March 25, 1930. J. W. MARTIN, JR 1,752,276

REFRIGERATING APPARATUS AND METHOD

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FIG. 2.

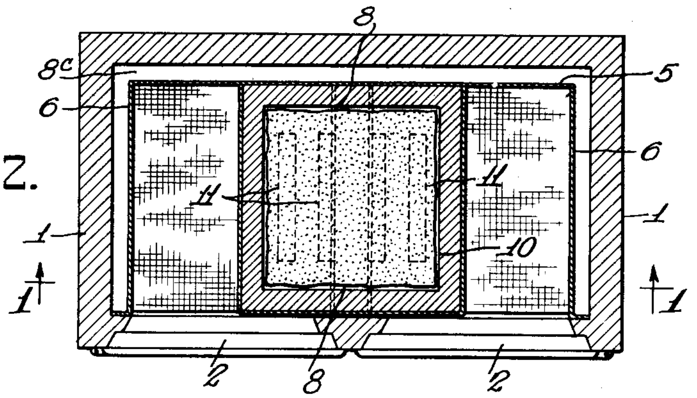
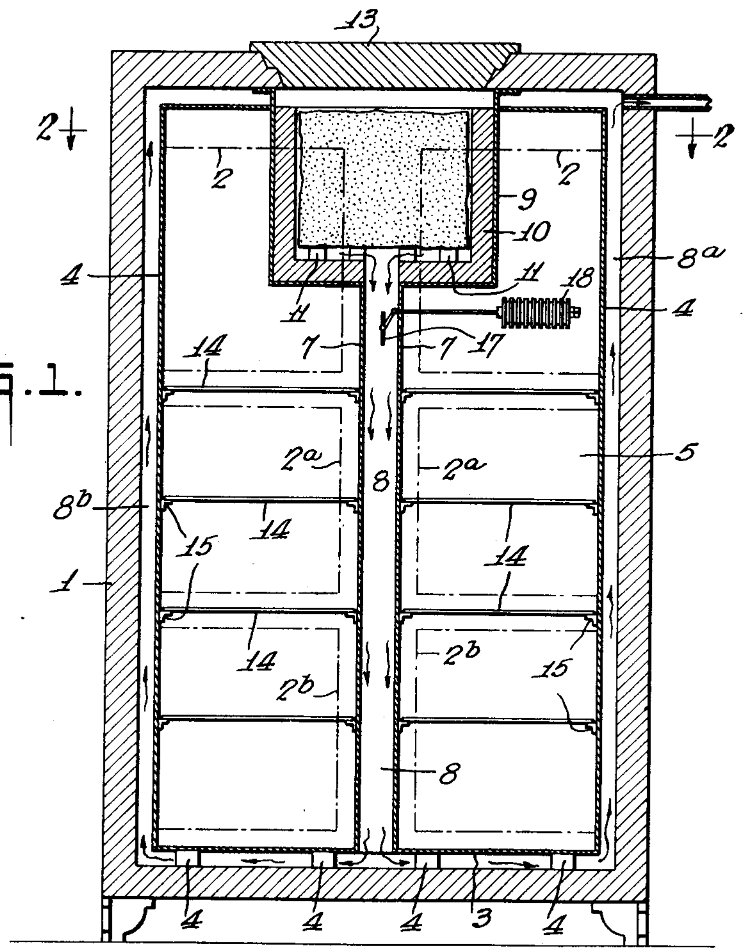


FIG. 1.



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REFRIGERATING APPARATUS AND METHOD

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FIG. 3.

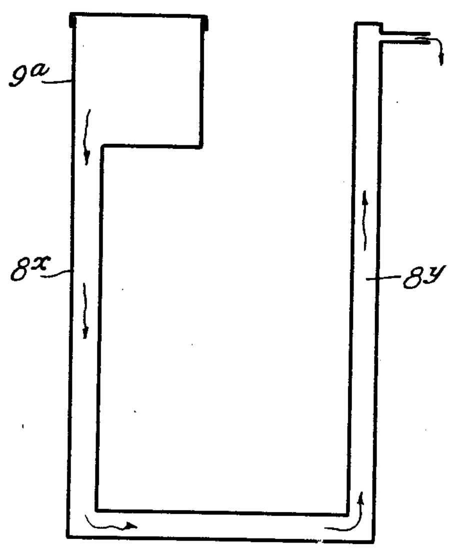


FIG. 6.

