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REFRIGERATING SYSTEM AND METHOD

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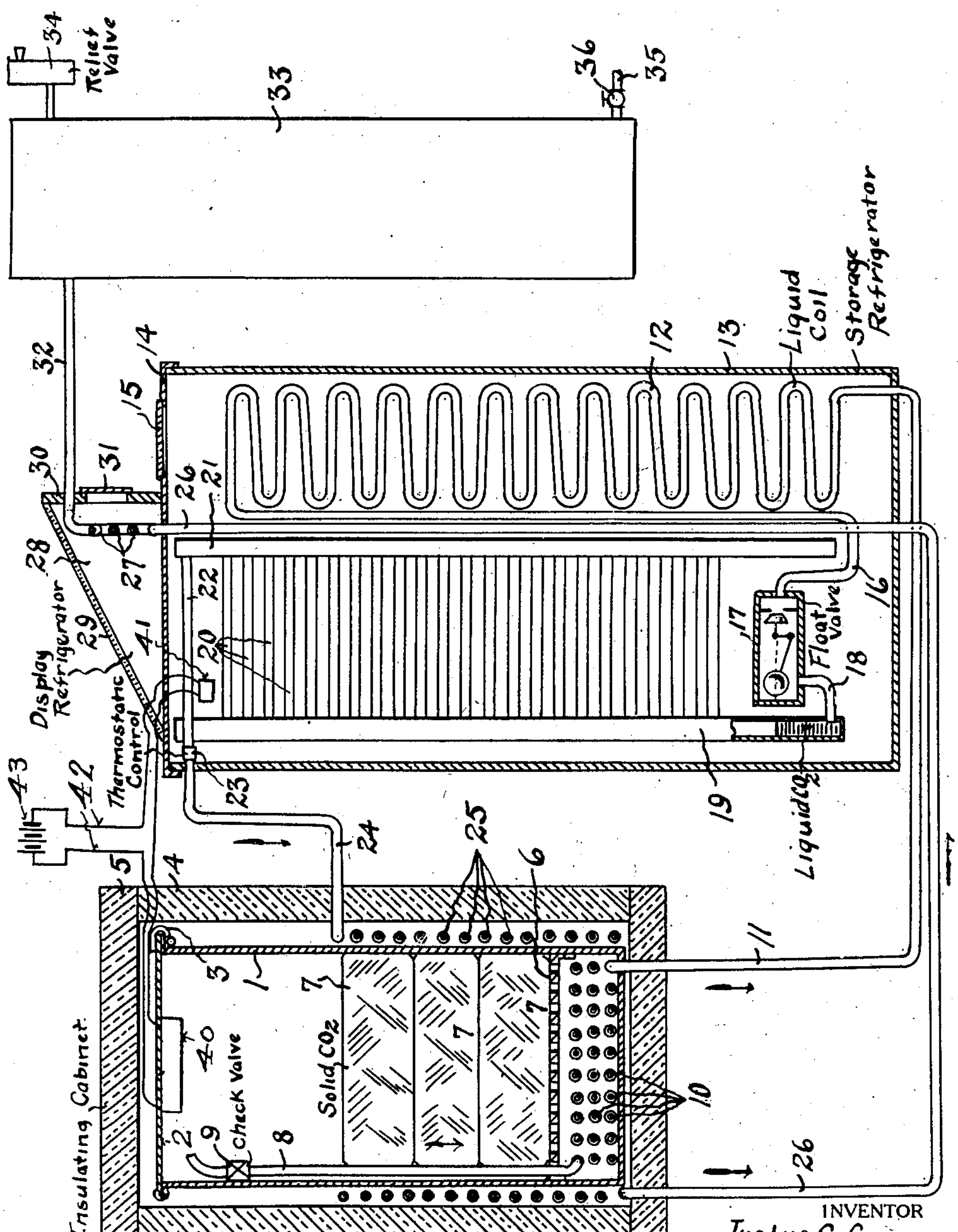

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UNITED STATES PATENT OFFICE

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REFRIGERATING SYSTEM AND METHOD

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This invention relates in general to refrigerating systems and methods.

