Oct. 10, 1939. D. H. KILLEFFER 2,175,267

METHOD OF AND APPARATUS FOR REFRIGERATION

Filed Oct. 9, 1934 2 Sheets-Sheet 1

Fig. 1.

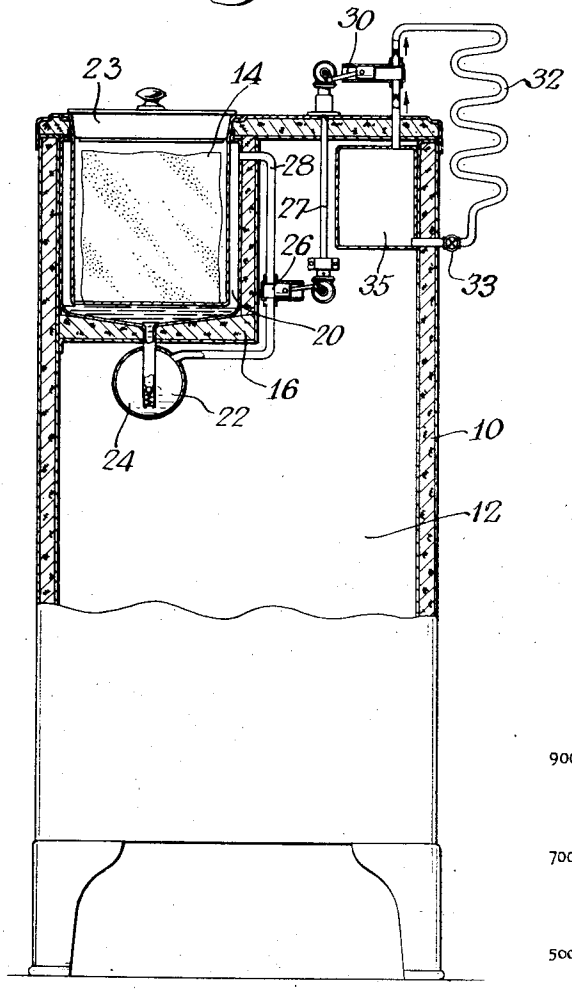


Fig. 4.

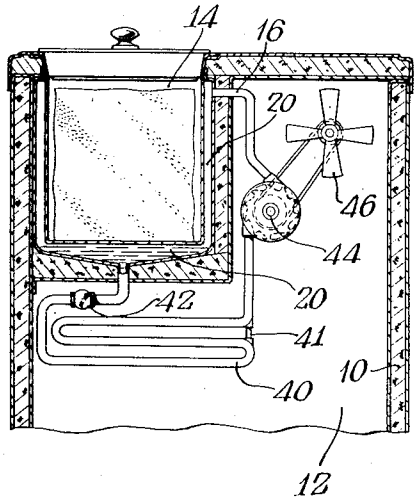
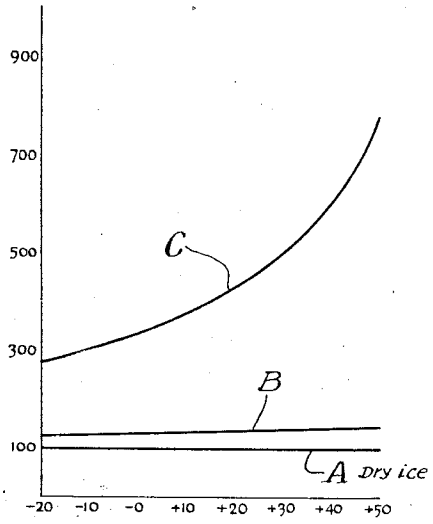


Fig. 2.



