May 27, 1952 W. L. EDEL 2,598,240

UNIFORM PRESSURE ABSORPTION EVAPORATOR

Filed Aug. 24, 1948 2 SHEETS—SHEET 1

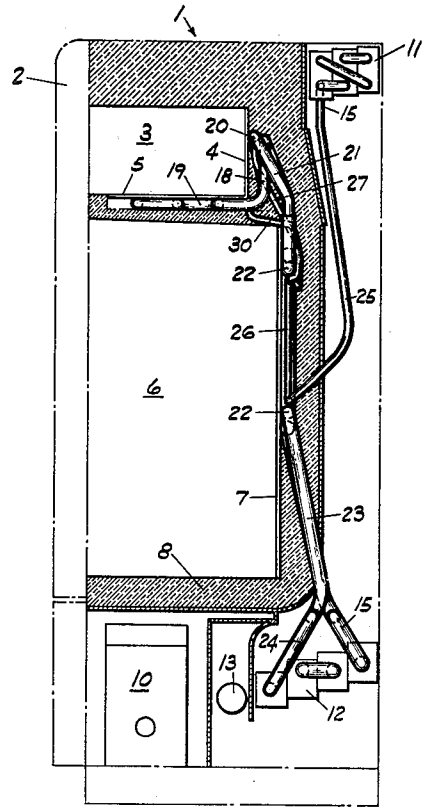


Fig. 1

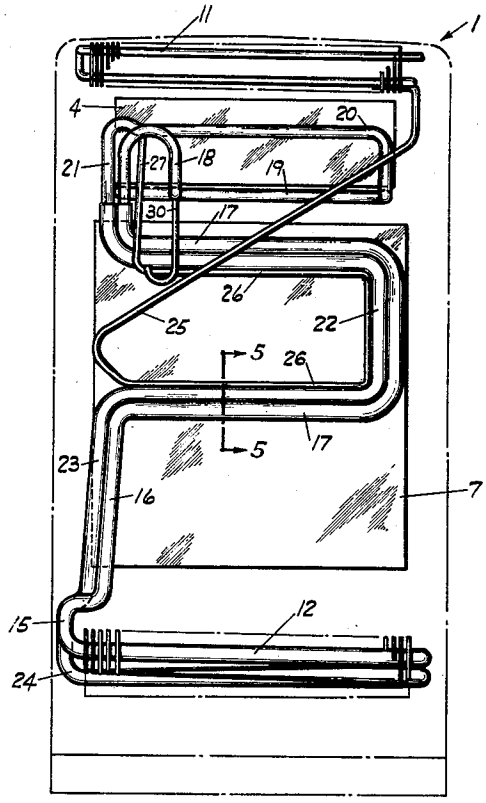


Fig. 2

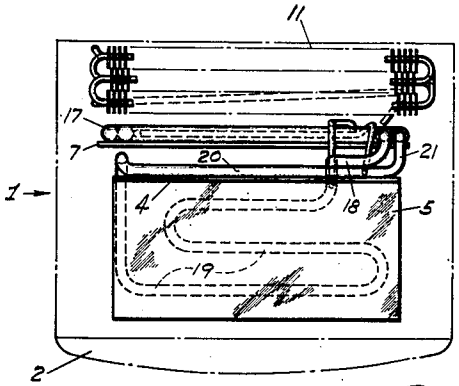


Fig. 3

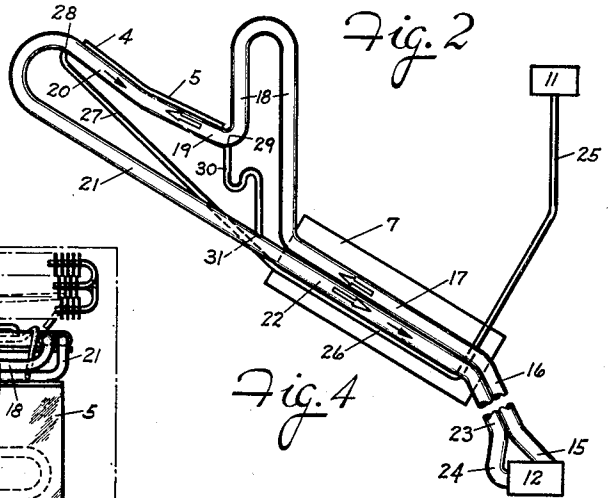


Fig. 4

INVENTOR.
WALTER L. EDEL
BY Arthur W. Colert
ATTORNEY

May 27, 1952 W. L. EDEL 2,598,240

UNIFORM PRESSURE ABSORPTION EVAPORATOR

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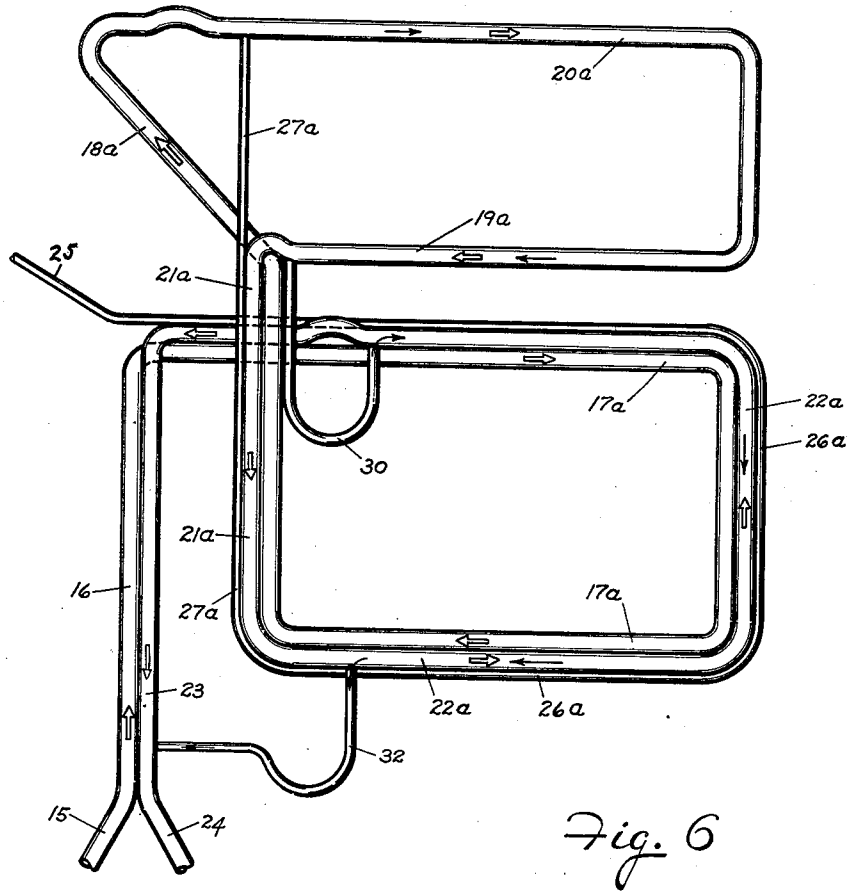


Fig. 6

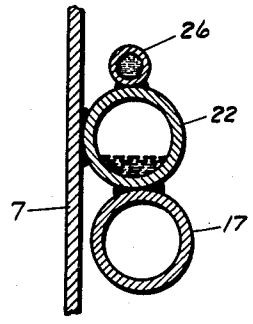


Fig. 5

INVENTOR.
WALTER L. EDEL
BY Arthur Robert
ATTORNEY

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UNIFORM PRESSURE ABSORPTION EVAPORATOR

Walter L. Edel, Louisville, Ky., assignor to Clayton & Lambert Manufacturing Company, Louisville, Ky., a corporation of Delaware

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8 Claims. (Cl. 62—119.5)

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With the increasing popularity of frozen foods, it has become highly desirable to provide household and like refrigerators with freezing and chilling compartments of requisite size and to maintain them at requisite temperatures. Thus, for example, in a room temperature of 110° F., it is desirable to maintain, under no load conditions, a 1 to 1.5 cubic foot freezing compartment and a 7 cubic foot chilling compartment at air temperatures which do not exceed the generally recommended maximums of 10° F. and 46° F. respectively.

