Nov. 13, 1956 S. M. BACKSTROM 2,770,108

ABSORPTION REFRIGERATION

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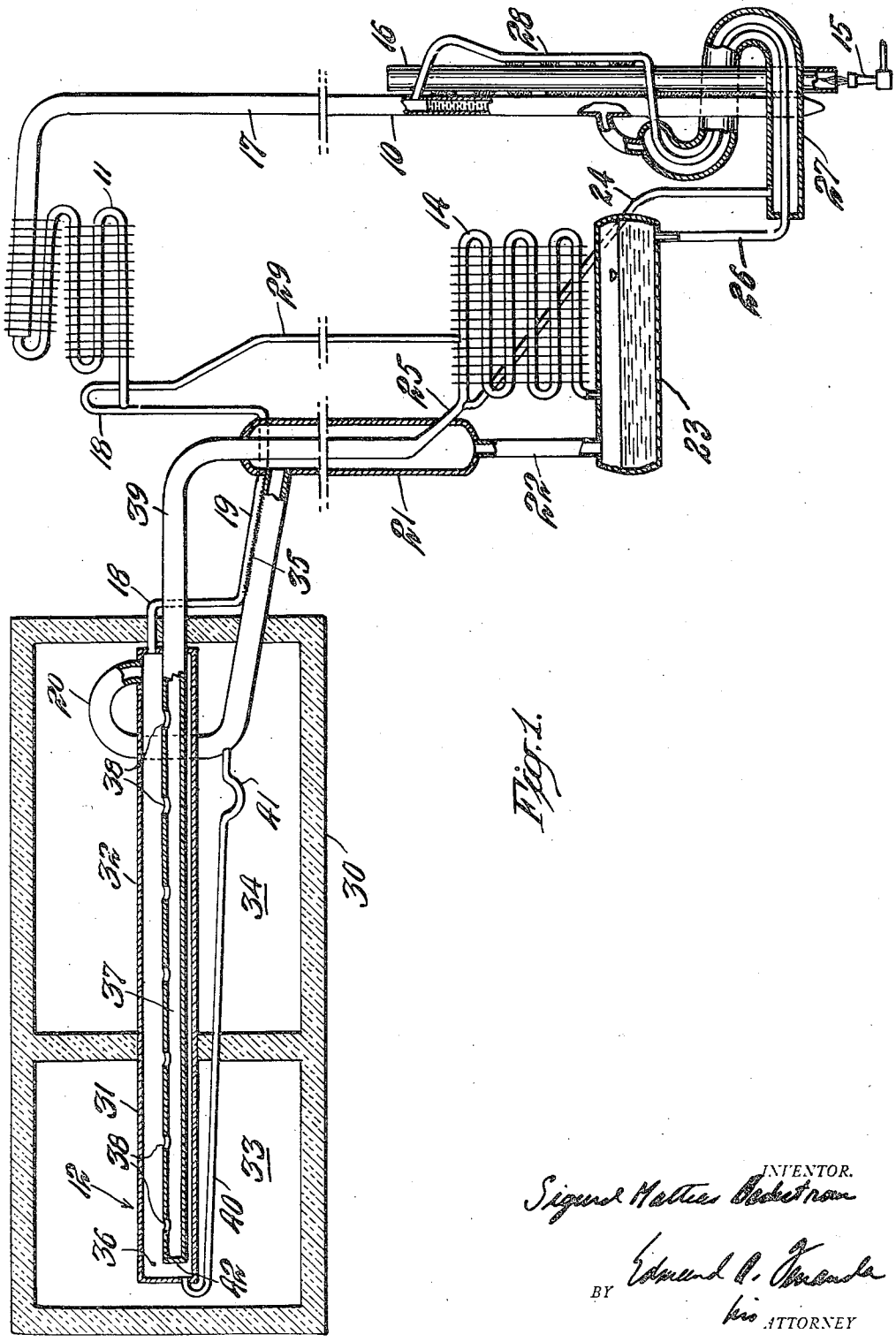


Fig. 1.

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Fig. 2.

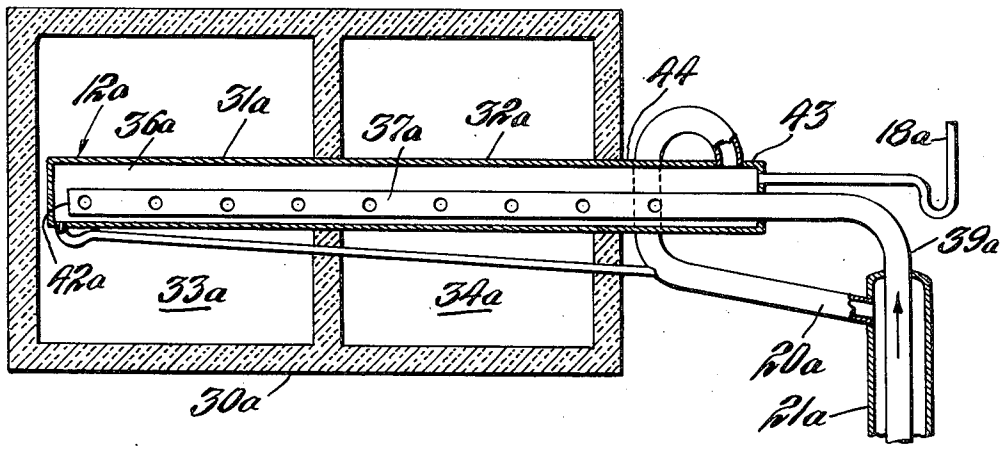
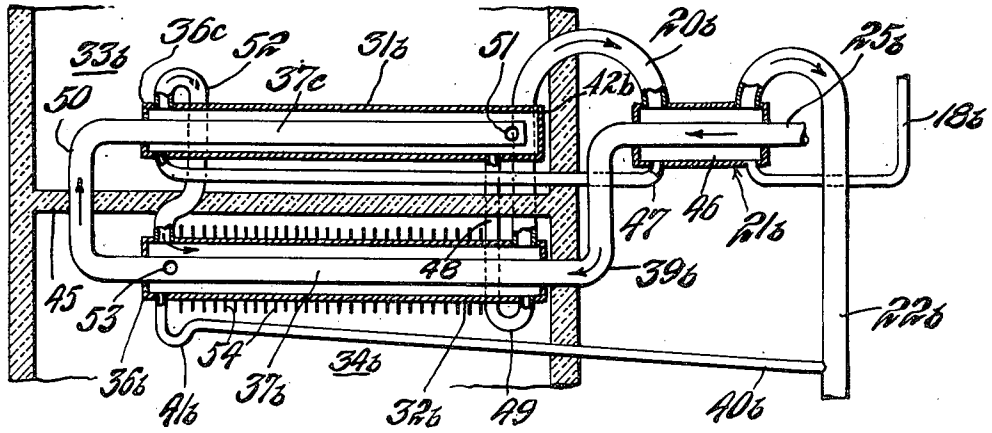


Fig. 3.