One of the objects of the invention is to provide a refrigerating system and method employing carbon dioxide refrigerant in its solid, liquid, and gaseous phases.

Another object of this invention is the provision of apparatus and methods by means of which solid carbon dioxide may be employed to do useful refrigerating work by heat exchange between the solid CO_2 and the space or the medium to be refrigerated.

Another object of this invention is the provision of apparatus and methods by means of which maximum economy may be effected in utilizing solid carbon dioxide for refrigerating purposes.

A still further object of this invention is the provision of means whereby a complete heat exchange between the solid CO_2 refrigerant and the medium to be refrigerated is effected, together with the application of external heat which is automatically introduced when necessary to make the heat exchange cycle complete and automatically operative.

Another object of this invention is the provision of relatively low and moderately high temperature refrigerating cabinets with carbon dioxide gas and liquid coils connected together for the purpose of utilizing solid carbon dioxide for refrigerating purposes, together with means for changing the state of the medium in the cycle.

A still further object of this invention is the provision of a system from which the carbon dioxide gas may be withdrawn after doing useful refrigerating work for such other purposes as may be available, such as for liquid carbonating purposes.

These and many other objects as will appear from the following disclosure are secured by means of the apparatus and methods of this invention.

This invention resides substantially in the combination, construction, arrangement, relative location of parts, steps and series of steps, all as will be explained in greater detail in the following specification.

The accompanying drawing is a diagrammatic view with some parts in cross section of the apparatus of this invention.

The general object of this invention is to provide apparatus and methods by means of which the cooling properties of solid carbon dioxide may be utilized to the maximum extent in doing useful refrigerating work. In general the system comprises a container for the solid carbon dioxide so proportioned with respect to the volume of solid CO_2 placed therein that the gas generated therefrom will be liquefied in a primary condenser coil located at the bottom of of the container by the combined action of the built-up pressure in the container and the cooling work of the solid CO_2 in close proximity with the said primary condenser coil. The liquefied carbon dioxide is then passed into a refrigerating chamber and circulated through the liquid coil, delivered to a gas coil, and there permitted to vaporize. This vaporization of the liquid is caused by absorption of heat from the refrigerating chamber thereby cooling it. Means is provided between the liquid and gas coils for insuring that liquid delivered to the gas coils may vaporize therein. This vapor is then circulated in heat exchange relation with the container holding the solid carbon dioxide through a secondary condenser coil whereby it is cooled and gives up heat to effect further vaporization or sublimation of the solid carbon dioxide. The liquid, or a mixture of liquid and vapor, is then circulated through another refrigerating space which is maintained at refrigerating temperatures that are higher than those in the first refrigerator. The gas is then delivered to a storage tank from which it may be removed for any purpose, an example of which is for carbonating beverages.

The physical changes which occur in the operation of this apparatus will now be described in greater detail. One end of the primary condenser coil extends into the vapor space, and since it is open it permits the CO_2 to enter it as the solid CO_2 in the container sublimes. The bulk of this coil is located at the bottom of the container where it is in contact with and subjected to the cooling action of the solid CO_2. During sublimation heat is supplied to the solid CO_2 through the heat contacting wall of the container, the pressure rises and liquefaction of the CO_2 in the coil occurs. This liquid is immediately expelled from the condenser coil into a receiving coil located outside of the container where the liquid is momentarily held in readiness for use. The pressure-temperature relation for sublimation in the container and liquefaction in the primary condenser coil is then 150 lbs. pressure absolute and a liquid temperature of minus 40° F.