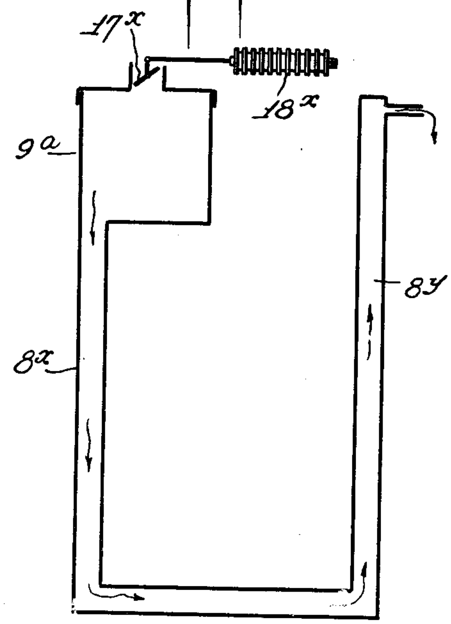


FIG. 4.

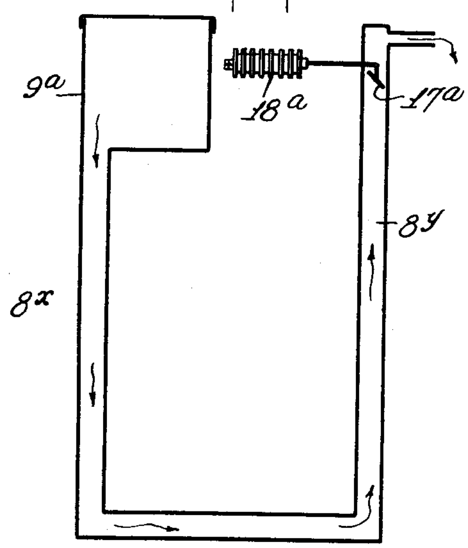
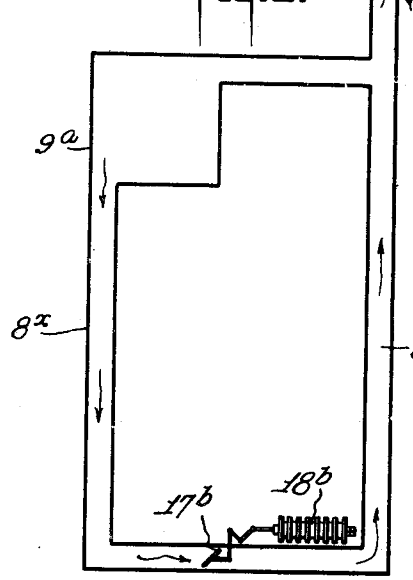


FIG. 5.



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REFRIGERATING APPARATUS AND METHOD