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ABSORPTION REFRIGERATION

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Fig. 4.

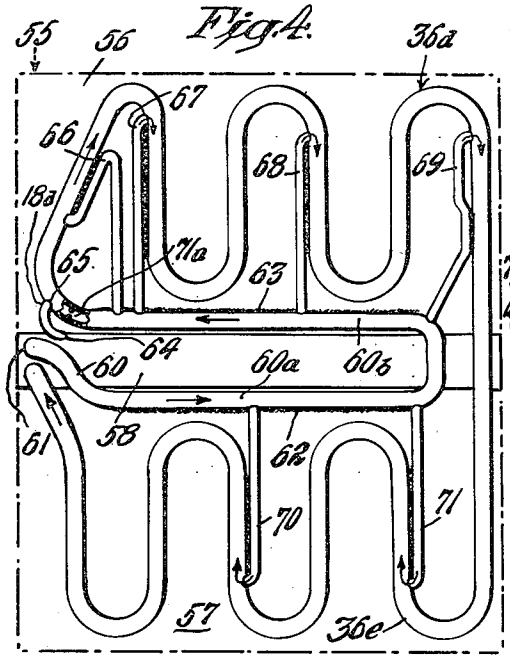


Fig. 5.

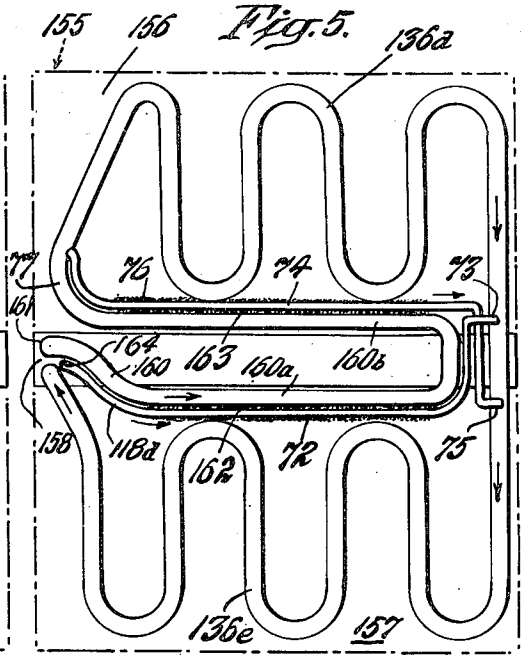
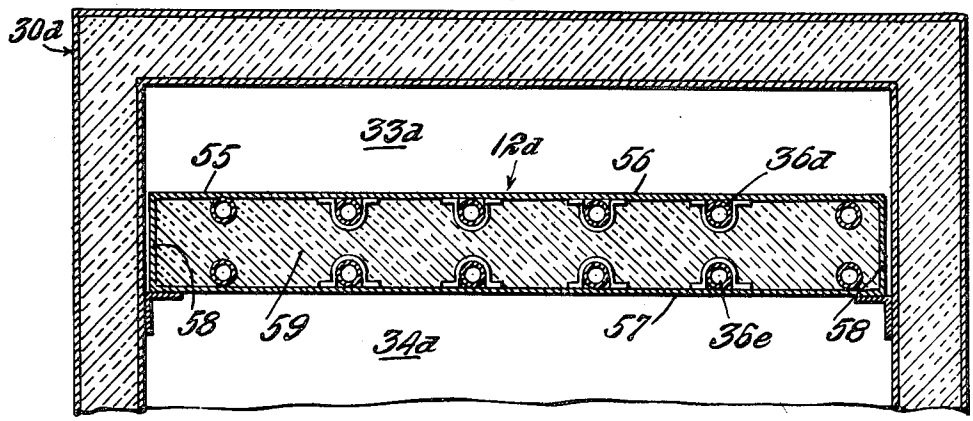


Fig. 6.



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2,770,108

ABSORPTION REFRIGERATION

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Application January 21, 1953, Serial No. 332,364

Claims priority, application Sweden January 23, 1952

10 Claims. (Cl. 62—119.5)

My invention relates to refrigeration, and more particularly to a refrigeration system employing evaporation of refrigerant fluid in the presence of an inert gas or pressure equalizing agent.

It is an object of the invention to improve the operation of refrigeration systems of this type adapted to produce refrigeration at a plurality of temperatures. More particularly, it is an object to effect a lower refrigeration temperature in the low temperature part or section of a plural temperature cooling unit.

In accord with the invention, a substantial cooling output is effected at an extremely low temperature level without jeopardizing the total cooling output in a temperature range up to the freezing temperature of water, for example. I accomplish this by effecting the lower refrigerating temperature in such manner that circulation of inert gas is still essentially the same as in a conventional system having a cooling unit which is connected in the inert gas circuit and provided with a single elongated path of flow for the inert gas. In one phase of the invention inert gas weak in refrigerant, and having essentially a constant partial pressure of refrigerant vapor, flows in a path of flow in thermal exchange relation with enriched inert gas flowing in the presence of liquid refrigerant and having a constantly increasing partial pressure of refrigerant vapor, the weak inert gas successively flowing in thermal exchange relation with such enriched gas in a higher and then the low temperature sections of a cooling unit arranged to effect cooling of spaces thermally segregated from one another.