The assumption of 150 pounds of pressure is only by way of example since this pressure may be varied between wide limits, depending upon the adjustment of the blow-off relief valve 34, or the adjustment of a relief valve which can be applied directly to container 1. The pressure within the system may be built up considerably higher than 150 pounds pressure by the sublimation of the solid carbon dioxide depending upon the quantity thereof present and the volume of the container and connected system. The pressure of 150 pounds was selected by way of example as a suitable operating pressure. Of course no liquid can form in the system until the pressure therein goes above at least 75 pounds absolute. Under operating conditions which would normally be encountered with this apparatus, liquid carbon dioxide will of course form in container 1 at the same time that solid carbon dioxide is present, together with carbon dioxide gas. In other words, when the triple point temperature and pressure conditions for carbon dioxide are attained within the container 1, carbon dioxide will be present in gaseous, liquid and solid form. This fact does not, however, prevent the apparatus from operating, nor prevent the formation of liquid carbon dioxide in the liquid coil 10 and in the other parts of the system as disclosed.

It is well known and has long been observed that carbon dioxide in process of liquefaction behaves differently than other well known gases such as for example ammonia. Ammonia during its process of liquefaction cannot be cooled to a lower temperature than that of the water overflow from the cooling condenser, while carbon dioxide on the other hand may be sub-cooled below the overflow temperature of the water. It has been observed in many tests that the temperature of carbon dioxide gas in a condenser during condensation varies considerably and this variation can be traced to the point of change in state, that is, where the gas changes into a liquid. This is due in a considerable measure to the fact that the heat does not readily travel through a layer of carbon dioxide gas or vapor. The insulating property of this gas is high, in fact, much higher than that of air so that the temperature of the liquid at the end of condensation, and where this temperature is lowest, is not affected by the higher temperature of the gas within the condenser, although the gas as well as the liquid, is at the same pressure.

This condition becomes more drastic and more apparent and is easily observed when solid carbon dioxide sublimes in a pressure vessel. In this case there appears to be an entire disruption of the relationship between temperature and pressure. For instance, the solid carbon dioxide at the bottom of the container is little influenced by the pressure present in the same container. The temperature of the solid carbon dioxide deviates little from its temperature of −109° F. regardless of the pressure which develops in the container by the sublimation of the solid into gas. The temperature of the liquid must necessarily be regulated above the temperature of crystallization which is adjusted by the flow of liquid out of the container into the liquid receiver. It is necessarily true that if the liquid which has collected at the bottom of the container is allowed to remain there in a static condition, it will be cooled by the solid carbon dioxide to the point of crystallization and thus solidified.

However, when this liquid is drawn from the container at a temperature above crystallization, it will not freeze as will readily be apparent. The pressure on the other hand which is developed by the continuous sublimation of the enclosed solid carbon dioxide mounts steadily to higher levels. Therefore, temperatures at great variation can be observed in the container; for instance, the gas which collects near the top of the container may approach the temperature existing on the outside thereof. At the approximate mid-distance between the top and the bottom of the container, the temperature will be found considerably lower; at the bottom where the liquid exists, temperatures of −40° F. occur, and, at the same time, the temperature of the metal bottom of the container upon which the solid carbon dioxide rests will be as low as −100° F. During all of this time, the pressure in the container will be close to that corresponding with the temperature of the gas near the top. In other words, if the temperature of the gas near the top of the container is approximately 60° F., the pressure within the container would be found to be above 700 pounds per square inch. Here again, it seems apparent that the insulating property of the gas prevents even temperature equalization of the gaseous body within the container.

Experiments carried on by competent physicists have shown that the volume of solid carbon dioxide increases during sublimation at the rate of .085% per 1° F. increases in temperature. In this respect, solid carbon dioxide behaves opposite to water ice; the latter increases in volume during freezing and decreases in volume on melting; while carbon dioxide decreases in volume while freezing and increases in volume when melting. This increase is as much as 28.5% at the triple point, but decreases with rising pressure.

The temperature increase at least in the solid field is, therefore, 1° F. per 1,544 pounds pressure. Tammann and Bridgeman found that the sublimation of solid carbon dioxide can be prevented only at an enormous pressure. For instance, solid carbon dioxide which has a pressure at the triple point of 75.14 pounds per square inch absolute and a corresponding temperature of −69.86° F. requires an increase in this pressure to 14,220 pounds per square inch with a rise in its temperature to −35.14° F. This demonstrates that the sublimation of solid carbon dioxide can be prevented only at an enormous increase in pressure.