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FIG. 7

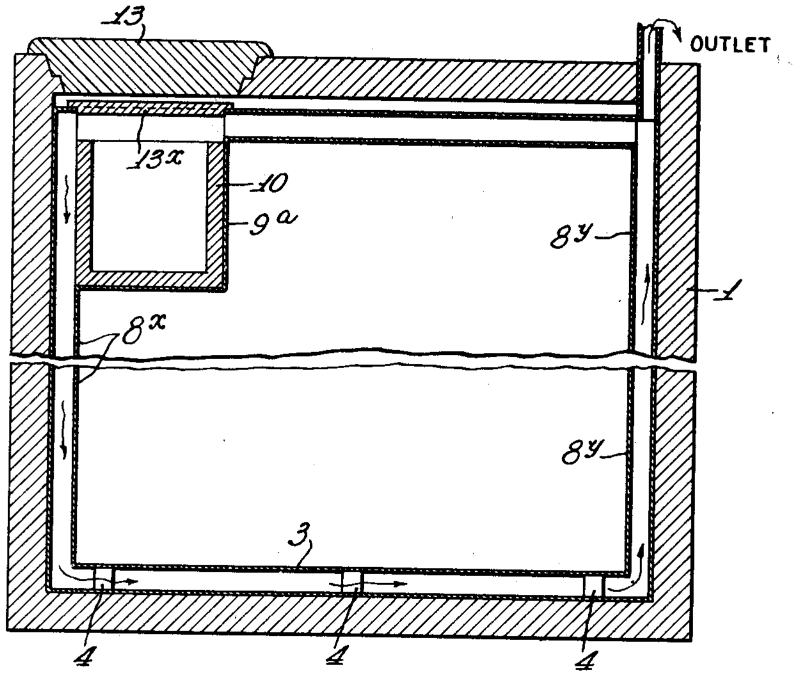
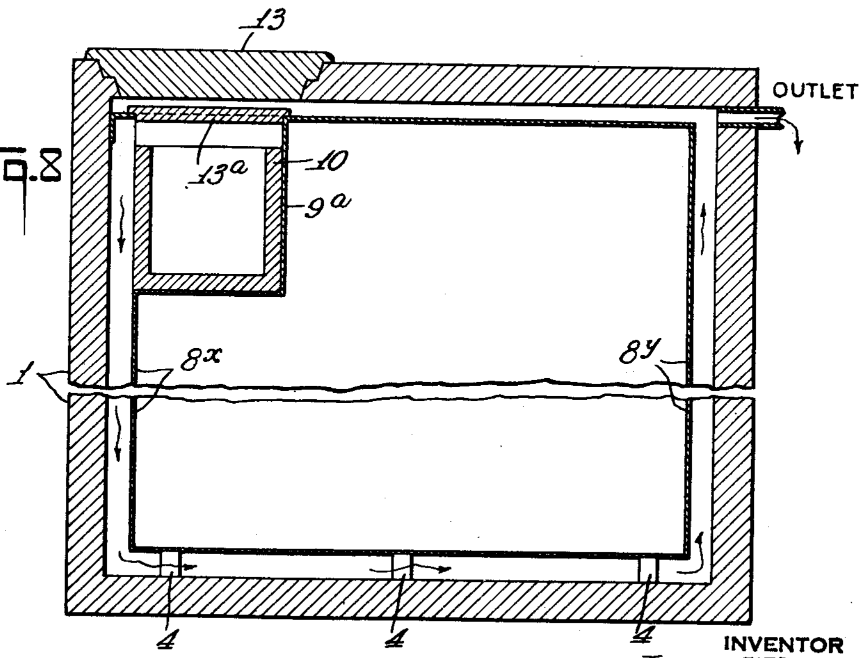


FIG. 8



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Patented Mar. 25, 1930 **1,752,276**

UNITED STATES PATENT OFFICE

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REFRIGERATING APPARATUS AND METHOD

Application filed December 8, 1928. Serial No. 324,639.

My present invention relates to apparatus and methods set forth in my application Serial No. 116,103, filed June 15, 1926, of which this case is a continuation in part.

Both cases relate to refrigerators of the type adapted to employ very intense refrigerants, particularly solid carbon dioxide, made either by freezing the liquid directly to solid blocs, or by expanding the liquid to so-called snow, which is then compressed into blocks.

It is applicable to refrigerators having side doors, as in ordinary household refrigerators, but certain features are of more general applicability and will be found useful in cold storage plants, refrigerating cars, trucks, and the like.

In both cases, the object is to utilize certain unique qualities or factors peculiar to the solid carbon dioxide, as for instance:—

Solid carbon dioxide sublimates directly to gas, without any intermediate liquid state at a temperature approximately 110° F. below zero although varying conditions may cause it to vary within wide limits above and below this temperature. The resulting carbon dioxide gas is very heavy because of its low temperature and also because of its great molecular weight as compared with air. Even at the same normal temperature carbon dioxide gas is much heavier than air, and it is a much better heat insulator.

Because of the greater weight of the gas, it results that when the sublimation of the solid carbon dioxide takes place at atmospheric pressure, in a container having openings at both top and bottom, the gas will tend to drain off by gravity through the lower opening and the atmosphere having access to the container through the upper opening, will tend to drain in at the top of the container.

An important factor is that when discharged through passages in protective or heat absorbing relation to the refrigerator space, the gas will tend to carry along with it the heat that penetrates through the walls of the passage. Thus a substantial amount of this heat may be carried away and discharged outside the refrigerator, either by leaking out through the refrigerated space or by direct outside outlet from the passage.

Under some conditions, it is undesirable to have the interior of the refrigerated space filled with the sublimed CO_2 gas or in some cases even to have a small percentage of CO_2 gas in the atmosphere within the refrigerated space, as for example, in those cases when men must enter or work in the refrigerated space.

In this present application the purposes in view include efficient utilization of the heat absorbing value of the solid carbon dioxide; the high heat insulating value of said gas; and the heat purging value of the CO_2 gas; while still keeping the gas out of the atmosphere of the refrigerated space.