In another phase of the invention the lower refrigerating temperature is achieved by preventing increase in the refrigerant concentration of the weak inert gas supplied to different parts or elements of a cooling unit, and to introduce weak gas into different parts or elements having a partial pressure of refrigerant vapor which is essentially the same as that of the weak inert gas when it leaves the absorber. The supply pipe for weak inert gas desirably is cooled by the refrigerating effect produced by the cooling unit, and the weak inert gas, at successive regions in its path of flow in the cooling unit, always passes into the presence of liquid refrigerant with a partial pressure of refrigerant vapor essentially the same as that of the weak inert gas leaving the absorber of the refrigeration system.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the claims. The invention, both as to organization and method, together with the objects and advantages thereof, will be better understood by reference to the following description taken in connection with the accompanying drawings forming a part of this specification, and of which:

Fig. 1 illustrates more or less diagrammatically an absorption refrigeration system embodying the invention;

Figs. 2 and 3 are fragmentary views of parts like those shown in Fig. 1 illustrating other embodiments of the invention;

Fig. 4 is a fragmentary front elevation looking toward the rear of a storage space of a refrigerator, partly broken away and in section, illustrating a further embodiment of the invention including parts adapted to be connected in an absorption refrigeration system like that shown in Fig. 1; and

Figs. 5 and 6 diagrammatically represent different forms of the embodiment of Fig. 4 to show details more clearly.

Referring to Fig. 1, the invention is embodied in an absorption refrigeration system of a uniform pressure type containing an inert gas or pressure equalizing agent. A system of this type includes a generator 10, condenser 11, cooling unit or evaporator 12 and an absorber 14 which are interconnected in a manner well known in the art and which will briefly be described hereinafter. The system contains a solution of refrigerant in absorption liquid, such as ammonia in water, for example, and also an auxiliary agent or inert gas, such as hydrogen.

The generator 10 is heated in any suitable manner, as by an electrical heating element or a gas burner 15, for example, which projects its flame into the lower end of a flue 16 with which the generator 10 is in thermal contact. By heating the generator 10, refrigerant vapor is expelled out of solution and flows upwardly through conduit 17 into the air cooled condenser 11. Refrigerant liquefied in the condenser 11 flows therefrom through a conduit 18, having a liquid trap 19, into the upper part of the evaporator or cooling unit 12 and evaporates and diffuses therein into inert gas to produce a refrigerating effect, as will be described more fully hereinafter.

The rich gas mixture of refrigerant and inert gas formed in cooling unit 12 flows therefrom through a conduit 20, gas heat exchanger 21, conduit 22 and absorber vessel 23 into the lower end of the air cooled absorber 14 which is in the form of a looped coil. In absorber 14 the rich gas mixture flows counter-current to downwardly flowing weak absorption liquid which enters through a conduit 24. The absorption liquid absorbs refrigerant vapor from inert gas, and inert gas weak in refrigerant flows from absorber 14 through conduit 25 and gas heat exchanger 21 back to the evaporator 12.

The circulation of gas in the gas circuit just described is due to the difference in specific weight of the columns of gas rich and weak, respectively, in refrigerant vapor. Since the column of gas rich in refrigerant vapor and flowing from cooling unit 12 to the absorber 14 is heavier than the column of gas weak in refrigerant and flowing from the absorber 14 to the cooling unit 12, a force is produced or developed within the system for causing circulation of gas in the manner described.

Absorption liquid enriched in refrigerant flows from the lower part of absorber 14 into the vessel 23. From the vessel 23 enriched absorption liquid is conducted through a conduit 26 and a liquid heat exchanger 27 to a vapor lift or thermosyphon tube 28 in thermal contact with the flue 16. Liquid is raised by vapor lift action through tube 28 into the upper part of generator 10. Refrigerant vapor expelled out of solution in generator 10, together with refrigerant vapor entering through tube 28, flows upwardly through conduit 17 and into condenser 11, as previously explained.

Absorption liquid from which refrigerant has been expelled flows from generator 10 through liquid heat exchanger 27 and conduit 24 into the upper part of absorber 14. This circulation of absorption liquid is effected by raising of liquid in tube 28 by vapor lift action. The lower end of the condenser 11 is connected by a conduit 29 to the gas circuit, as to the upper part

of the absorber coil 14, for example, so that any non-condensable gas which may pass into the condenser can flow to the gas circuit and not be trapped in the condenser.

The cooling unit 12, which is arranged in a thermally insulated interior of a refrigerator cabinet 30, includes low and higher temperature cooling sections 31 and 32 arranged to abstract heat from thermally segregated spaces 33 and 34, respectively, of the cabinet. The space 33 of the cabinet 30 may be referred to as a freezing compartment adapted to receive trays for freezing water and other matter to be frozen. Accordingly, the low temperature cooling section 31 desirably may be provided with one or more shelves (not shown) upon which may be placed ice trays containing water to be frozen. The higher temperature cooling section 32 desirably may be provided with a plurality of heat transfer members (not shown) whereby a relatively extensive heat transfer surface is obtained for cooling air in the space 34.

In order to introduce liquid refrigerant into the cooling unit 12 at a lower temperature than the temperature at which it flows from the condenser 11, the refrigerant may be cooled in any suitable manner. By way of example, heat may be abstracted from liquid refrigerant in its path of flow from the condenser 11 by arranging the liquid trap 19 of conduit 18 in thermal exchange relation with the conduit 20 through which relatively cool inert gas, which is enriched in refrigerant, flows from cooling unit 12 to the absorber 14, as indicated at 35 in Fig. 1.

In accordance with my invention, in order to obtain a lower temperature in cooling section 31, the cooling unit 12 is employed to effect cooling of inert gas weak in refrigerant and subdivided streams of such inert gas flow into the presence of liquid refrigerant at a number of places. The cooling unit 12 comprises an elongated jacket or tubular member 36 within which is positioned pipe 37 having spaced apart apertures or openings 38 in the ceiling or top portion thereof, the outer jacket and inner pipe being essentially horizontally disposed.

Liquid refrigerant is introduced into the right-hand end of jacket 36 from conduit 18. Inert gas weak in refrigerant passes from the upper end of heat exchanger 21 through a conduit 39 communicating with the right-hand end of the pipe 37. Inert gas enriched in refrigerant flows from the right-hand end of jacket 36 through the conduit 20 to the upper end of the gas heat exchanger 21. Unevaporated refrigerant passes from the left-hand end of jacket 36 through an overflow or drain pipe 40 which is formed with a U-trap 41 and communicates with the lower part of conduit 20.

