooled leaves the evaporator, is small. In such case where a single refrigerant is used, only a fraction of the surface of the evaporator is operated at high efficiency and the remaining portion of the surface of the evaporator is operated at relatively low efficiency.

By utilizing two component refrigerants in substantial equilibrium between the liquid and vapor phases, a better mean effective temperature difference is obtained than is otherwise possible, and loss of temperature head is avoided as in the case where remixing of liquid can occur.

By utilizing condenser and evaporator surfaces of the same size as that which would ordinarily be used when the system is charged with a single refrigerant, the logarithmic mean effective temperature difference between the coolant and medium to be cooled would be the same as for the ordinary system, but due to the fact that this temperature difference remains practically constant for each element of the surface, the arithmetic mean effective temperature difference is decreased and consequently also the total effective temperature range between cooler and condenser temperatures with a corresponding decrease in the amount of power required. Alternatively, the amount of surface or the amount of coolant could be decreased in comparison with the amounts ordinarily used and a new balance struck between surface, coolant quantities and power.

The system in accordance with the invention can be used where coolant is at a premium so that while under ordinary conditions, a system utilizing a single refrigerant could not be operated, a system in accordance with the instant invention may be operated satisfactorily with less than a normal amount of coolant for the condenser.

Another advantage flowing from the invention is that it enables the use of small self-contained apparatus as for room cooling purposes, where the surface for cooling and condensing may be reduced and a minimum of refrigerant employed. Such advantages apply not only to unitary apparatus but may be applied generally in a wide variety of applications where the vapor and liquid travel together (of two different but miscible refrigerants) and are in equilibrium, so that the refrigerant temperature from beginning to the end of the interchanger can be varied and thus maintain a substantially constant temperature difference in counterflow relationship with the gas or liquid contacting the surface through which the refrigerants pass.

It will be obvious to those skilled in the art that various changes may be made without departing from the spirit of the invention and therefore the invention is not limited to what is shown in the drawings and described in the specification but only as indicated in the appended claims.

What is claimed is:

1. The method of producing refrigeration comprising progressively evaporating a plurality of miscible refrigerant components having different boiling points by passing in generally counterflow relationship thereto a medium to be cooled, said components having such varying boiling points and being so proportioned that the temperature differential between the medium to be cooled flowing in heat exchange relationship with the refrigerants and the refrigerants is substantially constant throughout the entire path of heat interchange, compressing the gases formed by the volatilization of the components of the multiple refrigerant, condensing the compressed gases, and then re-evaporating the liquefied multiple refrigerant to repeat the refrigerating cycle.

2. The method of producing refrigeration comprising progressively evaporating a plurality of miscible refrigerant components having different boiling points by passing in generally counterflow relationship thereto a medium to be cooled, said components having such varying boiling points and being so proportioned that the temperature differential between the medium to be cooled flowing in heat exchange relationship with the refrigerants and the refrigerants is substantially constant throughout the entire path of heat interchange, compressing the gases formed by the volatilization of the components of the multiple refrigerant, condensing the compressed gases by passing in counterflow relationship thereto a coolant, the quantities of each refrigerant component within the condenser being so proportioned and each component having a different condensation point corresponding to different temperature-pressure relationships that the temperature differential between the multiple refrigerant and the coolant is substantially constant throughout the path of heat exchange of the coolant, and then re-evaporating the liquefied multiple refrigerant to repeat the refrigeration cycle.

3. A method of efficiently utilizing the heat exchange surfaces of a refrigeration system which consists in supplying a mixture of miscible refrigerant components of different boiling points in gaseous form to a condenser, passing the mixture in the condenser in counterflow relation with a coolant passing through the condenser to condense a liquid rich in the component of higher boiling point, and continuing passage of the mixture through the condenser in heat exchange relation with coolant of progressively lower temperature to progressively liquefy greater amounts of the component of lower boiling point until all of the component of lower boiling point is liquefied.

4. A method of efficiently utilizing the heat exchange surfaces of a refrigeration system which consists in supplying a mixture of miscible refrigerant components of different boiling points in gaseous form to a condenser, passing the mixture in the condenser in counterflow relation with a coolant passing through the condenser to condense a liquid rich in the component of higher boiling point, and continuing passage of the mixture through the condenser in heat exchange relation with coolant of progresively lower temperature to progressively liquefy greater amounts of the component of lower boiling point until all of the component of lower boiling point is liquefied thereby maintaining a substantially constant temperature difference

throughout the condenser between the coolant and the refrigerant mixture.

5. A method of efficiently utilizing the heat exchange surfaces of a refrigeration system which consists in supplying a mixture of miscible refrigerant components of different boiling points in gaseous form to a condenser, passing the mixture in the condenser in counterflow relation with a coolant passing through the condenser to condense a liquid rich in the component of higher boiling point, continuing passage of the mixture through the condenser in heat exchange relation with coolant of progressively lower temperature to progressively liquefy greater amounts of the component of lower boiling point until all of the component of lower boiling point is liquefied, then supplying the liquid mixture of miscible refrigerant components of different boiling points to an evaporator, progressively evaporating the mixture as it travels through the evaporator with the liquid and vapor phases in substantial equilibrium by passing in generally counterflow relation thereto a medium to be cooled thereby forming a vapor rich in the component of lower boiling point, and continuing passage of the mixture through the evaporator in heat exchange relation with medium to be cooled of progressively higher temperature until the component of higher boiling point is evaporated.

6. A method of efficiently utilizing the heat exchange surfaces of a refrigeration system which consists in supplying a liquid mixture of miscible refrigerant components of different boiling points to an evaporator, progressively evaporating the mixture as it travels through the

evaporator with the liquid and vapor phases in substantial equilibrium by passing in generally counterflow relation thereto a medium to be cooled thereby forming a vapor rich in the component of lower boiling point, continuing passage of the mixture through the evaporator in heat exchange relation with medium to be cooled of progressively higher temperature until the component of higher boiling point is evaporated, compressing the gases formed by the volatilization of the components of the multiple refrigerant, then supplying the mixture of miscible refrigerant components of different boiling points in gaseous form to a condenser, passing the mixture in the condenser in counterflow relation with the coolant passing through the condenser to condense a liquid rich in the component of higher boiling point and continuing passage of the mixture through the condenser in heat exchange relation with coolant of progressively lower temperature to progressively liquefy greater amounts of the component of lower boiling point until all of the component of lower boiling point is liquefied.

CARLYLE M. ASHLEY.

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