Preferably, the carbon dioxide refrigerant is in a compartment in the top of the refrigerator, whence the heavy gas flows downward in an interspace between the walls of a suitable conduit to a bottom space through which the gas flows laterally to and up through passages betwen the outer refrigerator shell and the inner shell which encloses the refrigerated space. In my prior application, certain of the specific claims are directed to the arrangement wherein the compartment communicates with and can draw in air or gas from the top of the refrigerator and other specific claims are directed to the feature of having the gas that reaches the top of the interspace spill over into said refrigerated space, but in the present case, certain of the specific claims are directed to having the top of the compartment for the refrigerant closed in and other specific claims are directed to arrangements whereby the gas reaching the top of the interspace is discharged outside of the refrigerator.

When the down-flow conduit is arranged as a central partition, the inner metal shell is refrigerated by the primary down-flow and then is both refrigerated and heat-insulated by the countercurrent flow of gas in the exterior interspace between the inner shell and the exterior refrigerator casing. In such case, the primary down-flow is entirely within and surrounded by the refrigerated space, while the flow across the bottom, and up the sides and back operates to refrigerate and insulate the outer shell, and to convey outside the refrigerator, the sensible heat absorbed by the gas.

While the arrangement of the down-flow column as a central partition in the refrigerator with two counter-balancing upflow columns in the outer walls is a desirable arrangement, I find that it is entirely practicable and in some cases preferable to have only two columns, the down-flow column being an outer wall of the refrigerator, the same as the upflow column.

In the present case, the upper compartment containing the solid carbon dioxide is preferably closed so that the above described circulation is forced by the pressure of the generated gas, but even if the entire flow circuit is vented to atmosphere, and the gas is left free to spill over the top of the solid carbon dioxide chamber, it does not do so because the down-column being naturally colder and more dense than the up-column will establish an unbalanced condition whereby the partly warmed and therefore lighter gas will ooze out from the top of the up-flow column and under normal operating conditions, the colder carbon dioxide gas will not rise out of the top of the solid carbon dioxide containing compartment even though the latter be vented or entirely open, the tendency being to cause air to be drawn downward into said compartment, thereby accelerating the melting of the solid carbon dioxide until the circulation is checked either by lowering temperature and increasing density of the up-column or by closing a controlling valve.

The outlet of the upflow column may be made higher or lower than the inlet of the downflow column and I may employ valves either in the down-column or the cross-connection or the up-column, controlled manually or by well known thermostatic elements, such as bi-metallic strips or metallic bellows tubes. The natural self-regulating quality of the counterbalance may thus be subject to arbitrary control.

The valve may be arranged to control flow from the solid carbon dioxide in the down-column either by cutting it off entirely or limiting it to a small predetermined minimum. Whenever the thermo-static valve is open, the extremely heavy gas will fall rapidly in the down-column, creating a suction, tending to draw air into the top of the solid carbon dioxide box. Whatever air is drawn in, it has the remarkable effect of lowering its sublimating point and causes a substantial increase in the evaporation rate.

The above and other features of my invention will be more evident from the following description in connection with the accompanying drawings, in which—

Figs. 1 and 2 are sections showing my invention as applied to a refrigerator of the domestic type, Fig. 1 being a vertical section on the line 1—1, Fig. 2, and Fig. 2 a horizontal section on the line 2—2, Fig. 1;

Figs. 3, 4, 5 and 6 are diagrammatic views of modification showing the paths of flow of the carbon dioxide gas and various points at which valves may be applied.

Figs. 7 and 8 are vertical sectional views of other modifications.