During operation, inert gas weak in refrigerant flows from the upper end of the absorber 14 through conduit 25, inner passage of gas heat exchanger 21 and conduit 39 into the right-hand end of pipe 37. Such inert gas flows toward the left-hand end of pipe 37 and emerges therefrom through the openings 38 into the jacket 36. Liquid refrigerant flowing toward the left-hand end of jacket 36 evaporates and diffuses into the inert gas entering through the openings 38, with consequent absorption of heat. The inert gas in the space of jacket 36 about the pipe 37 can only flow toward the right and counter-current to weak inert gas flowing toward the left in pipe 37. Hence, when liquid refrigerant evaporates and diffuses into inert gas in the outer space of jacket 36 about the pipe 37, heat is abstracted from weak inert gas flowing toward the left in pipe 37.

In the embodiment of Fig. 1, the liquid trap 19 of the refrigerant supply line or conduit 18 is arranged in thermal relation with the conduit 20 at 35, as previously explained. In this way cool inert gas enriched in refrigerant vapor abstracts heat from refrigerant condensate flowing to the cooling unit 12. In addition, weak inert gas entering the right-hand end of pipe 37 flows in thermal relation with enriched inert gas flowing about the pipe

37 and about to pass from the jacket 36. Hence, both the liquid refrigerant and weak inert gas are cooled before the weak gas passes through the openings 38 in pipe 37 and these fluids flow in the presence of each other, thereby lowering the temperature of the cooling unit 12.

By providing the arrangement shown in which the openings 38 are distributed lengthwise of the pipe 37, the temperature of the weak gas at 42, at the closed end of the pipe, is the lowest possible. This is accomplished by introducing into the jacket 36, through the openings 38, inert gas which is always weak in refrigerant vapor. Stated another way, weak inert gas, at successive regions in its path of flow toward the left in pipe 37, always passes through the openings 38 with a partial pressure of refrigerant vapor which is essentially the same as that of the weak inert gas leaving the upper part of absorber 14.

The temperature at which liquid refrigerant evaporates and diffuses into inert gas, at different regions lengthwise of jacket 36, is dependent upon the partial pressure of refrigerant vapor in the weak gas. At the region of the opening 38 at the extreme right-hand end of pipe 37, the weak gas passing therethrough mixes with enriched inert gas flowing toward such region from the left-hand end of jacket 36. Such mixing of weak and enriched inert gas serves a useful purpose, because it lowers the partial vapor pressure of refrigerant vapor in the resulting gas mixture and enables liquid refrigerant to evaporate and diffuse into such gas mixture at a lower temperature than would otherwise be possible.

This same result occurs at the region of each opening 38 in pipe 37, the only difference being that weak inert gas passing through each opening lengthwise of the pipe, which is nearer to the closed end 42 of the pipe, mixes with inert gas which is less enriched in refrigerant vapor. Hence, as the weak inert gas and liquid refrigerant move toward the left in pipe 37 and jacket 36, respectively, heat is abstracted from these fluids with evaporation of liquid refrigerant into inert gas in the space surrounding the pipe 37, thereby bringing down the temperature of these fluids.

At the extreme left-hand end 42 of the low temperature cooling section 31, the weak inert gas within pipe 37 and liquid refrigerant in the bottom of the jacket 36 are at the lowest temperature possible. Since the closed end 42 of pipe 37 marks the region of the cooling unit 12 at which liquid refrigerant evaporates and diffuses into weak inert gas having the lowest possible partial vapor pressure of refrigerant vapor, it will be understood that the lowest refrigerating temperature will be produced at such closed end 42 of the pipe. Since the liquid refrigerant and weak inert gas while flowing toward the left in jacket 36 and pipe 37, respectively, are constantly being subjected to cooling effect at progressively lower temperature levels, less of the refrigerating effect at the region 42 of the low temperature cooling section 31 is employed to bring down the temperature of these fluids when they flow into the presence of each other, thereby contributing to the low temperature produced at the region 42 of the cooling unit. Under established operating conditions the temperature at 42 in Fig. 1 will fall approximately to the saturation temperature for refrigerant vapor at a vapor pressure which is equal to the partial refrigerant vapor pressure in the weak inert gas leaving the absorber 14.

By way of example, it may be assumed that weak inert gas, after flowing in heat exchange relation with cool enriched gas in the gas heat exchanger 21 enters the right-hand end of pipe 37 at a temperature of about +10° C. Also, it may be assumed that liquid refrigerant, after being pre-cooled at 35, enters the right-hand end of jacket 36 at about 0° C. As previously explained, the weak gas flowing in pipe 37 becomes progressively cooler; and, after the refrigeration system has been operating for a sufficient length of time, the temperature at the region 42 of the cooling unit 12 may fall to about −20 to −25°

C. The temperature of the cooling unit **12** becomes progressively higher toward the right-hand end thereof at the region conduit **20** is connected thereto. This is so because the partial vapor pressure of the refrigerant is a gradient lengthwise of the space about the pipe **37**, so that the evaporating temperature of the liquid refrigerant is also a gradient.

One of the advantages gained from the present improvement is that a substantial cooling output is effected at an extremely low temperature level while still obtaining a maximum total cooling output in a temperature range up to 0° C., for example. Stated another way, the invention makes it possible to obtain cooling output at an extremely low temperature level without jeopardizing and at the expense of the total cooling output in a temperature range up to the freezing temperature of water. This advantage is realized because the gas circulation in a refrigeration system embodying a cooling unit in accord with the invention is essentially the same as the gas circulation in a system employing a conventional cooling unit having an elongated path of flow for inert gas having a single inlet and single outlet and in which liquid refrigerant evaporates and diffuses in the presence of the gas.

In a refrigeration system having low and higher temperature refrigerating sections like the cooling sections **31** and **32**, for example, the greater part of the liquid refrigerant will evaporate and diffuse into inert gas in the higher temperature cooling section **32**. In any particular case, the number and size of the openings **38** may be selected to effect a suitable temperature distribution to provide low and higher temperature cooling sections, each of which will be effective to abstract heat from a zone or space thermally segregated from another zone or zones from which heat is abstracted at a different temperature level. When the region **42** of the cooling unit **12** is employed as a low temperature cooling section in the manner explained above, the openings **38** desirably are of increasingly larger size from the right to the left-hand end of the pipe **37**.