It has been found extremely difficult to achieve a performance of this character in absorption refrigerators of the uniform pressure type. This may be illustrated by reference to the performance of what is undoubtedly the best absorption refrigerator of the uniform pressure type thus far developed and marketed.

This particular refrigerator comprises: (1) a refrigerator cabinet having a food storage chamber divided into a freezing compartment approximating 1.1 cubic feet and a chilling compartment approximating 7.2 cubic feet; (2) an evaporator in the form of an elongate tube having its colder section, which is hereinafter called the freezing section, arranged to refrigerate the freezing compartment, and its warmer section, which is hereinafter called the chilling section, arranged to refrigerate the chilling compartment; (3) a heat exchanger placing the purified hydrogen gas, flowing upwardly from the absorber to the evaporator, in heat exchange relationship with the heavy mixed gas and residual liquor flowing downwardly from the evaporator outlet to the absorber; (4) a liquid tube conducting the residual liquor from the evaporator outlet to the heat exchanger; and (5) a gas tube separately conducting the heavy mixed gas from the evaporator outlet to the heat exchanger, this tube being arranged in direct heat exchange relationship with the incoming liquid ammonia feed line to precool the ammonia.

With a room temperature of 110° F., this refrigerator maintains the freezing compartment at a no load air temperature of 20 to 24° F. which exceeds the recommended maximum by 10 to 14° F.

The principal object of this invention is to effect a substantial improvement in the performance of absorption refrigerators of the uniform pressure type and, more particularly, to secure, in such type of refrigerator, freezing compartment temperatures well within the presently recommended maximum.

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Another object is to achieve the principal objective without any offsetting disadvantage such as an objectionable change in overall size or weight, in manufacturing or operating costs, or in overall operation.

A further object is to provide an extremely simple means for effecting a substantial improvement in the performance of this type of refrigerator and, more particularly, for producing and maintaining, in the freezing compartment, temperatures low enough to insure highly satisfactory operation under all normally encountered conditions.

I have found that a substantial reduction in the freezing compartment air temperature may be effected simply by placing either or both of the incoming hydrogen and ammonia feed lines going to the evaporator in direct physical heat exchange relationship with the chilling section of the evaporator so as to precool either or both of these fluids before they enter the evaporator. In this way the introduction of heat into the freezing section is minimized and the securement of lower freezing temperatures promoted.

Off hand, one mght expect that the introduction of heat into the evaporator chilling section would deleteriously affect its operation and bring about substantially higher air temperatures in the chilling compartment. Surprisingly, however, the pre-cooling of the incoming hydrogen and ammonia in the chilling section does not appear to do so. It may be that the production of substantially lower operating temperatures in the freezing section results in the production, in the chilling section, of better operating conditions which partly or wholly offset any disadvantage arising from the introduction of heat into the chilling section. Furthermore, since the heat introduced into the chilling section at any one point, and particularly at the point where the relatively warm feed lines first come into contact with the chilling section of the evaporator, is at a higher temperature than the temperature prevailing at that point within the evaporator chilling section, I have reason to believe that the thermal efficiency of the chilling section, and the operating efficiency of the refrigerating mechanism as a whole, is substantially improved and this improvement may be sufficient to offset, or even outweigh, any disadvantage arising from the introduction of heat into the chilling section.

Whatever the reason may be, I have not experienced any difficulty in obtaining chilling compartment air temperatures below the recommended maximum. For example, with a re-

frigerator having freezing and chilling compartments of 1¼ and 7 cubic feet respectively, and with a room temperature of 110° F., I have been able to secure freezing and chilling compartment air temperatures of 5° and 44° F. A performance of this character compares favorably with any of the presently available household refrigerators regardless of type.

