April 14, 1925. 1,533,646

A. L. GIVENS

REFRIGERATOR

Filed July 5, 1924

Fig. 1

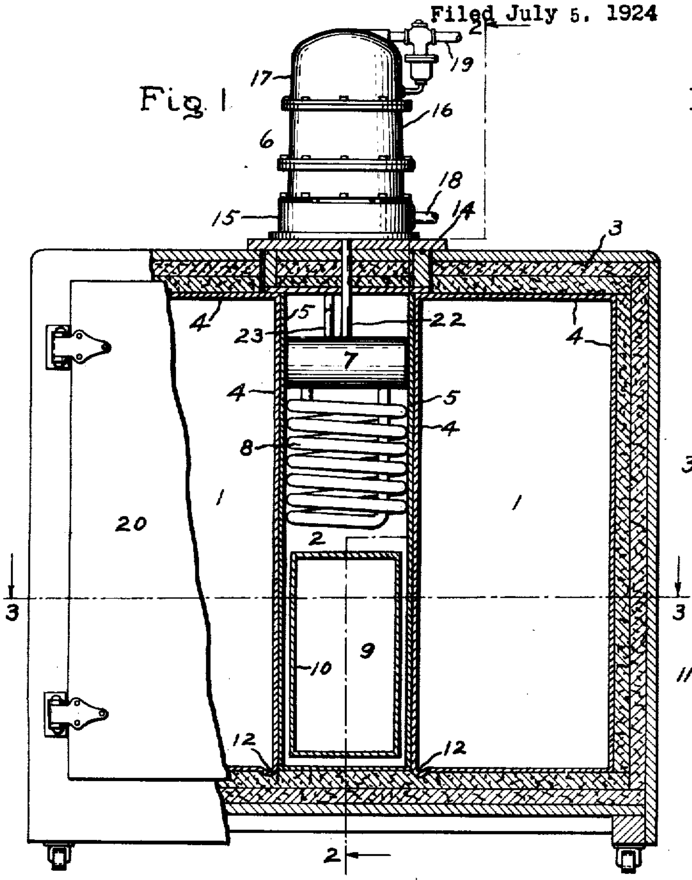


Fig. 2.

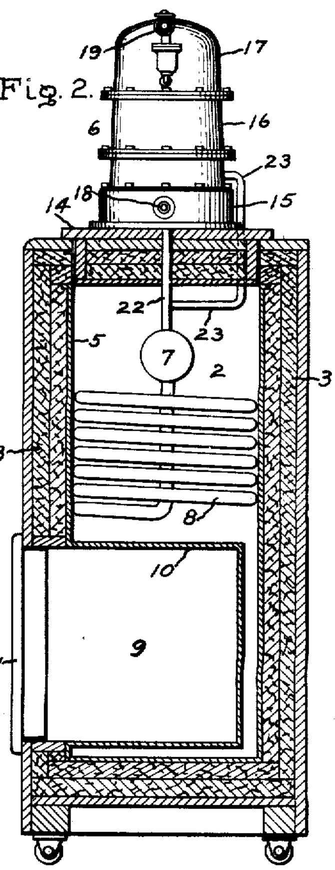
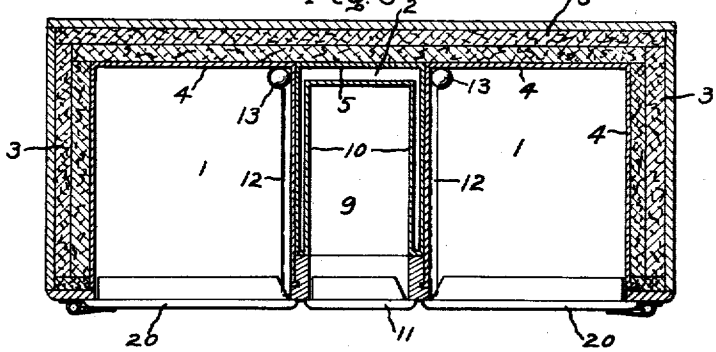


Fig. 3



Inventor
Albert L. Givens
by Alexander F. [signature]
His Attorney

Patented Apr. 14, 1925. **1,533,646**

UNITED STATES PATENT OFFICE.

ALBERT L. GIVENS, OF FORT WAYNE, INDIANA, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

REFRIGERATOR.

Application filed July 5, 1924. Serial No. 724,215.

To all whom it may concern:

Be it known that I, Albert L. Givens, a citizen of the United States, residing at Fort Wayne, in the county of Allen, State of Indiana, have invented certain new and useful Improvements in Refrigerators, of which the following is a specification.

My invention relates to refrigerators and is particularly applicable to refrigerators designed for use in connection with artificial refrigerating machines.