INVENTOR

David H. Killeffer

BY

Hammond & Littell

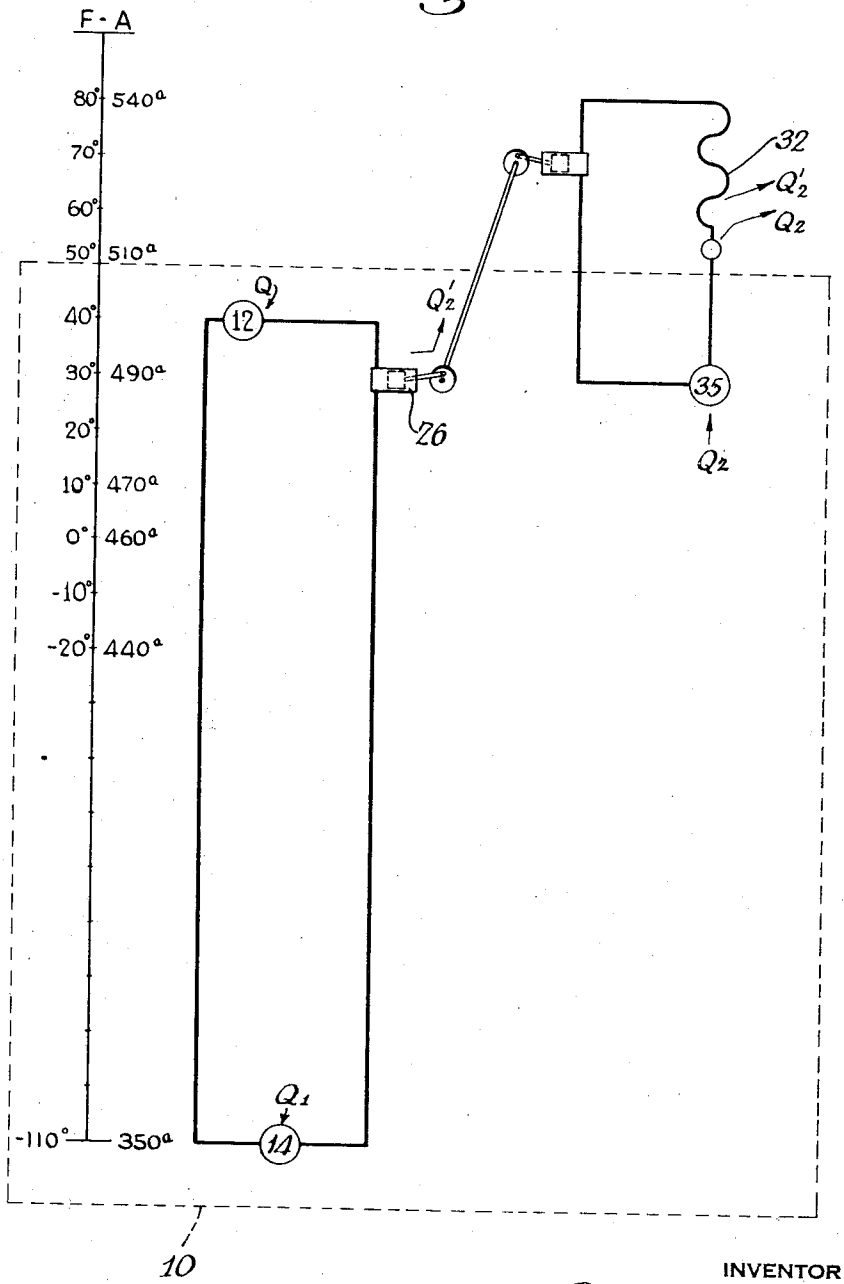
ATTORNEYS

Oct. 10, 1939. D. H. KILLEFFER 2,175,267

METHOD OF AND APPARATUS FOR REFRIGERATION

Filed Oct. 9, 1934 2 Sheets-Sheet 2

Fig. 3.



INVENTOR
David H. Killeffer
BY
Hammond & Hull
ATTORNEYS

Patented Oct. 10, 1939

2,175,267

UNITED STATES PATENT OFFICE

2,175,267

METHOD OF AND APPARATUS FOR REFRIGERATION

David H. Killeffer, Crestwood, N. Y.

Application October 9, 1934, Serial No. 747,548

16 Claims. (Cl. 62—91.5)

This invention relates to the art of refrigeration and more particularly to the use of low temperature refrigerants, such as solid carbon dioxide which absorbs heat from the refrigerated space at a temperature much below that required to be maintained in the space.

One of the principal objects of the present invention is to provide a new method of increasing the effective refrigeration available from low temperature refrigerants by interposing between the refrigerated space and the low temperature refrigerant, a heat engine which absorbs heat from the refrigerated space and converts part of it into work and transmits the remainder to the low temperature refrigerant.