In Figs. 1 and 2, a refrigerator of the upright type is conventionally indicated as comprising a container or box-like structure, 1, the outer walls of which are of any suitable heat insulating construction, doors, 2, 2^a, 2^b being indicated. In this is fitted a smaller container or lining structure which may be of sheet metal, and sufficiently smaller than the interior of the box of the refrigerator, to leave the required upflow passages between said lining and the interior walls of said box. The lining structures may comprise a bottom, 3, resting on suitable supporting blocks, 4, parallel with the floor, a back, 5, parallel with the back of the refrigerator and sides, 6, 6, parallel with the sides of the refrigerator, with a central partition comprising spaced apart walls, 7, 7, providing a downflow passage, 8, leading from a solid carbon dioxide container, 9, which latter is preferably protected by wood or other insulating material, 10, in which the solid carbon dioxide may be supported on blocks 11. The refrigerator may have a closely fitting removable section, 13, through which solid carbon dioxide may be charged into the solid carbon dioxide box. The edges of the inner container are fitted airtight around the door openings so that the bottom, side and back interspaces will be airtight; and the top of the solid carbon dioxide container may be similarly fitted, thought this is not so essential, for reasons explained above. The down passage, 8, between the partition walls, 7, 7, is closed in both front and back, as is also the solid carbon dioxide container, 9. The operation of this arrangement shown in Figs. 1 and 2 will be evident from the drawings. The closure, 13, being removed, the block of solid carbon dioxide will be charged into the solid carbon dioxide box, 9, and the cover 13 closed. The article or materials to be refrigerated, will be within the inner or lining container from whence the gas is excluded as above described. The solid carbon dioxide having an extremely low melting point, or rather, sublimating point, approximately −110° F., will absorb heat from its surroundings and will gasify. The gas will circulate in the paths shown by the arrows, gravitating through the down passage, 8, flowing laterally and rearwardly at the bottom, then upward in the interspaces, 8^a, 8^b, and 8^c, at the sides and back, ultimately flowing out through the high level outlet. The dry gas in the solid carbon dioxide box, 9, will speedily displace all air from box, 9, and the remarkable insulating effect of said gas will then be available to retard conduction or convection of the heat from the walls, 9, to the solid carbon dioxide. The overflow gas may be discharged outside the structure, and as shown in Fig. 5, may be returned to the top of box 9, thus excluding air from the solid carbon dioxide at all times, as shown in Fig. 5.

As before described, the warmer the gas is in the up-passages, 8^a, 8^b, 8^c, the more rapid will be the downflow of the colder gas in 8. The great weight of the fresh gas will tend to create a slight suction at the top of the solid carbon dioxide box, 9, and, if permitted by leakage or by opening of a valve, as in Fig. 6, air will flow in. As explained above, small percentages of air will effectively accelerate evaporation of the solid carbon dioxide besides lowering the temperature, but in the present case, I prefer to keep the air out the gas space, as well as to keep the gas out of the inner refrigerated space. In the present case the thermo-balance and unbalance conditions exist and will become effective if permitted, but the rate of evaporation is preferably controlled by the insulation of the solid carbon dioxide box 9, in conjunction with valves. For instance, a valve 17 may be arranged to partially or wholly close or open the downflow passage, 8. Such valve may be operated by hand or, as diagrammatically indicated in the drawings, by means of a thermostat, 18, of the well known metallic bellows type.

If any one of the doors 2, are opened, only the cold air above the lower edge of that door opening can spill out and with the central partition as shown, only the air in one compartment, on one side of the partition will spill. Even if the entire refrigerating space is drained, it is still impossible to unduly warm up the side and back walls, 4, 5, or the partition wall, 7, and there will be at all times a substantial volume of cold gas within operating to quickly restore the standard low temperature, the instant the doors are closed and the walls can again work on a single body of confined atmosphere.

As explained in my prior application and as indicated in Figs. 1, 2 and 8 hereof, the inner container may be a single wall fitted airtight to the outer container or insulating shell; or it may be a complete airtight, double-wall structure, as in Figs. 3 to 7.

Valves theremostatic or hand operated may be applied as shown in Fig. 1, at the outlet of the solid carbon dioxide box or, as diagrammatically indicated at 17^a, 18^a, in Fig. 4, at the high level outlet of the up-column, or, as shown at 17^b, 18^b, in Fig. 5, in the cross-connection between the columns, or at the high level inlet to the solid carbon dioxide box. The latter method of control, which has certain advantages, is indicated in Fig. 6. In this figure, the top of the solid carbon dioxide box, 9^a, is closed in by cover, 9^b, having an upstanding inlet, 9^c, adapted to be closed or opened by a balanced valve, 17^x, controlled by a bellows thermostat, 18^x. With this apparatus, as in Figs. 1, 2, 3, 7 and 8, gravity downflows in 8^y cannot operate to suck in warm air at the top of the solid carbon dioxide box so long as 17^x is closed. Consequently, the box is kept full of very cold highly insulating gas and evaporation depends entirely on the rate of conduction of heat through the walls of the container. In this situation, the circulation is at a minimum and the up-column, 8^y, may become relatively warm without having any tendency to accelerate down circulation in 8^a, because 8^a is in effect a barometric column sealed by cold gas at the bottom by a U-bend of the conduit. Hence, the pressure differential takes effect merely as a suction on closed valve 17^x, at the upper end of said barometric column. In this situation, opening of valve 17^x by thermostat, 18^x, permits all the accumulated differential to operate instantly, the suction drawing in warm air through 9^c to rapidly melt the solid carbon dioxide, and the accumulated cold gas flowing with corresponding rapidity downward through 8^x, across and up through 8^y, the other leg of the U, and from the top of 8^y it flows down into the refrigerating space. It will be noted that in Fig. 1 opening of valve 17 operates merely to relieve any pressure that may have accumulated in 9.