The invention is illustrated in the accompanying drawings wherein:

Figure 1 is a side view of one embodiment of the invention, the refrigerator cabinet being shown more or less in outline;

Figure 2 is a rear view of Figure 1 with the insulation removed;

Figure 3 is a top view of Figure 2 with the insulation removed;

Figure 4 is a schematic view illustrating the arrangement of the parts forming the evaporator, heat exchanger, hydrogen gas feed line and the ammonia feed line;

Figure 5 is a section taken along line 5—5 of Figure 2 illustrating how the tubes are bonded; and

Figure 6 is a schematic view of a modified form of evaporator.

The uniform pressure absorption refrigerator, illustrated in Figures 1–4, is assumed to be, and is explained as, one utilizing an ammonia, hydrogen and water system, although any other suitable system may be employed. As illustrated, this refrigerator comprises: a cabinet; and a refrigerating mechanism.

The cabinet 1 has: an insulating front door 2 providing access to an unobstructed freezing compartment 3, formed by appropriate walls including rear and bottom walls 4 and 5, and an unobstructed chilling compartment 6, formed by appropriate walls including rear wall 7, the walls 4, 5 and 7 being composed of heat conductive material preferably metal; and suitable heat insulating material 8 completely surrounding each compartment except at their open door-insulated front ends.

The refrigerating mechanism comprises: a generator 10; an air cooled ammonia condenser 11; an air cooled absorber 12; a strong and weak liquor heat exchanger not shown; a receiver 13; and an elongated tube extending upwardly from the absorber and then downwardly back to the absorber to form an evaporator, a heat exchanger between the evaporator and the absorber 12, and the endless gas circuit required for the operation of the absorber, heat exchanger and evaporator.

The evaporator has two sections, namely: a freezing section outside of the freezing compartment 3 but in direct physical heat transfer relationship with its rear and bottom walls 4 and 5; and a chilling section outside of the chilling compartment but in direct physical heat transfer relationship with its rear wall 7. This evaporator is one in which the hydrogen gas and ammonia liquor are initially fed to opposite (lower and upper) ends of the freezing section to flow in countercurrent relationship and the resulting mixed gas and partially evaporated ammonia liquor are finally fed to the upper end of the chilling section to flow in concurrent relationship. The paths of these materials are explained in the following paragraphs in connection with Figure 4.

As shown in Figure 4, the gas, in flowing upwardly from the absorber and downwardly back to it, passes through the following sections of the elongated tube: an absorber outlet section 15, heat exchanger section 16, precooling section 17 and connector section 18, all for the upward flow of relatively pure hydrogen gas; evaporator freezing sections 19 and 20 for the upward flow of mixed gas; and connector section 21, evaporator chilling section 22, heat exchanger section 23 and absorber inlet section 24, all for the downward flow of the heavy mixed gas.

The liquor flowing from the ammonia condenser 11, passes through the following sections: downwardly through section 25 of the ammonia feed line; upwardly through precooling section 26 and section 27 of that feed line to feed point 28 where it enters the upper end of the freezing section 20 adjacent the connection of that section to the connector section 21; downwardly through the freezing sections 20 and 19 to the exit point 29 where it leaves the freezing section; downwardly through transfer line 30 to the feed point 31 where it enters the upper end of the chilling section 22 adjacent the connection of that section to the connector section 21; and thence downwardly through chilling section 22, heat exchange section 23, absorber inlet section 24 to the absorber 12.

It will now be appreciated that the incoming ammonia is fed to the upper end of the freezing section while the incoming hydrogen is fed to the lower end of the freezing section so that these fluids flow through the freezing section in countercurrent relationship to each other. However, both of these fluids are fed to the upper end of the chilling section to flow in concurrent relationship therethrough. It will also be understood that the ammonia is only partially evaporated in the freezing section, its evaporation being completed, or substantially completed, in the chilling section.