As a specific feature of my invention I may provide an apparatus in the form of a heat engine which is operated by an evaporated secondary refrigerant normally condensed by the low temperature primary refrigerant and use the work of such engine in the refrigerated chamber to operate a fan, in which case the total amount of refrigeration is the same as when using the primary refrigerant alone although the rate of cooling will be increased and more uniform temperatures result.

Another object of my invention is to provide a heat engine operated by an evaporated secondary refrigerant normally condensed by a low temperature primary refrigerant such as solid carbon dioxide and evaporated by the heat of a refrigerated space using the generated work to operate a mechanical device beyond the refrigerated space or to operate a compression refrigerating system which may additionally cool the refrigerated space.

A further object of my invention is to provide a combined solid carbon dioxide and mechanical compression refrigeration system for a chamber to be refrigerated in which the total theoretical refrigeration is from two and one-half to nine times the refrigeration effect of the "dry ice" alone, such efficiencies varying with the temperature of the refrigerated chamber.

Further objects and advantages of my invention will appear from the following description thereof taken in connection with the attached drawings which illustrate preferred forms of embodiment thereof, and in which:

Figure 1 is a side elevation with parts in section and parts diagrammatically shown, showing the refrigerator having a combined low temperature refrigerant cooling chamber and a mechanical refrigerator;

Figure 2 is a diagram showing the relative efficiencies of the improved apparatus at various refrigerator temperatures;

Figure 3 is a diagram of the relative temperature positions of the respective element, and

Figure 4 is a partial vertical section of the upper part of the refrigerator showing a combined low temperature refrigerant chamber and an internal fan.

The use of solid carbon dioxide commonly known as "dry ice" and other low temperature refrigerants of this type is especially desirable for many types of refrigeration because of their economy, ease of handling and the possibility of obtaining lower temperatures than could normally be obtained by water ice. Such refrigerants have certain disadvantages and it has heretofore been impractical to use the available energy in the heat flow from normal refrigerator temperatures of 30° to 50° F. to temperatures of —110° F. In fact it has been common practice to blanket or insulate the low temperature refrigerating chamber because such temperatures were so low as to be entirely undesirable in commercial practice.

Another objection to the use of low temperature refrigerants is that a refrigerator normally requires but a small volume of refrigerant and the rate of heat transfer to the refrigerated space is rather poor unless artificial air currents are set up and a fan for this purpose decreases the amount of available refrigeration by the heat equivalent of the power required to operate the fan.

I have found that I can materially increase the cooling or heat exchange efficiency of low temperature refrigerants and obtain other beneficial results without any power expenditure and at relatively low initial cost of the low temperature refrigerants. "Dry ice" or solid carbon dioxide which has a temperature of approximately —110° F., is frequently used in present day refrigerators and although I shall refer to it specifically, it is to be understood that I am not limited to it as other low temperature refrigerants operate substantially the same. With solid carbon dioxide at —110° F. and refrigerator temperatures usually in the range of about 30° to 50° F., depending on the nature of the materials to be kept cold, the difference in temperature is considerable and the energy available, due to the flow of heat through this range although not heretofore used successfully is very substantial.

I have discovered that I can materially increase the total amount of refrigeration normally obtainable from a quantity of low temperature refrigerant such as solid carbon dioxide by taking advantage of the physical fact that the flow of heat from a higher to a lower temperature is a potential source of energy. If, therefore, this potential energy can be converted into mechanical energy and dissipated outside of the refrigerator chamber, this is an additional amount of energy given up by the refrigerated chamber and as there can be no loss with respect to the initial value of the low temperature refrigerant, which is also in the refrigerated chamber, I am

able to obtain an efficiency much greater than one.

Expressed in form of typical conditions, it may be assumed that the quantity of heat Q which is given up by the refrigerator chamber is normally equal to the quantity of heat absorbed Q_c by the solid carbon dioxide plus any work W which may be done.

(1) $$(Q=Q_c+W)$$

In the usual case, however, no external work is done, the value of W is 0 and the theoretical efficiency is one. Even if there is work done by the flow of heat, it is dissipated in the refrigerator chamber and no beneficial effect is realized.