From the above, it will be evident that the preferred forms of my apparatus include a U-conduit arrangement affording potentially counterbalanced columns of the carbon dioxide gas, but with a circulation that is normally forced by the refrigerant gas evolution in one of said legs, preferably but not necessarily localized at the top thereof. So while there is a perpetual tendency of the column in said generator leg to overbalance the other column and cause outflow at the upper end thereof, the rate of gas flow is governed primarily by the rate at which heat is conducted into the solid carbon dioxide box and other things being equal, this depends on how warm the air is within the refrigerated space. This in turn is subject to some variation by means of valves that may be used to vary the pressure on the solid carbon dioxide, and in practice this may be modified by inleaking air, even when the outer casing is supposed to be airtight. In all cases the bottom of the U-bend is like a water-sealed plumber's trap in that the heavy gas settling thereto by gravity from the generator leg, operates as a heavier fluid seal to prevent reverse flow or bubbling back of warmed gas or air from the other leg. Hence, the generator leg is characteristically a downflow leg discharging through the other leg which is therefore characteristically an upflow leg; and when the upper end of said generator leg is sealed, a substantial below-atmosphere condition may be then maintained, because of the heavy gas seal in the bottom of the U-conduit.

It will be evident that a very short up-leg 8^y, that is a J-shaped arrangement, would be effective for sealing the apparatus against reverse flow or bubbling back of lighter gas or air into the up-leg 8^x.

In referring to the above arrangements as U-type and J-type, it will be evident the relative cross-sectional areas of the legs and of the lateral connection between them are disregarded because it is a fundamental principle of fluids that the gravity pressures with resulting counter-balances or differentials between communicating columns, depend upon the vertical heights of the columns and specific gravities of fluid in said columns. In Fig. 1, the horizontal cross-sectional area of the up-leg extending around three walls of the refrigerator may be approximately 4 times the cross-section of the down-leg 8, whereas in the other figures these areas are approximately the same. The difference is, therefore, one of degree, the much greater heat absorbing surface of up-leg in Fig. 1 tending to keep the gas column in that leg proportionally warmer and therefore of less specific gravity.

From the above explanation of the broad principles of my method it will be evident that it may be utilized in various specific forms of apparatus disclosing a vast number of specific variations as to horizontal sectional areas of the columns; conductivities and radiating rates of the upflow column, as determined by the materials of the walls thereof or the degree of insulation of said materials; and as to location and relative arrangement of the solid carbon dioxide containing-box, the down-column and the up-column, each with reference to the other. In general, decrease of heat absorbing capacity of the down-column in any of the known ways, as by small cross-section or cylindrical cross-section or insulation will tend to great weight and low specific gravity of the down-column, and consequently to a lower temperature of the upflow or actively heat absorbing column, while great heat absorbing capacity for the up-column, as by highly conducting walls of great area as compared with the flow section will tend to suction effect in the solid carbon dioxide box and tend to accelerate evaporation. As a specific illustration, this principle would contemplate employing a relatively small pipe connection, like the pipe 21 in Fig. 3 of my prior application, extended upward so as to constitute the downflow column, as well as the crossflow column. Such a pipe could be used in place of the partition conduit 8 in Fig. 1. In Figs. 1 and 2, the upflow space, 8^c, at the rear, may be omitted or may be partitioned from spaces 8^a, 8^b, thus making the latter two separate upflow legs each independently responsive to different heat conditions in the spaces on the respective opposite sides of partition 7, 7. In general, there may be as many separate or parallel connected up-legs and down-legs as may be desired.

The priciples described in connection with Fig. 5, are applied in a refrigerator construction such as assumed for all the figures. In Fig. 7 there is no change except omission of the thermostat, a complete double wall circulating system being inserted in the insulating box 1. In Fig. 8 are embodied two other of the described modifications, that is, the return circuit from the outlet at the top of the up-leg, back to the top of the solid carbon dioxide box is omitted and the inner container is a single shell utilizing the outer box as one wall for the gas flow passages. As in Fig. 1 and 7, the top of the solid carbon dioxide box 9 is closed against intake of gas or air and the refrigerated space is sealed against intake of gas from the box and the interspaces leading therefrom.