In the specific embodiment shown in Figs. 1–3, the freezing section 20 is L-shaped so that it extends horizontally across the upper part of the rear wall 4 and thence vertically downward along one side edge of that wall to the bottom edge where it connects into the freezing section 19 which extends in a serpentine manner along the bottom wall 5 to the exit point 29. The chilling section 22 is U-shaped extending horizontally along the upper edge of rear wall 7 and thence downwardly along the side edge to a point adjacent the central horizontal level of the chilling compartment 6 and thence horizontally across the rear wall 7 to the opposite side edge where it joins heat exchanger section 23 which slopes rearwardly away from the rear wall of the chilling compartment.

In accordance with my invention, either or both of the incoming hydrogen gas and ammonia liquor feed lines are placed in precooling relationship with the evaporator chilling section 22 in order to precool these incoming fluids before they enter the evaporator. Accordingly, I show the hydrogen precooling section 17 and ammonia precooling section 26 both in direct physical contact with the evaporator chilling section 22. Preferably also these precooling sections 17 and 26 are arranged with their fluids flowing in the same direction but in counterflow relationship to the gas and liquid flowing through chilling section 22.

The tubular sections forming each part of the evaporator are soldered, or otherwise bonded, directly to the adjacent wall. Thus, freezing section 19 is bonded to the bottom wall 5 of the freezing compartment, while freezing section 20

and chilling section 22 are respectively bonded to rear walls 4 and 7. The walls 4, 5 and 7 may either form part of the compartments 3 and 6 or they may be separate walls which, when the refrigerator is assembled, are brought into good heat transfer relationship with the corresponding walls of the food compartments. As indicated in Figure 5, only the evaporator tubes are bonded to the food compartment walls. The precooling sections 17 and 26 are bonded to the chilling section 22 but are spaced from the rear wall 7 so as to avoid the direct transfer of heat from either of these incoming feed line sections to rear wall 7.

With an arrangement of the foregoing character operating in a room temperature of 100° F., I have achieved a performance of the following character: hydrogen leaving the absorber at a temperature of 118° F. is cooled in the heat exchanger section 16 to about 57° F. then in the precooling section 17 to a temperature approximating 17° F., while ammonia leaving the condenser at a temperature approximating 128° F. is precooled in section 26 to a temperature approximating 15° F. This ammonia, entering freezing section 29 at 15° F., evaporates as it passes downwardly through freezing sections 20 and 19. In so doing, it cools itself, by such evaporation, to a much lower temperature by the time it reaches the ammonia exit point 29 at the lower end of the freezing section. This exit point 29 corresponds to the point of initial refrigeration because it is in the area where the incoming precooled hydrogen first strikes the evaporating stream of ammonia. The low temperatured hydrogen and the still lower temperatured ammonia thus cooperate to promote the achievement of an extremely low temperature adjacent this point of initial refrigeration. The operating temperature of the freezing section of the evaporator naturally rises progressively through sections 19 and 20 but remains below 0° F. at the point where these sections join and reaches a temperature approximating 3° F. at the upper end of section 20 where the outgoing mixed gas enters the connector 21. With these temperature conditions, the freezing section produced an air temperature approximating 5° F. in a 1¼ cubic foot freezing compartment.

The performance of the chilling section, under the same conditions of operation, is indicated by the chilling tube temperatures which approximate 8° F. at the upper end of the chilling tube, 22° F. at its center, and 49° F. at its lower end. With these temperature conditions, the chilling section produced an air temperature approximating 43° F. in a 7 cubic foot chilling compartment.