I propose to use this potential energy, convert it into mechanical work, and dissipate the work outside of the refrigerator chamber, or I may use this mechanical work to operate an additional refrigerating system or I may dissipate the energy in aiding heat transfer within the refrigerator without loss of refrigerating efficiency as compared to previous systems. By dissipating the work W outside of the chamber, I have increased the amount of heat Q given up by the refrigerator to include in addition to the amount normally absorbed by the solid carbon dioxide or other low temperature refrigerant Q_c, the heat equivalent of the work W. The quantity Q_c which is the amount of heat absorbed by each unit of solid carbon dioxide or other low temperature refrigerant is fixed and Q will vary depending on the apparatus used. In such cases, the efficiency will always be one or more.

Although there is a considerable temperature differential through which the heat flows, it is essential that the work which can be done be converted by an efficient mechanism. For my purpose, I find that a heat engine of the reciprocating or turbine type is most suitable and that I can obtain highly desirable benefits from it. Furthermore, by controlling the operation of the heat engine, I am able to control the rate of evaporation of the secondary refrigerant and therefore the amount of refrigeration in the refrigerated chamber.

One form of apparatus which is suitable to carry out the features of my invention is shown diagrammatically in Figure 1, and the data of operation are generally illustrated on Figures 2 and 3. In Figure 1, the refrigerator is generally shown as having insulated walls **10** and a refrigerated chamber **12** which is adapted to be maintained at any desired temperature which varies ordinarily from 30° to 50° F. The refrigerator is provided with a low temperature refrigerating chamber **14** which is insulated from the chamber **12** by the walls **16** and preferably this chamber has a hollow wall **20** through which a suitable secondary refrigerant may pass. If "dry ice" or solid carbon dioxide is used as the primary refrigerant it may be placed in the chamber **14** through the insulated door **23** in a well known manner.

The secondary refrigerant surrounding the "dry ice" chamber may be of any suitable type such as ethylene oxide, anhydrous ammonia, or other low boiling point liquids which are difficultly condensible and whose freezing point is not above the temperature of the solid carbon dioxide or other primary low temperature refrigerant used in the chamber **14**. The refrigerant will collect when condensed in the sloping bottom of the chamber from which it will flow through the valve **22** by gravity into the evaporator **24**. The valve **22** is preferably a check valve so that the liquid cannot return under higher pressures.

The evaporator **24** is exposed to the heat of the chamber **12** and may be provided with fins on its surface to secure an easier transfer of heat from the refrigerator space to its contents. It is connected in a closed circuit with the refrigerant chamber **20** through the heat engine **26**, which may be of any suitable pressure type, such as reciprocating, turbine or other type. The heat engine **26** is adapted to operate a shaft **27** through which the mechanical energy may be transferred outside of the refrigerator compartment **12** and if desired, it may be provided with a flywheel for regulating the operation.

In operation, the refrigerant in the chamber **20** will normally be condensed by the low temperature of the solid carbon dioxide. The liquid will then be free to pass through the valve **22** into the evaporator **24**. Due to the high temperature of the evaporator, the liquid will be vaporized and the pressure generated will be sufficient to operate the engine **26**.

The exhaust vapor from the engine **26** is conducted through the pipes **28** back to the hollow chamber **20** where it accumulates until the pressure in the evaporator equalizes which occurs after complete evaporation of the liquid in the evaporator. Then after the liquid has condensed in the chamber **20** and passed through the one way valve **22** the cycle of operation begins again. It is to be understood that the hydrostatic head of the liquid and the resistance of the valves and the engine will be so correlated that the flow will occur in this manner.

The work done by the engine **26** is conducted out of the refrigerator compartment **12** by the shaft **27** and may be used for any suitable purpose. Merely dissipating it in external friction will increase the efficiency of refrigeration of the "dry ice" as will appear from the prior formula in which any value for W or work must necessarily increase the value of Q absorbed from the refrigerator chamber **12**. Preferably, however, I provide a compression refrigeration circuit including the compressor **30** which operates on a suitable refrigerant such as ammonia which in turn passes as a liquid through the condenser **32** to the expansion valve **33** for a subsequent expansion in the evaporator **35** which is within the refrigerator chamber **12**. This evaporator will withdraw a considerable amount of heat from the chamber as the amount of heat transferred to the atmosphere by the condenser **32** in a compression system is much greater than the energy consumed in its operation. The expanded gases will return to the pump **30** for further compression to complete the cycle.