This explains the increase in pressure within the container during the sublimation of solid carbon dioxide to above 700 pounds per square inch when enclosed in a pressure vessel, while the liquid temperature near the bottom may be as low as −40° F. with a still much lower temperature at the bottom where solid carbon dioxide is in direct contact with the metal of the container.

The equilibrium condition for the fluid phases of solid carbon dioxide shows that the pressure in the container would still climb much higher if none of the enclosed carbon dioxide is withdrawn. Hence, in practice, the apparatus is provided with a safety disc proportioned to break at 1,200 pounds per square inch, so that the container will not be subjected to dangerous pressure conditions.

The liquid is now available for refrigerating requirements which is accomplished by allowing it to vaporize in cooling coils or other heat absorbing bodies. During this vaporization the heat absorbed in a refrigerator, for example, is then equivalent to all of the heat carried by the cold liquid out of the solid CO_2 container. Thus, in giving up its low temperature heat while doing refrigerating work, or in other words by absorbing heat from the refrigerator space as well as the goods placed therein the liquid completely vaporizes and finally its vapor becomes super-heated. This super-heated vapor is then returned to the solid CO_2 container through a secondary condenser coil wound around the outside of the container. During the heat exchange with the solid CO_2 in the container the vapor in the secondary condenser coil is cooled and finally recondensed. Hence the heat necessary to produce sublimation of the solid CO_2 is the identical quantity of heat absorbed in the refrigerator during the vaporiation of the liquid and the super-heating of the vapor. Theoretically, therefore, the heat exchange between the solid carbon dioxide in the container and the heat in the refrigerator is 100%; it being understood that heat losses are substantially eliminated by adequate insulation.

However, it has been found in practice that there is a deficiency in heat which is carried back from the refrigerator to the solid CO_2 and that by reason of such deficiency there developes a shortage in vapor sublimation and therefore of liquefaction. This deficiency is obviously small and can easily be supplied by heat from some external source. In the system of this invention a small electrical heating element automatically controlled by a thermostatic switch placed inside of the refrigerator is employed. Due to the insufficiency of heat carried into the solid carbon dioxide the solid carbon dioxide does not sublime in sufficient quantity so that the temperature in the refrigerator space will slowly rise. As soon as the upper predetermined temperature limit has been reached in the refrigerator the thermostatic switch automatically closes to complete the circuit to the electrical heating element. The heat generated by this heating element within the solid CO_2 container causes a greater quantity of solid CO_2 to sublime, and as a consequence provides more liquid to increase refrigeration and to lower the temperature in the refrigerator. At a predetermined lower temperature limit in the refrigerator the thermostatic switch automatically opens and the process then continues as a closed cycle.

There are other objects of this invention as will appear from the following detailed disclosure.

Referring to the drawing, the container for the solid carbon dioxide is shown at 1 having a movable cover 2 which is held in sealing relation with the container by any suitable clamping means 3. This container is supported within a heat insulating cabinet 4 provided with a removable cover 5. Within the container 1 and spaced a suitable distance from the bottom thereof is a transverse perforated wall 6 on which one or more blocks 7 of solid carbon dioxide are supported. The volume of the container 1 with respect to the volume of solid placed therein must be such that the solid may vaporize and generate pressure. Opening into container 1 is a pipe 8 which is provided with a check valve 9. Below the perforated partition 6 and within the container 1 is the primary condenser coil 10 into one end of which is connected the pipe 8. The other end of this condenser coil is connected by pipe 11 to the liquid coil 12 within the refrigerator 13, which may be a storage container for articles to be cooled. This container 13 is provided with a cover 14 and a door 15 of any suitable construction. The container may be placed within a heat insulating cabinet in the usual and well known manner, or may itself be made of heat insulating material such as refrigerator cabinets and the like.