I claim:

1. A refrigerating apparatus comprising a receptacle, a container for solidified carbon dioxide in the upper portion thereof, a downflow conduit therefrom and an upflow outlet conduit from the latter; the container being closed against inlet of air and the upflow outlet discharging outside the apparatus.

2. A refrigerating apparatus comprising a receptacle, a container for solidified carbon dioxide in the upper portion thereof, a downflow conduit therefrom and an upflow outlet conduit from the latter, said parts being in U-relation; said outlet discharging outside the apparatus and said conduits and container being substantially airtight against in-leak of air and out-leak of gas except through said outlet.

3. A refrigerating apparatus, including an exterior insulating container and in the upper portion of the latter a container for solidified carbon dioxide, a downflow gas-conduit therefrom and an upflow outlet conduit from the latter, the outlet orifice of said upflow conduit being at approximately the same level as the top of the container for the solidified carbon dioxide, and a high level outlet discharging the warmer part of the gas outside said exterior insulating container.

4. A refrigerating apparatus, including an exterior insulating container and within the latter a container for solidified carbon dioxide, a downflow gas-conduit therefrom and an upflow outlet conduit from the latter, the top of said upflow conduit being at approximately the same level as the top of the interior container, in combination with thermostatic means for controlling flow of the gas in said conduit.

5. Refrigerating apparatus, including an outer container, an inner container or liner within the outer container and spaced therefrom, a container for solid carbon dioxide secured to the inner container, the parts being arranged so that the gas sublimated from the solid carbon dioxide flows from the container thereof into the interspace between the outer and inner containers, and a high level exhaust duct communicating with said interspace and leading outside the outer container.

6. Refrigerating apparatus, including an outer container, an inner container of smaller size than said outer container, affording an interspace for circulation of gas between said containers, a container for solid carbon dioxide, the parts being arranged so that the gas sublimated from the solid carbon dioxide flows from the container thereof into the interspace between the two containers, a high level exhaust duct communicating with the upper part of said interspace and leading outside the outside container.

7. Refrigerating apparatus, including an outer container, an inner container or liner of sheet metal of smaller size than said outer container and spaced therefrom, affording an air-tight interspace between said containers, a container for solid carbon dioxide closed against free entry of air and positioned in the upper portion of the inner container, the parts being arranged so that the gas sublimated from the solid carbon dioxide flows from the container thereof into the interspace between the two containers, a high level exhaust duct communicating with the upper part of said interspace and leading outside the outside container, and a valve controlling said exhaust duct.

8. Refrigerating apparatus, including an outer container of insulating material having a side door, an inner container or liner of sheet metal of smaller size than said outer container having an opening registering with and secured air-tight about the doorway through the outer container and forming therewith an interspace having no communication with the interior of the inner container; a container for solid carbon dioxide closed against free entry of air and positioned in the upper portion of the inner container, the parts being arranged so that the gas sublimated from the solid carbon dioxide flows from the container thereof into the interspace between the two containers; and a high level exhaust duct communicating with said interspace and leading outside the outside container.

9. Refrigerating apparatus, including an outer container of insulating material having a side door, an inner container having inwardly presented metal walls and affording interspaces between said inner walls and said outer container for downflow and upflow of gas, said inner container having an opening registering with the doorway of the outer container and sealed against outlet of gas either through said doorway or into said inner container; and a container for solid carbon dioxide closed against free entry of air and positioned in the upper portion of said outer container, arranged so that the gas sublimating therefrom is led directly from the container of the solid carbon dioxide into said interspace and said interspace communicating near the top with a duct which leads outside of the outside container.

10. Refrigerating apparatus, including an outer container of insulating material having a side door, an inner container having inwardly presented metal walls and affording interspaces between said inner walls and said outer container for downflow and upflow of gas, said inner container having an opening registering with the doorway of the outer container and sealed against outlet of gas either through said doorway or into said inner container; and a container for solid carbon dioxide closed against free entry of air and positioned in the upper portion of said outer container, arranged so that the gas sublimating therefrom is led directly from the container of the solid carbon dioxide into said interspace and said interspace communicating near the top with a duct which leads outside of the outside container; and a valve controlling flow of gas in said interspace from said container for the solid carbon dioxide to said duct.