In the ordinary household refrigerator, in which ice is employed as the cooling medium, it is customary to connect the various food compartments of the refrigerator with the ice compartment in such a manner that there is a continuous circulation of air from the cooling compartment downwardly through one or more food compartments and thence to another range of food compartments in which the air rises until it becomes warm, and is finally delivered into the cooling compartment, where it comes into contact with the ice and again becomes cool.

In the application of artificial refrigerating machines to household refrigerators, the same arrangement as above described has been customarily employed, the evaporator of the artificial refrigerating machine being located in the cooling compartment corresponding to the ice compartment of the ordinary household refrigerator, and the various compartments being so connected by passages that cool air flows downwardly from the cooling compartment through one or more food compartments in which the air rises as it takes up heat, and is finally delivered to the cooling compartment, where it is again cooled by contact with the evaporator of the refrigerating machine.

In such refrigerators it is customary to provide the various compartments—particularly the food compartments—with thin metal walls. These thin metallic walls are, of course, continually receiving heat from the outside atmosphere, which leaks through the insulating casing (generally cork, or something of that kind) by which the food compartments and cooling compartment of the refrigerator are surrounded. These walls have some thermal conductivity, but practically all of the heat leaking through the insulating casing is taken away by the circulation of the air inside the refrigerator compartments, which takes up the heat as it comes in contact with these walls and transfers it to the cooling compartment, where it is cooled again, either by the melting ice or by the evaporator of the artificial refrigerating machine.

In systems of the character above described, whatever deleterious matter is taken up by the air in its passage through the food compartments is delivered in the cooling compartment and is deposited on the ice or on the walls of the evaporator of an artificial refrigerating machine, if such be employed. This causes no serious difficulty where ice is employed as a cooling medium, because the ice is continually melting away, and the products which condense thereon are carried away by the water which is produced as the ice melts. When, however, an artificial refrigerating machine is employed, difficulties do arise, due to the fact that there is no means for removing the condensation products from the evaporator of the artificial refrigerating machine, excepting by washing it off from time to time, and this is frequently a very difficult thing to do, because it is a difficult thing to make readily accessible those parts of the artificial refrigerating machine which are cool and on which condensation occurs.

It is the object of my invention to avoid the difficulties above described, and to so construct a refrigerator which is cooled by artificial refrigeration that all parts of the refrigerator in which deposits are likely to occur by condensation of vapors arising from the food contained therein will be readily accessible and easily cleaned, and so that all parts of the artificial refrigerating machine which are within the refrigerator proper may be kept clean. To this end, I arrange for a transfer of substantially all of the heat from the food compartment to the evaporator of the artificial refrigerating machine by conduction through the walls of the food compartment, instead of by circulation of air through the food compartment and the cooling compartment, as has been the practice in the past. In this way I am able to close off the food compartment completely from the cooling compartment, and by making the shelves of the food compartment removable, as is the present custom, it becomes very easy to remove any products of condensation from the walls of the food compartment, by periodically removing the shelves and thoroughly washing this compartment, which, since it comprises only plane surfaces may readily be cleaned.

In a refrigerator constructed in accordance with my invention, the heat which leaks through the insulating casing surrounding the refrigerator passes from the walls of the food compartment directly by thermal conduction through these walls into the evaporator of the artificial refrigerating machine, and in order to make it practicable to cool the food compartment of a refrigerator in this way, it is necessary that the walls of the food compartment should have a thermal capacity very much in excess of that which is found in the thin metallic lining of the ordinary refrigerator, and it is also necessary that these walls should have a good thermal connection with the evaporator of the refrigerating machine, where in the ordinary household refrigerator employing air circulation no such thermal path is necessary.

My construction permits the building of a smaller refrigerator for the same size of food and cooling compartments than was heretofore possible, since it eliminates air passages and other waste space. Furthermore, the heat entering a refrigerator built in accordance with my invention through the casing thereof is transferred to the cooling compartment with less temperature drop than was heretofore possible. This permits the refrigerating machine to be operated at a higher temperature than heretofore. In other words, heretofore, in order to maintain the warmest spot in the food compartment at say 50 deg. F. it was necessary to operate the refrigerating machine so as to produce a temperature of 15 to 20 deg. F. in the evaporator. With my arrangement, with a temperature of say 50 deg. F. in the warmest spot of the food compartment, it is only necessary to operate the refrigerating machine so as to get a temperature of 30 to 32 deg. F. in the evaporator. It is well known that a refrigerating machine is more efficient when it is operating to produce a high temperature in the evaporator and therefore my construction permits the refrigerating machine to operate more efficiently than was heretofore possible.

Other features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing, in which Fig. 1 is an elevation, partly in section, of a refrigerator embodying my invention; Fig. 2 is a sectional view taken on the line 2—2 of Fig. 1, and Fig. 3 is a sectional view taken on the line 3—3 of Fig. 1.