The other end of liquid coil 12 is connected by pipe 16 to a float valve 17 of any well known construction. The outlet of the float valve is connected by pipe 18 to a header 19. The float valve is arranged with respect to the header 19 so that a suitable body of liquid carbon dioxide will be maintained therein as indicated in the drawing. At 21 is another header which is connected to the header 19 by a plurality of parallel pipes 20.

Near the top of header 21 is provided a pipe connection 22 leading to a thermostatic control valve 23. This thermostatic control valve may be of any well known type and is placed within the refrigerator so as to be subject to the temperature conditions therein. It is, of course, adjusted so as to prevent the temperature within the cabinet falling below the predetermined value and acts to shut off the flow of gas when that value is attained. The outlet of the thermostatic control valve 23 is connected by pipe 24 which extends to a secondary condenser coil 25 which encircles the container 1 in heat exchange relation. The outlet of coil 25 is connected by a pipe 26 to a cooling coil 27. This cooling coil 27 is within a space 28 formed by the glass wall 29 and the rear wall 30. The space 28 provides, for example, refrigerated display cabinet such as used in stores selling perishable products. This cabinet is provided with a suitable door 31 by means of which access to the interior may be had.

Suitably mounted within the container 1 is an electrical heating coil 40 of any suitable constructon. At 41 is a thermostatic switch which is exposed to the temperature conditions within the refrigerator 13. 43 represents any suitable current source connected to the heater element and the thermostatic switch by wires 42. It is, of course, apparent that this invention is not limited to an electrical heating means for supplying external heat since other well known forms of heating devices may be used.

The outlet of coil 27 is connected by pipe 32 to a gas storage receiving tank 33. This tank is provided with a suitable release valve 34 for permitting the escape of the gas if the pressure therein tends to build above a predetermined value. This tank is also provided with a delivery pipe 35 and control valve 36 by means of which the gas may be delivered for any use, such as for example the carbonating of beverages.

The operation of this apparatus is as follows: A suitable quantity of solid carbon dioxide in the form of blocks 7 is placed within the container 1, which is sealed by means of cover 2 and clamp 3. The insulating cabinet 4 is then closed by means of the cover 5. As the solid carbon dioxide sublimates the gas formed within the free space in the container then flows down through pipe 8 of cooling coil 10 where it is cooled sufficiently to liquefy. The liquid then flows through pipe 11 to the liquid coil 12 within the refrigerator 13. The liquid, of course, absorbs some heat. It then flows from the float valve into the header 19. The float valve is arranged so as to maintain a suitable carbon dioxide liquid level within the header 19. The liquid within the header slowly boils off into gaseous form and travels to the header 21 through the branch pipes 20.

The transformation of the liquid to gaseous form causes further absorption of heat from the refrigerators and the articles therein, as does the relatively cold gas flowing through the pipes 20. This flow of gas is controlled by the thermostatic control valve 23. The gas then flows from pipe 24 to the secondary condenser coil 25 where it is cooled and again liquefied, giving up its heat to effect further gasification of the solid carbon dioxide within the container 1. The liquid, or the mixture of liquid and vapor then flows through pipe 26 to the cooling coil 27 within the second refrigerating space 28 where it absorbs heat therefrom, as well as from the articles therein. The gas is then delivered through pipe 32 to the storage receiving tank 33.

It will be apparent from the above description that this process is a very economical one. With the apparatus disclosed and the method employed the very cold solid carbon dioxide is transformed into liquid and gaseous phases and employed to do useful work in absorbing heat from articles to be cooled. Furthermore, the heat absorbed is employed to effect further vaporization of the solid, and finally the still relatively cool gas at a super-atmospheric pressure is available for other uses.

Any deficiency in this heat exchange is then supplied by heat from an outside source so controlled by the thermostatic switch that only such heat deficiency as may actually develop is made up from any convenient outside source.