11. Refrigerating apparatus, including an outer container of insulating material having a top door or trap and a side door; an air-tight inner container or liner having inwardly presented top, bottom and side metal walls and affording interspaces between said inner walls and said outer container for circulation of gas; said inner container having also an opening registering with the doorway of the outer container and sealed against outlet of gas either through said doorway or into said inner container; a container for solid carbon dioxide closed against free entry of air and positioned in the upper portion of said outer container in registry with the top door or trap thereof, and arranged so that the gas sublimating therefrom is led directly from the container of the solid carbon dioxide into said space, said space communicating with a high level duct which leads outside of the outside container.

12. In a refrigerator accessible through a side-opening closure whereby the portion of the refrigerated space above the bottom of the opening may be drained of the relatively cold, dense atmosphere normally filling the refrigerated space, means for refrigeration of the space within the refrigerator by intensely cold gas sublimated from solid carbon dioxide, including a container for solid carbon dioxide closed against free entry of air and

positioned in the upper portion of the refrigerator, and upwardly extending conductive walls in heat absorbing relation to the refrigerated space, arranged to confine gas sublimating from the solid carbon dioxide against flow into said space and affording only high level outlet thereof to the exterior air whereby a substantial body of the intensely cold gas is maintained outside of but in conductive relation to said space although the latter may be drained and refilled with warm air by opening of said closure.

13. The method of refrigerating products by evaporation of solid carbon dioxide which includes causing it to evaporate in a closed container, confining the resultant gas to form a down-flow static column and to form an upflow counterbalancing column, the gas from the upflow column being discharged outside the refrigerated space.

14. The method of refrigerating products by evaporation of solidified carbon dioxide which includes causing it to evaporate in a container the top of which is closed, confining and guiding the resultant gas through an air-tight conduit to form a down-flow column and to form an upflow counterbalancing column and discharging the gas from the top of the upflow column outside the refrigerated space.

15. The method of controlling refrigeration by evaporation of solid carbon dioxide, which includes enclosing it in a container closed against outlet or inlet at the top and discharging the gas therefrom through a downflow and upflow conduit whereby the solid carbon dioxide is sealed against inlet of air through said conduit and the rate of sublimation is determined by the amount of heat conducted through the walls of said container.

16. The method of controlling refrigeration by evaporation of solid carbon dioxide, which includes enclosing it in a container closed against outlet or inlet at the top and discharging the gas therefrom through a downflow and upflow conduit whereby the solid carbon dioxide is sealed against inlet of air through said conduit and the rate of sublimation is determined by the amount of heat conducted through the walls of said container; and maintaining both said container and conduit in heat absorbing relation to the refrigerated space.

17. A refrigerating apparatus including a chamber for products to be refrigerated, a container enclosing solidified carbon dioxide, separated from but in heat exchange relation with the refrigerated chamber and means for insulating as well as cooling said chamber, including thin flat conduits arranged as an insulating and cooling wall or walls for the refrigerated space, and connected for continuous inflow and throughflow of gas from said container, and for discharge thereof to the exterior after it has traversed said conduits.

18. A chamber for products to be refrigerated, having most of its exterior walls and floor of insulating double wall construction, in combination with a container enclosing solidified carbon dioxide in heat exchange relation with said chamber and connected to discharge the gas evaporating from said solid into and through the interior of said double wall portions of said chamber, and thence to the exterior atmosphere.

19. Refrigerating apparatus, including outer and inner containers formed and arranged to confine and permit circulation of gas between said containers, in combination with a container enclosing solid carbon dioxide arranged so that said solid may absorb heat derived from the inner container, and arranged for flow of the resulting dry cold gas between the containers thereby forming a continuously renewed insulation of dry gas interposed between and absorbing heat from said inner and outer containers; and a high level exhaust duct to which said gas rises as it warms, and through which the excess gas is discharged to the exterior atmosphere.

20. Refrigerating apparatus, including a container enclosing a space for products to be refrigerated and having walls arranged to afford insulating paths for circulation of insulating and cooling gas between the inner and outer surfaces of said walls, in combination with a container enclosing solid carbon dioxide arranged so that said solid may absorb heat derived from within the refrigerating space and arranged so that the resulting cold dry gas flows into said circulation paths, thereby maintaining a continuously renewed insulation of dry cold gas interposed between and absorbing heat from the refrigerated space and the exterior; and a high level outlet to which said gas rises as it warms, and through which the excess gas is discharged to the exterior atmosphere.

Signed, at New York city, in the county and State of New York, this 6th day of December, 1928.

JAMES W. MARTIN, Jr.