From the following tables it will be seen that the refrigeration due to the compression refrigeration system may be from one and one-half to eight or more times that of the simple solid carbon dioxide system and in addition to it. There is practically no loss of refrigeration due to the blanketing of the solid carbon dioxide chamber in its cooling of the low boiling point liquid in the chamber **20** inasmuch as it occurs at a temperature far below the desired temperature of the refrigerated chamber. In such case the work done is returned in the form of refrigeration to the system with a very high overall result, and although the efficiency of the compressor may somewhat reduce the maximum theoretical amount of refrigera-

tion, it will not reduce it below several times the normal available refrigeration of the solid carbon dioxide alone.

The curves of Figure 2 are based on the apparatus shown in Figure 1 with assumed temperatures of solid carbon dioxide of —110° F. or 350° absolute and varying temperatures of the refrigerator chamber. No attempt has been made to show results with extreme accuracy as the only object is to illustrate the general principles involved. It is to be understood therefore that the relative effects are in conformity with known data and the precise mathematical details are not used.

The accepted formula for the work available in a refrigerator having a temperature T_1, and being cooled by a refrigerant at a temperature T_2 may be expressed as follows where Q_1 is the quantity of heat absorbed at T_1, and Q_2 is the quantity of heat rejected at T_2. The quantity of heat Q_2 is identical with the quantity Q_c in Equation "1" above.

(2) $$\frac{T_1-T_2}{T_2}=\frac{Q_1-Q_2}{Q_2}$$

Now by substituting the temperatures of T_1 as 490 and T_2 as 350, the work done is

$$\frac{490-350}{350}=\frac{\text{work}}{Q_2}$$

The value of Q_2 is 250 B. t. u./# solid carbon dioxide based on the latent heat of sublimation of solid CO_2 at —109.6° F.

$$\text{Work}=250\times 2/5=100 \text{ B. t. u.}$$

If the temperature T is selected for varying refrigerator temperatures of 50° F., 30° F., 10° F., 0° F. and —20° F., the range for commercial practice, then by using the corresponding absolute temperatures it will be found that the work available and the total refrigeration available when the work W (equal to Q_1-Q_2) is expended outside the refrigerator compartment 12 is as follows:

(3)

T	Q_1-Q_2	Q_2	Total	Percent
50	114	250	364	146
30	100	250	350	140
10	85.7	250	336	134
0	78.6	250	329	132
—20	64.3	250	314	126

This is the basis for Curve B.

If now the available work is converted into refrigeration by mechanical compression, the same formula is proper although the symbols have a slightly different significance.

If T_1=temperature of the refrigerator and T_a=condenser temperature (outside air), the formula may be expressed as follows:

(4) $$\frac{T_a-T_1}{T_a}=\frac{AW}{Q_a}$$

Now assuming T_1 to be 30° F. or 490° absolute and T_a to be 80° F. or 540° absolute, and AW=100 B. t. u. at 30° F.

then

$$Q_a=1080 \text{ B. t. u.}$$

and the total refrigeration is

$$1080+250=1330 \text{ B. t. u./\#}$$

For different refrigerator temperatures, the quantity AW varies according to Table 3, and the total refrigeration is shown in the following table.

(5)

Air temperature	Refrigerator temperature	Q_a	"Dry Ice"	Total	Percent
	° F.				
80° F.	50	2050	250	2300	920
80° F.	30	1080	250	1330	532
80° F.	10	662	250	912	365
80° F.	0	531	250	781	312
80° F.	—20	347	250	597	239

This is the basis for Curve C.

In a schematic form, as shown in Figure 3, it will clearly appear that the heat of the refrigerated chamber which may be represented at 12 and as having a temperature of 40° F., will give up a quantity of heat Q which heat will cause such a pressure on the secondary refrigerant that it will operate the compressor 26. The expanded refrigerant will then pass to the condenser or primary refrigerant chamber 14 which being at the extreme temperature of —110°, if containing solid carbon dioxide, will cause a condensation and heat exchange. It is to be noted that as the primary chamber is also within the refrigerator walls 10, there will be a direct entry of heat Q_1 into such compartment.

Now due to the operation of the heat engine 26, there is a certain amount of heat or equivalent work Q'_a which goes out of the compartment and is dissipated. This is in accordance with Formula 1 $Q=Q_c+W$ and as Q_c is fixed as the heat required to sublime the low temperature refrigerant such as solid carbon dioxide, the amount of heat which can be extracted by the combined system is greater than the heat which could normally be extracted by the low temperature refrigerant alone.