The approximate temperatures and pressures involved will be given in an illustrative sense and with no intention of restricting the scope of the invention. The solid carbon dioxide is at approximately minus 109° F. When it is permitted to vaporize within the container 1 the gas pressure therein rises to approximately 150 pounds pressure per square inch. This gas at this pressure and temperature when it flows through the primary condensing coil 10 in heat exchange relation with the soild is under such conditions that it liquefies. The liquid flowing from the coils through pipe 11 into liquid coil 12 is at approximately minus 40° F., and 150 lbs. pressure. The gas flowing from the gas pipes

20 through pipes 22 and 24 is at approximately minus 10° F. and 115 lbs. pressure. After flowing through the cooling coils 25 the gas is at approximately minus 50° F. and 100 lbs. pressure. After leaving the coil 27 the gas is at from minus 10° to 0° F. and at approximately 80 lbs. pressure. It is stored within the gas storage tank at approximately 80 lbs. pressure.

Among the many uses to which this still relatively cool gas at super-atmospheric pressure may be applied is that of carbonating beverages. Beverages are usually carbonated at about 35 lbs. pressure per square inch, so that the gas in the storage tank is at once available for this purpose.

The check valve 9 is provided in the pipe 8 so that when the container 1 is open for the admission of further solid carbon dioxide the pressures within the various pipes and coils will not escape into the atmosphere as it would do if no check valve were provided.

From the foregoing disclosure it will be apparent that this invention involves certain principles of construction and operation which may be readily embodied in other apparatus and methods as will be apparent to those skilled in the art. I do not, therefore, desire to be strictly limited by the disclosure, either in the drawing or specification, as given for the purpose of illustrating my invention, but rather to the scope of the appended claims.

What I seek to secure by United States Letters Patent is:

1. In a refrigerating apparatus, the combination comprising two refrigerators, refrigerating coils in said refrigerators, and means connected to said coils for receiving solid carbon dioxide from which liquid carbon dioxide refrigerant is delivered to the coils of said refrigerators.

2. In a refrigerating apparatus, the combination comprising a container for solid carbon dioxide, a refrigerating cabinet having a cooling coil therein, connections between the container and the cooling coil, a coil surrounding said container and connected to the cooling coil of the refrigerating cabinet, a second refrigerating cabinet having a cooling coil therein, and connections between the cooling coil in the second refrigerating cabinet and the cooling coil surrounding the container.

3. In a refrigerating apparatus of the type described, the combination comprising a container for solid carbon dioxide, a cooling coil in heat exchange relation with said container and opening into the interior thereof, a refrigerating cabinet, a cooling coil in said cabinet connected to said first cooling coil, another coil encircling the container and connected to the cooling coil within the refrigerating cabinet, a second refrigerating cabinet having a cooling coil therein, and connections between the cooling coil in the second refrigerating cabinet and the cooling coil encircling said container.

4. In a refrigerating apparatus of the type described, the combination comprising a container for solid carbon dioxide, a cooling coil in heat exchange relation with said container and opening into the interior thereof, a refrigerating cabinet, a cooling coil in said cabinet connected to said first cooling coil, another coil encircling the container and connected to the cooling coil within the refrigerating cabinet, a second refrigerating cabinet having a cooling coil therein, connections between the cooling coil in the second refrigerating cabinet and the cooling coil encircling said container, and means within said first cooling cabinet in the connections between the cooling coil therein and the cooling coil encircling said container for maintaining a predetermined temperature condition within that cabinet.

5. In a refrigerating apparatus of the type described, the combination comprising a container for solid carbon dioxide, a cooling coil in heat exchange relation with said container and opening into the interior thereof, a refrigerating cabinet, a cooling coil in said cabinet connected to said first cooling coil, another coil encircling the container and connected to the cooling coil within the refrigerating cabinet, a second refrigerating cabinet having a cooling coil therein, connections between the cooling coil in the second refrigerating cabinet and the cooling coil encircling said container, and gaseous carbon dioxide storing means connected to the cooling coil within the second refrigerating cabinet.