In Fig. 2, in which like parts are referred to by generally similar reference numerals, I have diagrammatically shown another embodiment of my invention which is generally like the embodiment just described and differs therefrom in that a part of jacket **36***a* projects exteriorly of the cabinet **30***a* and may partly or completely replace the gas heat exchanger **21***a*. In Fig. 2 the extreme left-hand part **31***a* of the cooling unit **12***a* is arranged to abstract heat from space **33***a*, the intermediate part **32***a* thereof is arranged to abstract heat from space **34***a* and the right-hand part **43** serves as a precooler which is disposed exteriorly of the space **34***a*.

In Fig. 2 it will also be seen that liquid refrigerant flowing from the condenser through conduit **18***a* is introduced directly into the right-hand end of jacket **34***a* and does not flow in thermal relation with cool enriched inert gas in the particular manner indicated at **35** in Fig. 1 and described above. However, essentially the same end result is achieved by providing the jacket section **43** in which liquid refrigerant evaporates and diffuses into inert gas flowing toward the right-hand end of jacket **36***a*, with consequent absorption of heat. In this way heat is abstracted from weak inert gas flowing through the section of pipe **37***a* in the jacket part **43** and also from liquid refrigerant flowing into such jacket part from the supply line **18***a*.

In an air-cooled refrigeration system of the type under consideration, it may be assumed that weak inert gas enters the right-hand end of pipe **37***a* from conduit **39***a* at a temperature of about +50° C. This would be the case if the gas heat exchanger **21***a* were not employed and is simply given by way of example to illustrate the effectiveness of the part **43** for precooling weak inert gas prior to entering the higher temperature evaporator section **32***a*. Such assumed temperature of +50° C. for weak inert gas essentially corresponds to the operating temperature of a conventional absorber in an air-cooled refrigeration system.

It may also be assumed that the liquid refrigerant entering the part **43** from conduit **18***a* is also at a temperature of about +50° C. which corresponds essentially to the condensation temperature of a conventional air-cooled refrigeration system. With a suitable concentration of refrigerant in the absorption liquid and under normal pressures prevailing in refrigeration systems of the kind under consideration, the cooling unit **12***a* will operate to produce a refrigerating temperature as low as −20 to −25° C. at the region **42***a*.

The temperature of cooling unit **12***a* increases from the region **42***a* toward the part **43**, and, in the arrangement of Fig. 2, it may be assumed that the temperature at the region **44**, which is immediately outside the space **34***a*, is slightly above 0° C. and about +10° C., for example. Due to heat abstracted from weak inert gas and liquid refrigerant in the part **43**, it may be assumed the enriched inert gas leaves the jacket **36***a* and enters the conduit **20***a* at a temperature of about +40° C. Such enriched gas may pass through the gas heat exchanger **21***a* or flow directly to the absorber vessel, if desired.

In the embodiments of Figs. 1 and 2, the elongated jackets or tubular members **36** and **36***a* of the cooling units are essentially disposed in a single horizontal plane and may comprise coils formed of piping which desirably are longer than the elongated tubular members or jackets seen in Figs. 1 and 2. Such evaporator piping may include straight portions and bends which are disposed in such manner that liquid refrigerant can trickle by gravity flow therethrough from the liquid inlet end to the liquid outlet end from which unevaporated refrigerant drains.

Evaporator piping of the kind just referred to, which is disposed essentially in a single horizontal plane, inherently has a gentle downward slope and may be provided with internal screening bearing against the inner surface thereof to promote distribution of liquid refrigerant about the inner periphery of the piping which serves as the outer jacket or tubular member of the cooling unit. One portion of the elongated piping may form a part of the low temperature cooling section arranged to abstract heat from a first zone or space, while another portion thereof may form a part of a higher temperature cooling section arranged to abstract heat from a second space or zone thermally segregated from the first zone or space.

In Fig. 3 I have shown another form of my invention in which the low and higher temperature cooling sections **31***b* and **32***b* are disposed in different horizontal planes one above the other, so as to abstract heat from spaces **33***b* and **34***b* which are thermally segregated by a horizontal partition **45**. In Fig. 3 liquid refrigerant flows from a condenser (not shown) through a conduit **18***b*, outer passage **46** of a horizontal gas heat exchanger **21***b* and conduit **47** to the extreme left-hand end of the low temperature evaporator section **31***b*. After flowing toward the right in the low temperature cooling section **31***b*, liquid refrigerant passes through a vertical connection **48** into the higher temperature cooling section and flows toward the left therein. Unevaporated refrigerant drains from the higher temperature cooling section through a conduit **40***b* to the conduit **22***b* for flow to the absorber. Conduits **43** and **40***b* are formed with liquid traps **49** and **41***b*, respectively, to prevent flow of inert gas therethrough.

Inert gas weak in refrigerant flows from the absorber through a conduit **25***b*, inner passage of gas heat exchanger **21***b* and conduit **39***b* into pipe **37***b* which is disposed lengthwise within the jacket or elongated tubular member **36***b* of the higher temperature cooling section **32***b*. The left-hand end of pipe **37***b* is connected by a vertical connection **50** to pipe **37***c* which extends lengthwise within the jacket or elongated tubular member **36***c* of

the low temperature cooling section 31*b*. An opening 51 is provided at the right-hand closed end of pipe 37*c* through which inert gas weak in refrigerant flows into the presence of liquid refrigerant, such inert gas flowing toward the left in tubular member 36*c* of Fig. 3 in counterflow to and in the presence of liquid refrigerant. Hence, when liquid refrigerant evaporates and diffuses into inert gas in the outer space of jacket 36*c* about the pipe 37*c*, heat is abstracted from weak inert gas flowing toward the right in pipe 37*c*.

Partially enriched inert gas passes from the left hand end of the jacket 36*c* through a vertical connection 52 and then flows toward the right in the jacket 36*b* of the higher temperature cooling section 32*b*. Inert gas enriched in refrigerant flows from the right-hand end of the higher temperature cooling section 32*b* through conduit 20*b*, outer passage of the gas heat exchanger 21*b* and conduit 22*b* to the absorber. At the region the lower end of connection 52 communicates with the left-hand end of jacket 36*b*, the pipe 37*b* is provided with an opening 53 through which is diverted a part of the weak inert gas flowing toward the left in pipe 37*b*. Accordingly, weak inert gas in its path of flow through the higher and low temperature cooling sections 32*b* and 31*b*, respectively, passes through the openings 53 and 51 with a partial pressure of refrigerant vapor which is essentially the same as that of the weak inert gas leaving the absorber.