When the compressor refrigerator cycle is operated, the heat which is required to operate the compressor 26, W is dissipated by the condenser 32 and this condenser similarly dissipates the heat of compression which enters the evaporator 35. As heretofore shown, this total heat may be from two and a half to nine times the heat which is absorbed by the solid carbon dioxide. The efficiency therefore of the combined systems is greater than one and at normal refrigerator temperatures of 30° F., to 50° F., this is greater than seven times the solid carbon dioxide rate.

It may be found that the combination compression system may involve undue expense in some small installations. In such installations however, it is common to use a circulating fan to promote heat exchange and such fans are of course supplied with outside energy, which is dissipated within the refrigerator. Such arrangement is justified as a rule since the exposed portion of dry ice is usually small and remote parts of the refrigerator do not become adequately cooled without forced circulation.

In a modified form of apparatus as shown in Figure 4, the available energy of the heat flow is used to operate a circulating fan and inasmuch as no outside energy is added, the efficiency of cooling is not reduced and, at the same time the rate of cooling is increased. The apparatus is similar to that shown in Figure 1 and includes the insulated walls 10 surrounding the refrigerated chamber 12 and a primary refrigerating chamber 14 also enclosed in insulated walls 16.

The low boiling point secondary refrigerant

in the hollow walls 20 surrounding the primary refrigerating chamber empties into the evaporator 40 which may be of modified tubular form. This evaporator is provided with a suitable check valve 42 allowing the liquid to move into the evaporator from the secondary refrigerant chamber 20 but not allowing it to return. The evaporator, 40 may be of the self-bleeding type having the bleeding device 41 if desired.

A turbine motor 44 of the heat engine type is used in this modified form of embodiment and is placed in the gas discharge circuit leading from the evaporator 40 to the secondary refrigerant condenser 20. This motor 44 is connected in turn to a fan 46 mounted within the refrigerated chamber 12 in a suitable position to facilitate heat transfer.

As heretofore described, the secondary refrigerant enters the evaporator 40 and in a similar manner will be evaporated to create sufficient pressure for rotation of the fan and useful work. The exhaust from the motor 44 will return as gas to the condenser 20 and coming in contact with the cold walls of the primary low temperature refrigerating chamber, the gas will be condensed to a liquid and collect in the lower reservoir. When the pressure equalizes due to the complete evaporation of the secondary refrigerant, the secondary refrigerant which has been condensed will again run into and fill the evaporator 40.

The amount of heat removed from the refrigerator 12 can be controlled in a simple manner by controlling the operation of the fan 46 or the motor 26 in the first embodiment. The rotation of the motor permits passage of the secondary refrigerant vapor through the cycle and when retarded, the transfer of heat to the low temperature primary refrigerant is retarded.

The cycle of secondary refrigerant is continuous and automatic while the primary refrigerant lasts. For continuous operation of the motor 44 or 26, suitable fly wheels and other devices may be found desirable. The increase of heat removal at the higher temperatures of refrigerating chamber may make it desirable under certain conditions to cool the chamber in two stages and especially is this true with air conditioning or in other applications where it is desirable to cool large volumes at relatively high initial temperature.

While I have shown and described preferred forms of embodiment of my invention it is to be understood that the entire apparatus is shown as diagrammatic to illustrate the application of my invention and that many refinements of heat exchange nature could be used without in any sense departing from the scope of my invention. I therefore desire a broad interpretation of my invention within the scope and spirit of the disclosure herein and of the claims appended hereinafter.

I claim:

1. A refrigerating circuit including a low temperature refrigerant source of the class of solid carbon dioxide, an intermediate refrigerating circuit energized by the heat of a substance to be cooled, and a compression refrigeration circuit effecting additional refrigeration of the substance to be cooled, said compression refrigeration circuit being energized by the flow of heat through said intermediate circuit from the substance to be cooled to the low temperature refrigerant source, the characteristic of said joint refrigerating circuits being such that the total refrigeration theoretically available increases as the temperature of the substance to be cooled is increased.