6. In a refrigerating apparatus of the type described, the combination comprising a refrigerating cabinet having a liquid cooling coil and a gas cooling coil therein, connections between said coils including a float valve for controlling the delivery of liquid from the liquid coil to the gas coil, and means for delivering liquid carbon dioxide to the liquid coil.

7. In a refrigerating apparatus of the type described, the combination comprising a refrigerating cabinet having a liquid cooling coil and a gas cooling coil therein, connections between said coils including a float valve for controlling the delivery of liquid from the liquid coil to the gas coil, and means for transforming solid carbon dioxide into liquid carbon dioxide connected to the liquid coil of the refrigerator.

8. In a refrigerating apparatus of the type described, the combination comprising a container for receiving solid carbon dioxide, a condensing coil in heat exchange relation with said container and opening therein, a refrigerator having a liquid coil and a gas coil therein connected together, a connection between the condensing coil and the liquid

coil, a cooling coil in heat exchange relation with said container, a connection between that cooling coil and the gas coil of the refrigerator, a second refrigerator having a cooling coil therein, and a connection between the cooling coil of the second refrigerator and the cooling coil in heat exchange relation with the container.

9. In a refrigerating apparatus of the type described, the combination comprising a container for receiving solid carbon dioxide, a condensing coil in heat exchange relation with said container and opening therein, a refrigerator having a liquid coil and a gas coil therein connected together, a connection between the condensing coil and the liquid coil, a cooling coil in heat exchange relation with said container, a connection between that cooling coil and the gas coil of the refrigerator, a second refrigerator having a cooling coil therein, a connection between the cooling coil of the second refrigerator and the cooling coil in heat exchange relation with the container, and means in the connection between the liquid coil and the gas coil of the refrigerator for maintaining a predetermined quantity of liquid in the gas coil.

10. In a refrigerating apparatus of the type described, the combination comprising a container for receiving solid carbon dioxide, a condensing coil in heat exchange relation with said container and opening therein, a refrigerator having a liquid coil and a gas coil therein connected together, a connection between the condensing coil and the liquid coil, a cooling coil in heat exchange relation with said container, a connection between that cooling coil and the gas coil of the refrigerator, a second refrigerator having a cooling coil therein, a connection between the cooling coil of the second refrigerator and the cooling coil in heat exchange relation with the container, and means connected to the cooling coil of the second refrigerator for receiving and storing the gas delivered therefrom.

11. In a refrigerating method of the type described the steps of sublimating solid carbon dioxide to form gaseous carbon dioxide, circulating the gaseous carbon dioxide in heat exchange relation with the solid carbon dioxide to liquefy it, circulating the liquid carbon dioxide within a space to be refrigerated, transforming the liquid carbon dioxide to gaseous carbon dioxide within that space, circulating the gaseous carbon dioxide in heat exchange relation with solid carbon dioxide to cool it, and circulating the cooled carbon dioxide gas in heat exchange relation with the refrigerating space.

12. In a refrigerating method of the type described, the steps of sublimating solid carbon dioxide to form gaseous carbon dioxide, circulating the gaseous carbon dioxide in heat exchange relation with the solid carbon dioxide to liquefy it, circulating the liquid carbon dioxide within a space to be refrigerated, transforming the liquid carbon dioxide to gaseous carbon dioxide within that space, circulating the gaseous carbon dioxide in heat exchange relation with solid carbon dioxide to cool it, circulating the cooled carbon dioxide gas in heat exchange relation with the refrigerating space, and storing the carbon dioxide gas at super-atmospheric pressure.

13. A refrigerating cycle employing solid carbon dioxide comprising transforming solid carbon dioxide into gaseous carbon dioxide, circulating the gaseous carbon dioxide in heat exchange relation to the remaining solid carbon dioxide to liquefy it, circulating the liquid carbon dioxide in heat exchange relation with articles to be cooled, transforming the liquid carbon dioxide into gaseous carbon dioxide and circulating the gaseous carbon dioxide in heat exchange relation with articles to be cooled, circulating the relatively warm gaseous carbon dioxide in heat exchange relation with the solid carbon dioxide to cool the gas and effect further vaporization of the solid, and circulating the cooled carbon dioxide gas in heat exchange relation with articles to be cooled.