The space 33*b* may be referred to as the freezing compartment in which the low temperature cooling section 31*b* is adapted to receive trays of freezing water and other matter to be frozen. The higher temperature cooling section desirably operates above the freezing temperature of water and may be provided with a plurality of heat transfer members 54, so that a relatively extensive heat transfer surface is obtained for cooling air in the space 34*b*.

In Fig. 3 weak inert gas flows through pipe 37*b* in thermal relation with enriched inert gas in the outer jacket 36*b* and then flows through pipe 37*c* in thermal relation with enriched inert gas in the jacket 36*c*. Hence, the weak gas flowing successively through pipes 37*b* and 37*c* becomes progressively cooler; and, after the refrigeration system has been operating for a sufficient length of time, the temperature at the region 42*b* of the cooling unit will reach a low temperature which may be as low as —20° to —25° C., for example.

As in the previously described embodiments, the elongated jackets or tubular members 36*b* and 36*c* desirably are longer than the jackets illustrated in Fig. 3 and may comprise coils formed of piping having straight portions and connecting bends, for example. Such coils desirably are provided with internal screening or other liquid distributing provisions and formed and arranged so that liquid refrigerant will trickle by gravity flow therethrough. Further, a suitable horizontal plate or member may be arranged in thermal contact with the coil forming the elongated jacket 36*c* for supporting thereon matter to be frozen.

Another form of low temperature cooling unit 12*d* is shown in Fig. 6 which comprises a casing 55 serving as a partition in a cabinet 30*d* to divide the thermally insulated interior thereof into upper and lower compartments 33*d* and 34*d*, respectively. The casing 55 comprises top and bottom horizontal walls 56 and 57 connected by vertical walls 58 at the front, rear and lateral sides of the casing. A low temperature cooling coil 36*d* is arranged in thermal relation with the underside of the top wall 56 while a higher temperature coil 36*e* is arranged in thermal relation with the top surface of the bottom wall 57. A suitable insulating material 59 may be retained in the casing 55 so that the low temperature coil 36*d* and shelf 56 thermally connected thereto is primarily effective to abstract heat from the upper compartment 33*d* and the low temperature coil 36*e* and shelf 57 thermally connected thereto is primarily effective to abstract heat from the lower compartment 34*d*. Essentially, the top wall 56 and coil 36*d* form a low temperature cooling section and the bottom wall 57 and coil 36*e* form a higher temperature cooling section for effecting cooling of adjacent compartments thermally segregated from one another. If desired, a plurality of heat transfer members, similar to the members 54 in Fig. 3, may be provided at the underside of the bottom wall 57.

One manner of arranging the coils 36*d* and 36*e* in the container 55 is illustrated in Fig. 4 in which the rear wall 58 of the container is shown in solid lines and the underside of the top shelf 56 and top side of the bottom shelf 57 are shown in dotted lines, thus diagrammatically representing the interior of the casing with the rear wall 57 and the top and bottom horizontal walls 56 and 57 projecting forwardly therefrom. In Fig. 4 weak inert gas flows from the absorber to the cooling unit 12*d* through piping 60 which passes through an opening 61 in the rear wall 58 of the container and includes a first section 60*a* heat conductively connected at 62 to the top surface of the bottom shelf 57 and a second section 60*b* heat conductively connected at 63 to the bottom surface of the top shelf 56.

Liquid refrigerant flows from the condenser to the cooling unit 12*d* through a conduit 18*d* which passes through an opening 64 in the rear wall 58 of the container and is connected at 65 to the left-hand end of the upper coil 36*d* at which region inert gas weak in refrigerant is introduced from the second section 60*b* of the weak gas supply line. In addition, weak inert gas is diverted from the second pipe section 60*b* through a number of conduits 66, 67, 68 and 69 to a number of spaced apart points of the upper coil 36*d*. As shown in Fig. 4, a portion of each of conduits 66, 67, 68 and 69 is heat conductively connected in a lengthwise direction with parts of the looped coil 36*d*. In addition, weak inert gas is diverted from the first pipe section 60*a* through several conduits 70 and 71 to spaced apart points of the lower coil 36*e*. A portion of each of conduits 70 and 71 is heat conductively connected in a lengthwise direction with parts of the looped coil 36*e*. Liquid refrigerant flows from left to right in coil 36*d* and then flows from right to left in the lower coil 36*e*.

A suitable throttling device 71*a* desirably is provided in the second pipe section 60*b* for weak inert gas at a region just before the weak gas flows in the presence of liquid refrigerant. If desired, the device 71*a* may more or less act to completely block off flow of weak gas in which case the weak gas first flows into the presence of liquid refrigerant through the conduit 65. It will now be seen that weak inert gas is cooled in both sections 60*a* and 60*b* of the supply line or piping 60, first by the wall 57 of the higher temperature cooling section and then by the wall 56 of the low temperature evaporator section, and that such cooling of the weak gas is effected without any increase in the partial pressure of the refrigerant vapor in the gas.

In order that the higher temperature coil 36*e* will be effectively employed to abstract heat from weak gas in the pipe section 60*a*, some weak gas is diverted from the latter through conduits 70 and 71 into the coil 36*e*. The conduit 70 is connected approximately to the middle part of coil 36*e*, while conduit 71 is connected to the end of the coil 36*e* at which partially enriched inert gas is received from the low temperature coil 36*d*. The thermal contact of conduits 70 and 71 with coil 36*e* promotes cooling of weak gas flowing through these conduits prior to mixing with enriched inert gas in coil 36*e*. In this way heat is effectively abstracted from weak gas flowing in section 60*b* of the weak gas supply line toward the throttling device 71*a*. While this may increase the average or mean refrigerating temperature produced in the higher temperature cooling section formed by the coil 36*e* and bottom wall 57, this is not objectionable because the refrigerating effect available for the bottom compartment 34*d* will still be adequately low for cooling

such compartment to a temperature which desirably is above the freezing temperature of water.