The performance of the refrigerator at room temperatures of 73.5° F. and 110° F. is shown by the following tabulation:

(*a*) Room temperature	73½° F.	110° F.
(*b*) Ammonia leaving condenser 11	94° F.	128° F.
(*c*) Hydrogen leaving absorber 12	87° F.	118° F.
(*d*) Hydrogen drop in precooling section 17 from entry to exit (exit temperature assumed to be same as (*g*) below).	26° F. to below 0.	57° F. to 17° F.
(*e*) Ammonia drop in precooling section 26 from entry to exit (entry temperature assumed to be same as (*b*) above and exit temperature assumed same as (*i*) below).	94° F. to below 0.	128° F. to 15° F.
(*f*) Chilling tube drop from outlet to inlet ends.	25° F. to below 0.	49° F. to 8° F.
(*g*) Hydrogen entering freezing section 19.	below 0	17° F.
(*h*) Mixed gas leaving freezing section 20.	below 0	3° F.
(*i*) Ammonia entering freezing section 20.	below 0	15° F.
(*j*) Freezing compartment air	minus 9° F.	5° F.
(*k*) Chilling compartment air	25° F.	43° F.

In connection with the operation of this refrigerator in a room temperature of 110° F., for example, it will be noted that, at a point corresponding to the outlet end of the chilling tube, the chilling tube temperature is 49° F., whereas the ammonia and hydrogen temperatures respectively are 79° F. and 8° F. higher. With these temperature differentials, the heat of the incoming ammonia and hydrogen should cause the liquor in the chilling tube to evaporate vigorously. This vigorous evaporation no doubt occurs throughout the length of the chilling tube because the chilling tube temperature at the inlet end is also appreciably lower than the incoming hydrogen and ammonia at the corresponding point. The vigorous evaporation, thus occasioned in the chilling section, should increase the thermal efficiency of that section and may increase the operating efficiency of the refrigerating mechanism as a whole. It is, therefore, possible that these increases effect, in the operation of the mechanism, an improvement which is so substantial that it either offsets or outweighs any disadvantage arising from the introduction of heat into the chilling section.

In the modification shown in Figure 6, ammonia and hydrogen are both fed to the upper end of the freezing section to flow concurrently therethrough and thence to opposite ends of the chilling section to flow in countercurrent relationship. Here the gas circuit, proceeding in the direction of gas flow, includes: absorber outlet section 15; heat exchanger section 16; precooling section 17*a*; connector section 18*a*; freezer sections 20*a*; and 19*a*; connector section 21*a*; chilling section 22*a*; heat exchanger section 23; and absorber inlet section 24. The liquor from the ammonia condenser passes through the following sections: section 25; precooling section 26*a* and section 27*a*, all in the feed line; freezing sections 20*a*; and 19*a*; transfer tube 30; chilling section 22*a*; and residual liquor tube 32 which connects the lower end of section 22*a* into the heat exchanger section 23.

In both of the arrangements shown in Figures 1–4 and 6, the chilling section is serially connected to one end of the freezing section by a gas connector containing substantially no liquid ammonia and in which no evaporation takes place. The connector 21 of Figures 1–4 is not in heat exchange relationship with any part of the gas circuit but in Figure 6 the corresponding connector 21*a* is in heat exchange relationship with both of the incoming gas and liquid ammonia feed lines. In both arrangements also, the precooling section of the incoming hydrogen line is connected to the inlet end of the freezing section by a connector in which no evaporation occurs. Accordingly, both arrangements involve conduit means forming evaporator freezing and chilling sections connected in series by a gas flow connector, the freezing section having a gas inlet and a liquid refrigerant feed point and the chilling section a mixed gas outlet with both sections and the gas flow connector cooperating to provide a gas path for the flow of inert gas from the gas inlet serially through the freezing section, the connector and the chilling section to the gas outlet and a path for the flow of liquid refrigerant from the feed point through the freezing section and thence through the chilling section.

This application is a continuation in part of

my application Serial No. 708,603 filed November 8, 1946, now abandoned.