14. A refrigerating cycle employing solid carbon dioxide comprising transforming solid carbon dioxide into gaseous carbon dioxide, circulating the gaseous carbon dioxide in heat exchange relation to the remaining solid carbon dioxide to liquefy it, circulating the liquid carbon dioxide in heat exchange relation with articles to be cooled, transforming the liquid carbon dioxide into gaseous carbon dioxide and circulating the gaseous carbon dioxide in heat exchange relation with articles to be cooled, circulating the relatively warm gaseous carbon dioxide in heat exchange relation with the solid carbon dioxide to cool the gas and effect further vaporization of the solid, circulating the cooled carbon dioxide gas in heat exchange relation with articles to be cooled, and using the carbon dioxide gas to carbonate beverages.

15. In a refrigerating apparatus, the combination comprising a container for solid carbon dioxide, a refrigerating cabinet having a cooling coil therein, connections between the container and the cooling coil, a coil surrounding said container and connected to the cooling coil of the refrigerating cabinet, a second refrigerating cabinet having a cooling coil therein, connections between the cooling coil in the second refrigerating cabinet and the cooling coil surrounding the container, and means for supplying external heat to the container.

16. In a refrigerating apparatus, the combination comprising a container for solid carbon dioxide, a refrigerating cabinet having a cooling coil therein, connections between the container and the cooling coil, a

coil surrounding said container and connected to the cooling coil of the refrigerating cabinet, a second refrigerating cabinet having a cooling coil therein, connections between the cooling coil in the second refrigerating cabinet and the cooling coil surrounding the container, means for supplying external heat to the container, and thermostatic means within the first refrigerating cabinet and connected to the heating means for automatically energizing it.

17. In a refrigerating apparatus, the combination comprising a container for solid carbon dioxide, a refrigerating cabinet having a cooling coil therein, connections between the container and the cooling coil, a coil surrounding said container and connected to the cooling coil of the refrigerating cabinet, a second refrigerating cabinet having a cooling coil therein, connections between the cooling coil in the second refrigerating cabinet and the cooling coil surrounding the container, an electrical heating device within said container, a thermostatic switch within the first refrigerating cabinet and connections between the electrical heating device and the thermostatic switch whereby the electrical heating device is energized upon the development of predetermined temperature conditions within the refrigerating cabinet.

18. In a refrigerating method of the type described, the steps of sublimating solid carbon dioxide to form gaseous carbon dioxide, circulating the gaseous carbon dioxide in heat exchange relation with the solid carbon dioxide to liquefy it, circulating the liquid carbon dioxide within a space to be refrigerated, transforming the liquid carbon dioxide to gaseous carbon dioxide within that space, circulating the gaseous carbon dioxide in heat exchange relation with solid carbon dioxide to cool it, circulating the cooled carbon dioxide gas in heat exchange relation with the refrigerating space, and supplying external heat to the solid carbon dioxide to increase sublimation.

19. In a refrigerating method of the type described, the steps of sublimating solid carbon dioxide to form gaseous carbon dioxide, circulating the gaseous carbon dioxide in heat exchange relation with the solid carbon dioxide to liquefy it, circulating the liquid carbon dioxide within a space to be refrigerated, transforming the liquid carbon dioxide to gaseous carbon dioxide within that space, circulating the gaseous carbon dioxide in heat exchange relation with solid carbon dioxide to cool it, circulating the cooled carbon dioxide gas in heat exchange relation with the refrigerating space, and supplying external heat under control of the temperature conditions in the first refrigerating space to increase the sublimation of the solid carbon dioxide.

20. A converter for changing solid carbon dioxide to liquid carbon dioxide, comprising a closed chamber and a condensing coil within said chamber, said condensing coil being open to the interior of the chamber.

In testimony whereof I have hereunto set my hand on this 10th day of October, A. D., 1930.

JUSTUS C. GOOSMANN.