The branch conduits 66, 67, 68 and 69 in the low temperature cooling section divert weak inert gas into different places of the upper coil 36*d* in essentially the same manner weak inert gas is diverted through openings 38 in the part of inner pipe 37 located in the low temperature cooling section 31 of the cooling unit 12 in Fig. 1. By selecting the desired number of such branch conduits and points at which the diverted weak inert gas is introduced into the upper coil 36*d*, an opportunity is afforded to determine the lowest possible refrigerating temperature which will be effected in the low temperature cooling section, as well as the relationship between the quantity of cooling effect to be produced at a higher temperature in the higher temperature cooling section and the quantity of cooling effect to be produced at a low temperature in the low temperature cooling section.

Another manner of arranging the coils 36*d* and 36*e* in Fig. 6 is illustrated in Fig. 5 in which like parts are referred to by the same reference numerals with one hundred added thereto. In Fig. 5 the weak inert gas piping 160 passes through an opening 161 in the rear wall 158 of container 155. The weak gas piping 160 includes a first section 160*a* thermally connected at 162 to the top of the bottom horizontal wall 157 and a second section 160*b* thermally connected at 163 to the underside of the top horizontal wall 156.

Liquid refrigerant flows from the condenser to the cooling unit 112*d* through a conduit 118*d* which passes through an opening 164 in the rear wall 158 of the container and is thermally connected at 72 to the top surface of the bottom wall 157. Liquid refrigerant is conducted from conduit 118*d* to a region 73 at the right-hand side of the low temperature coil 136*d*. Such liquid refrigerant flows from right to left in coil 136*d* and then passes through a connection 74 to a region 75 of coil 136*e* for flow therein from right to left in Fig. 5. The connection 74 for liquid refrigerant is thermally connected at 76 to the underside of the top wall 156.

The embodiment of Fig. 5 differs from Fig. 4 in that all of the weak inert gas, after flowing in thermal relation with the lower coil 136*e* and then in thermal relation with the upper coil 136*d*, is introduced at one point 77 to the left-hand end of the upper coil 136*d*. Essentially, weak inert gas in the pipe section 160*a* flows in heat exchange relation with inert gas flowing in the coil 136*e*. The partial pressure of refrigerant vapor in the weak gas in pipe section 160*a* remains unchanged while the partial pressure of refrigerant vapor in the inert gas flowing in coil 136*e* is constantly increasing. In effect, the weak gas in pipe section 160*a* is flowing in a general direction which is opposite to the general direction in which inert gas flows in coil 136*e* from the right to the left of the wall 157.

In a similar manner, weak inert gas in the pipe section 160*b* flows in heat exchange relation with inert gas flowing in the coil 136*d*. The partial pressure of refrigerant vapor in the weak gas in pipe section 160*b* remains unchanged while the partial pressure of refrigerant vapor in the inert gas flowing in coil 136*d* is constantly increasing. Hence, the weak gas in pipe section 160*b* is also flowing in a general direction which is opposite to the general direction in which inert gas flows in coil 136*d* from left to right at the wall 156.

While the embodiment of Fig. 5 differs from the preceding embodiments in that all of the inert gas is introduced into the presence of inert gas at the point 77, nevertheless an important advantage is realized in that an extremely low refrigerating temperature can be produced at such point for the reasons given above in describing the operation of the Fig. 1 embodiment. Even in the embodiment of Fig. 1, the pipe 37 may be closed throughout its length and a single opening 38 provided at the region 42. In such case, as in the embodiment of Fig. 5, the refrigerating temperature produced will increase in the direction of flow of the inert gas while flowing in the presence of liquid refrigerant. A similar arrangement may be employed in Fig. 2 in which openings 38*a* are formed in pipe 37*a* only at the left-hand closed end thereof and at the region thereof at the vicinity of the vertical partition between spaces 33*a* and 34*a*. Such an arrangement of the Fig. 2 embodiment will, of course, be generally similar to the embodiment of Fig. 3 in regard to the manner in which weak inert gas is supplied to different sections of the cooling unit.

While the pipe sections 60*a* and 60*b* in Fig. 4 may be of substantially the same length as the coils 36*e* and 36*d*, respectively, and in thermal contact with one another along their entire lengths, equally good results are obtained by employing the pipe sections 60*a* and 60*b* which provide a path of flow for weak gas which is considerably shorter and less than one-half the length of the path of flow for inert gas flowing in the presence of liquid refrigerant in the coils 36*d* and 36*e*. However, in the embodiment of Fig. 4, satisfactory heat exchange is effected between weak gas in pipe sections 60*a* and 60*b* and inert gas in the coils 36*e* and 36*d*, respectively, by reason of the fact that the pipe section 60*a* and coil 36*e* are thermally connected to the same bottom horizontal wall 57 while the pipe section 60*b* and coil 36*d* are thermally connected to the same top horizontal wall 56. Irrespective of the manner in which weak inert gas is introduced into the presence of liquid refrigerant in the different embodiments of the invention illustrated and described above, each of the embodiments disclosed herein provides an arrangement for effectively producing a relatively large part of the total refrigerating or cooling output of the refrigeration system at an extremely low temperature.

While several embodiments of the invention have been shown and described, it will be apparent that modifications and changes may be made without departing from the spirit and scope of the invention, as pointed out in the following claims.

What is claimed is:

1. An absorption refrigeration system having a circuit for circulation of inert gas including an absorber and a cooling element in which refrigerant fluid evaporates in the presence of such gas, said cooling element providing an elongated path of flow for inert gas from a first to a second end thereof, first conduit means in said circuit for flowing inert gas from the second end of said cooling element to said absorber, and second conduit means in said circuit for flowing inert gas from said absorber in thermal exchange relation with said cooling element in a direction generally extending from the second to the first end thereof and then introducing such inert gas into the presence of refrigerant fluid in said cooling element at the vicinity of the first end thereof, said second conduit means also including means for diverting inert gas from a number of regions along the length thereof into a number of different regions of said cooling element between the first and second ends thereof.

2. An absorption refrigeration system as set forth in claim 1 in which said means for diverting inert gas from each region of said second conduit means to each region of said cooling element constitutes a by-pass for the inert gas, successive bypasses communicating with said second conduit means in the direction of flow of inert gas therethrough diverting inert gas to regions of said cooling element which are successively nearer to the first end of said cooling element along the path of flow of inert gas from such first end of said cooling element to the second end thereof.