I claim as my invention:

1. In a refrigerator of the uniform pressure absorption type: an insulated cabinet providing separate insulated freezing and chilling compartments; conduit means forming an evaporator freezing section in heat exchange relation to said freezing compartment and a chilling section in heat exchange relation to said chilling compartment, said sections being connected in series by a connector for the flow of gas and by a separate transfer line for the flow of liquid refrigerant, the freezing section having a gas inlet and a liquid refrigerant feed point, and the chilling section having a mixed gas outlet, both of said sections cooperating to provide a gas path for the flow of gas from the gas inlet serially through the freezing section, the connector and the chilling section to the gas outlet and providing a liquid path for the flow of liquid refrigerant from said feed point serially through the freezing section, the transfer line and the chilling section; and conduit means forming separate passages for the separate flow of incoming liquid refrigerant into said feed point and of incoming inert gas into said gas inlet, both of said incoming passages being elongated and arranged in direct physical heat transfer relationship along a portion of their respective lengths with said chilling section.

2. An evaporator as specified in claim 1 wherein the direction of flow of liquid refrigerant and inert gas in the freezing and chilling sections are respectively countercurrent and concurrent.

3. In a refrigerator of the uniform pressure absorption type: an insulated cabinet interiorly providing insulated freezing and chilling compartments which are also separated from each other by insulation, each compartment having a heat-conductive wall presenting an inner face exposed to its compartment space and an outer face exposed to its compartment insulation; an absorber; a closed-circuit conduit connected between the absorber inlet and outlet for the circulation of inert refrigerant gas and including a freezing section in direct physical heat transfer relationship with the outer face of said freezing compartment wall to constitute a freezing evaporator, a chilling section in direct physical heat transfer relationship with the outer face of said chilling compartment wall to constitute a chilling evaporator, and a gas feed section for carrying inert gas from the absorber outlet to the freezing evaporator inlet; and supply line means for supplying evaporating liquid refrigerant to said freezing and chilling evaporators, said means including an elongate tube in the freezing evaporator supply line; said tube and said gas feed section both being in direct physical heat transfer relationship along a portion of their respective lengths with said chilling evaporator for precooling purposes.

4. In the refrigerator of claim 3 wherein: the direction of flow of liquid refrigerant and inert gas in the freezing and chilling sections are respectively countercurrent and concurrent.

5. In the refrigerator of claim 3 wherein: the precooled portion of said liquid refrigerant tube is spaced from the outer face of said chilling compartment wall.

6. In the refrigerator of claim 3 wherein: the precooled portion of said gas feed section is spaced from the outer face of said chilling compartment wall.

7. In a refrigerator of the uniform pressure absorption type: an insulated cabinet; an insulated partition dividing the interior of said cabinet into freezing and chilling compartments, said chilling compartment having a heat-conductive liner; an absorber; a closed-circuit inert refrigerant gas conduit having, for the flow of gas between the absorber outlet and inlet, elongate gas feed, freezing, connector, chilling and return sections, the feed section extending from the absorber outlet to the freezing section inlet and having relatively lower and upper elongate portions, the freezing section extending to the connector section inlet and being outside of the freezing compartment but in direct heat exchange relationship therewith to constitute a freezing evaporator, the connector section extending to the chilling section inlet, the chilling section extending to the return section inlet and being outside of the chilling compartment but in direct physical heat exchange relationship with said liner to constitute a chilling evaporator, and the return section extending from the chilling evaporator outlet to the absorber inlet; and supply line means for supplying evaporating liquid refrigerant to the freezing and chilling evaporators for flow therethrough, including an elongate tube in the freezing evaporator supply line; said elongate refrigerant liquid tube and the upper portion of said refrigerant gas feed section both being in direct physical heat exchange relationship along their respective lengths with the chilling evaporator for precooling purposes but spaced from said liner; and said return section and the lower portion of said feed section both being in direct physical heat exchange relationship with each other but spaced from said liner.

8. In the refrigerator of claim 7 wherein: the direction of flow of liquid refrigerant and inert gas in the freezing and chilling sections are respectively countercurrent and concurrent.

WALTER L. EDEL.

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