2. In a heat exchange apparatus of the refrigeration type for a chamber to be cooled, the combination of a receptacle adapted to contain a low temperature refrigerant, a low boiling point refrigerant in heat exchange relation with a refrigerant in said low temperature refrigerant receptacle, and adapted to be condensed thereby, evaporator means within said chamber to evaporate said low boiling point refrigerant by the heat of the contents of said chamber, and a prime mover receiving said evaporated refrigerant to convert the heat energy of the evaporated refrigerant to mechanical energy, means to dissipate said mechanical energy, whereby heat energy is removed from said chamber in addition to that absorbed by said low temperature refrigerant, said mechanical energy dissipating means increasing the effectiveness of said low temperature refrigerant.

3. The method of cooling large volumes of matter at relatively high temperature with a low temperature refrigerant of the class of solid carbon dioxide which comprises condensing a low boiling point refrigerant by heat exchange with the solid carbon dioxide, expanding the condensate in heat exchange relation with the large volume of matter to produce cooling therein, converting the heat energy to mechanical energy in a heat engine, converting said mechanical energy to refrigeration energy and additionally cooling the large volume of matter by said refrigeration.

4. In a heat exchange apparatus of the refrigeration type for a chamber to be cooled the combination of a receptacle adapted to contain a low temperature refrigerant, a condenser in heat exchange relation with the contents of the receptacle adapted to condense a low boiling point refrigerant, an evaporator in heat exchange relation with the contents of said chamber to evaporate said low boiling point refrigerant, said evaporator being connected to receive refrigerant from said condenser, a pressure type prime mover, means to conduct the evaporated low boiling point refrigerant in vapor phase to and through said prime mover and from the prime mover to the condenser, and means to dissipate the energy of said prime mover outside of the chamber and independent of the circulating low temperature refrigerant.

5. In a heat exchange apparatus of the refrigeration type for a chamber to be cooled the combination of a receptacle adapted to contain a low temperature refrigerant, a condenser in heat exchange relation with the contents of the receptacle adapted to condense a low boiling point refrigerant, an evaporator in heat exchange relation with the contents of said chamber to evaporate said low boiling point refrigerant, a pressure type prime mover, means to conduct the evaporated low boiling point refrigerant in vapor phase to and through said prime mover and from the prime mover to the condenser, and means to dissipate the energy of said prime mover to the atmosphere outside of the chamber to be cooled.

6. In a heat exchange apparatus of the refrigeration type for a chamber to be cooled the combination of a receptacle adapted to contain a low temperature refrigerant, a condenser in heat exchange relation with the contents of the receptacle adapted to condense a low boiling point refrigerant, an evaporator in heat exchange re-

lation with the contents of said chamber to evaporate said low boiling point refrigerant, a pressure type prime mover, means to conduct the low boiling point refrigerant in liquid phase from the condenser to the evaporator, the evaporated low boiling point refrigerant in vapor phase to and through said prime mover and from the prime mover to the condenser, and means to dissipate the energy of said prime mover comprising a compressor refrigerating machine having a compressor, a condenser and an evaporator, only said evaporator being within the chamber and means to drive said compressor from said prime mover.

7. In a heat exchange apparatus of the refrigeration type for a chamber to be cooled the combination of a receptacle adapted to contain a low temperature refrigerant, a condenser in heat exchange relation with the contents of the receptacle adapted to condense a low boiling point refrigerant, an evaporator in heat exchange relation with the contents of said chamber to evaporate said low boiling point refrigerant, a pressure type prime mover arranged to be driven by the flow of heat from the chamber to the low temperature refrigerant and a compression type refrigerating apparatus operated by said prime mover and comprising a second low boiling refrigerant.

8. The method of increasing the refrigerative effect of a low temperature refrigerant which consists in utilizing the flow of heat from the space or material to be cooled to said low temperature refrigerant to operate a prime mover and in applying the work produced by said prime mover to operate a supplementary refrigeration machine to cool said space or material additionally.

9. The method of increasing the refrigerative effect of a low temperature refrigerant which consists in abstracting heat from the space or material to be cooled by the evaporation of a low boiling refrigerant in heat exchange relation therewith, utilizing the vapor thus formed as the motive fluid in an expansion engine, condensing said vapor at low pressure by placing it in heat exchange relation with said low temperature refrigerant, and utilizing the work produced by said expansion engine to operate a supplementary compression refrigerating system to cool said space or material additionally.