3. An absorption refrigeration system having a circuit for circulation of inert gas including an absorber and low and higher temperature cooling elements in which refrigerant fluid evaporates in the presence of such gas, said low temperature cooling element providing an elongated path of flow for inert gas from a first to a second end

thereof, said higher temperature cooling element providing an elongated path of flow for inert gas from a first to a second end thereof, first conduit means in said circuit for flowing inert gas from the second end of said low temperature cooling element to the first end of said higher temperature cooling element and from the second end of the latter to said absorber, and second conduit means in said circuit for flowing inert gas from said absorber in thermal exchange relation successively with said higher temperature cooling element and said low temperature cooling element and then introducing such inert gas into the presence of refrigerant fluid in said low temperature cooling element at the vicinity of the first end thereof, said second conduit means also including means for diverting into the presence of refrigerant fluid in said higher temperature cooling element a part of the inert gas flowing therethrough after such gas flows in heat exchange relation with said higher temperature cooling element.

4. An absorption refrigeration system having a circuit for circulation of inert gas including an absorber and low and higher temperature cooling elements in which refrigerant fluid evaporates in the presence of such gas, said low temperature cooling element providing an elongated path of flow for inert gas from a first to a second end thereof, said higher temperature cooling element providing an elongated path of flow for inert gas from a first to a second end thereof, first conduit means in said circuit for flowing inert gas from the second end of said low temperature cooling element to the first end of said higher temperature cooling element and from the second end of the latter to said absorber, and second conduit means in said circuit for flowing inert gas from said absorber in thermal exchange relation successively with said higher temperature cooling element and said low temperature cooling element and then introducing such inert gas into the presence of refrigerant fluid in said low temperature cooling element at the vicinity of the first end thereof, said second conduit means also including means for diverting inert gas from a number of regions along the length thereof into a number of different regions of said low and higher temperature cooling elements between the first and second ends of each of said cooling elements.

5. An absorption refrigeration system as set forth in claim 4 in which said means for diverting inert gas from each region of said second conduit means to each region of said low and higher temperature cooling elements constitutes a by-pass for the inert gas, successive by-passes communicating with said second conduit means in the direction of flow of inert gas therethrough diverting inert gas to regions of said higher temperature cooling element and low temperature cooling element which are successively nearer to the first end of said low temperature cooling element along the path of flow of inert gas from such first end of said low temperature cooling element to the second end of said higher temperature cooling element.

6. A refrigerator comprising a cabinet having an interior provided with spaces thermally segregated from one another, an absorption refrigeration system having a circuit for circulation of inert gas including an absorber and low and higher temperature cooling elements in which refrigerant fluid evaporates in the presence of such gas, said low temperature cooling element being arranged to effect cooling of one of said spaces and said higher temperature cooling element being arranged to effect cooling of another of said spaces, first conduit means in said circuit for flowing inert gas from said low temperature cooling element to said higher temperature cooling element and from the latter to said absorber, and second conduit means in said circuit for flowing inert gas from said absorber in thermal exchange relation successively with said higher temperature cooling element and said low temperature cooling element and then introducing such inert gas into the presence of refrigerant fluid in said low temperature cooling element, said second conduit means also including means for diverting into the presence of refrigerant fluid in said higher temperature cooling element a part of the inert gas flowing therethrough after such gas flows in heat exchange relation with said higher temperature cooling element.

7. A refrigerator comprising a cabinet having thermally insulated walls forming a space, means providing a horizontally extending partition in said space to divide the latter into upper and lower compartments, an absorption refrigeration system having a circuit for circulation of inert gas including an absorber and low and higher temperature cooling elements one above the other and in which refrigerant fluid evaporates in the presence of such gas, said low temperature cooling element comprising piping essentially in a single horizontal plane which is disposed adjacent to and at the vicinity of said partition means at the top side thereof for cooling said upper compartment and said higher temperature cooling element comprising piping essentially in a single horizontal plane which is disposed adjacent to and at the vicinity of said partition means at the bottom side thereof for cooling said lower compartment, first conduit means in said circuit for conducting inert gas and refrigerant fluid from said low temperature cooling element to said higher temperature cooling element for flow therethrough and for conducting inert gas from the latter to said absorber, second conduit means in said circuit for flowing inert gas from said absorber into said low temperature cooling element, and conduit means for conducting refrigerant fluid to said low temperature cooling element into the presence of inert gas therein, the piping of said low and higher temperature cooling elements providing elongated paths of flow for the inert gas and having temperature gradients in which the temperature progressively increases from one end to the opposite end in the path of flow of each cooling element, said second conduit means including sections which in a lengthwise direction are in thermal relation with said low and higher temperature cooling elements for flowing inert gas out of the presence of liquid refrigerant from said absorber in thermal exchange relation with said higher temperature cooling element toward progressively cooler regions thereof and thence in thermal exchange relation with said low temperature cooling element toward progressively cooler regions thereof, said conduit means for liquid refrigerant being connected to said low temperature cooling element for conducting liquid refrigerant into the presence of the inert gas after the latter flows through both sections of said second conduit means in thermal exchange relation with said low and higher temperature cooling elements.

8. A refrigerator as set forth in claim 7 in which said partition means comprises a pair of spaced apart horizontal wall members, the piping of said low temperature cooling element being in good heat conductive connection with the underside of the top horizontal wall member and the piping of said higher temperature cooling element being in good heat conductive connection with the top surface of the bottom horizontal wall member, one section of said second conduit means being in heat exchange relation with the top surface of the bottom horizontal wall member and another section thereof being in heat exchange relation with the underside of the top horizontal wall member.

9. A refrigerator as set forth in claim 8 in which said conduit means for conducting refrigerant fluid to said low temperature cooling element includes a first portion in heat exchange relation with the top surface of said bottom horizontal wall member and a second portion in heat exchange relation with the underside of said top horizontal wall member.

10. A refrigerator as set forth in claim 7 in which said second conduit means includes means for diverting into said higher temperature cooling element a part of the inert gas flowing therethrough after such inert gas

flows in heat exchange relation with said higher temperature cooling element.

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