10. In a heat exchange apparatus of the refrigeration type for a chamber to be cooled the combination of a receptacle adapted to contain a low temperature refrigerant, a condenser in heat exchange relation with the contents of the receptacle adapted to condense a low boiling point refrigerant, an evaporator in heat exchange relation with the contents of said chamber to evaporate said low boiling point refrigerant, said evaporator being positioned at a lower lever than the condenser and the condenser and evaporator being arranged to provide a gravity circulation of the low boiling point refrigerant, a pressure prime mover, means to conduct the evaporated low boiling point refrigerant in vapor phase to and through said prime mover and from the prime mover to the condenser, and means to dissipate the energy of said prime mover to the atmosphere outside of and independent of said chamber.

11. The method of increasing the refrigerative effect of a low temperature refrigerant which consists in utilizing the flow of heat from the space or material to be cooled to said low temperature refrigerant to operate a prime mover and in applying the work produced by said prime mover to operate a supplementary refrigeration machine.

12. The combination, with a compartment to be cooled, of a receptacle for receiving solid carbon dioxide and mechanism arranged to circulate a low boiling point refrigerant in heat exchange relation with said receptacle and in heat exchange relation with the air in said compartment; said mechanism being made up of a circuit including a pressure type prime mover and means to bring about a flow of said refrigerant in vapor phase to said prime mover at the maximum pressure in the circuit and from said prime mover at the minimum pressure in the circuit to operate said prime mover.

13. The combination, with a compartment to be cooled, of a receptacle arranged to hold a charge of carbon dioxide adjacent said compartment, and a system for removing from said compartment energy over and above whatever energy may be expended in vaporizing said carbon dioxide; said system comprising an engine, a power dissipating device disposed outside of said compartment, means connecting said engine with said device and a circuit permanently charged with a secondary refrigerant and arranged within said compartment; said circuit including a condenser insulated from the interior of said compartment and disposed in heat exchange relation with said receptacle, means for receiving liquid from said condenser, evaporating the same and supplying the resulting vapor to said engine and means for returning the discharge from said engine to said condenser.

14. In the art of operating a cyclic system for cooling a refrigerated space, the method of utilizing the potential energy of an expanding saturated vapor to operate a prime mover which comprises the steps of condensing the vapor by heat exchange with a low temperature refrigerant, vaporizing said liquid by heat exchange with the contents of the space to be refrigerated, converting heat energy to mechanical energy by expanding said vapor in a prime mover and again condensing the vapor by heat exchange with a low temperature refrigerant and transferring the work of said prime mover outside of the refrigerated space.

15. The method of increasing the effective refrigeration of a chamber cooled by a low temperature refrigerant: said method comprising cyclically condensing, by heat exchange with the low temperature refrigerant, vapor of a secondary refrigerant; vaporizing the resulting liquid by heat exchange with the air of the space to be refrigerated; expanding said vapor in a heat engine and returning said expanded vapor to be condensed in the succeeding cycle of operation; transferring the power developed by the operation of said engine to a point outside of said space and at such point utilizing the power to propel a third refrigerant through a compression-condensation evaporation cycle and utilizing the evaporation of the last mentioned refrigerant to absorb heat from said space.

16. The combination with a refrigerator cabinet having a storage chamber and a low temperature refrigerant receptacle, of refrigerating apparatus for cooling the air in said chamber comprising an evaporator in said chamber, a condenser in said refrigerant receptacle, and an expansion engine, said evaporator, expansion engine and condenser being connected to form a

circuit for a low boiling point refrigerant wherein the vapor of said low boiling point refrigerant formed in the evaporator passes through the expansion engine to the condenser and is condensed therein and returned to the evaporator, mechanical means outside of the storage chamber for absorbing and dissipating the work done by said expansion engine and mechanical means to transfer the work done by said engine to the mechanical absorbing and dissipating means outside of the refrigerated chamber.

DAVID H. KILLEFFER.

CERTIFICATE OF CORRECTION.

Patent No. 2,175,267. October 10, 1939.

DAVID H. KILLEFFER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 5, first column, line 5, claim 6, after the comma and before the article "the" insert means to conduct; line 61, claim 10, for "lever" read level; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 5th day of December, A. D. 1939.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)