In the drawing there is shown a refrigerator having food compartments 1 and a cooling compartment 2 located between the two food compartments. The casing 3 of the refrigerator is made of heat insulating material such as cork or the like. The food compartments and the cooling compartment have metal walls which are in good thermal relation to each other and thick enough so that the heat leaking in from the outside through the heat insulation by which these walls are surrounded will be conducted from the walls of the food compartments to the cooling means in the cooling compartment substantially, solely by thermal conduction through the walls of the food compartments. In the particular arrangement shown in the drawing the cooling compartment has an opening at the top which is covered by the base of an artificial refrigerating machine 6, the evaporator of which extends into the cooling compartment and is in good thermal contact with the walls 5 of the cooling compartment. The evaporator is shown as comprising a receptacle 7 and evaporator coils 8. This good thermal contact between the walls of the cooling compartment and the evaporator may be obtained by filling the cooling compartment with brine so that the brine conducts heat from the walls 5 to the evaporator. I prefer, however, to have the walls of the evaporator in good thermal contact with the walls 5 of the cooling compartment. This good thermal contact may be obtained by soldering, welding, brazing or just a good metallic contact. The cooling compartment even with the latter construction may also advantageously be filled with brine. The metal walls 4 of the food compartment and the walls 5 of the cooling compartment may be made all in one piece but owing to the fact that the food compartments of refrigerators are usually lined on the inside with porcelain, which requires the walls of the food compartments to be subjected to a high temperature, I deem it advisable to build the food compartment and cooling compartment as separate structures and afterwards unite them in such a way as t get good thermal contact between them. This good thermal contact may be obtained in any usual way as by welding, hydrogen brazing or just good metallic contact. The portions of the metal walls 4 and the metal walls 5 which are in good thermal contact, completely separate the cooling compartment from the food compartments. The metal walls 4 of the food compartment and the metal walls of the cooling compartment must be of such thickness that the heat entering the refrigerator through the casing 3 thereof flows solely by conduction through the walls of the food compartment to the adjacent walls of the cooling compartment and thence to the evaporator. The food compartments are closed at the front by doors 20 of usual construction.

In the arrangement shown in the drawing, there are two food compartments separated by one cooling compartment. The proper thickness of the walls 4 and 5 may be determined by trial or they may be calculated. One method of calculating the thickness of the walls of a refrigerator with compartments arranged as shown in the drawing follows.

The following assumptions are made:

First, the casing 3 is made of two inches of cork and the linings 4 and 5 are made of iron.

Second, heat which leaks through that portion of the casing on the sides of the refrigerator farthest from the cooling compartment will divide into parts flowing in three different directions, one part to the metal wall of the top, one part to the metal wall of the back, and one part to the metal wall of the bottom. It has been further assumed that these parts are rectangular in shape for the sake of simplicity of the equations, although theoretically they should be triangular.

Third, the walls of either food compartment will be thick enough so that the temperature difference between the center and edges of the wall of either of the food compartments next the cooling compartment will be negligible, and further, that the cooling unit will be run at a low temperature, so that the edges of this wall will be at an assumed temperature, T_1, say 32° F.

Fourth, the evaporator of the refrigerating machine is in good thermal contact with the walls 5 of the cooling compartment, so that the temperature drop between these walls and the evaporator is negligible.

The conductivity of cork, 2″ thick, is .125 B. t. u. per square foot per hour per degree difference in temperature. Consider the heat leaking through this cork insulation and being absorbed by a strip of metal (dx) long and (W) wide, then the area for the flow of heat through the cork is Wdx.

If the temperature of the air outside of the box is (T_2) and the temperature of the strip (dx) is (T), then the heat flowing through the cork to the strip (dx) will be, $.125(T_2-T)Wdx$.

If (Q) is the flow of heat in the metal lining and (dQ) the increase in flow corresponding to the length (dx), then,

$$dQ=-.125\ W(T_2-T)dx$$

Let $K_1=.125W$

Then,

$$\frac{dQ}{dx}=-K_1(T_2-T) \quad (1)$$

The minus sign is used because (x) is measured from $x=0$ at the edge of the wall next the cooling unit, to $x=l$, at the middle of the far side of either food compartment. The heat flow increases, therefore, as (x) decreases, and this requires the minus sign in equation (1).

The heat conductivity of iron is 45.6 B. t. u. per sq. ft., per hour, with a temperature gradient of 1° F. per foot. If (d) is the thickness of the metal lining in inches and (W) is the width in feet, then the area of the section is $Wd/12$ sq. ft. The temperature gradient is, therefore,

$$\frac{dT}{dx}=\frac{12Q}{45.6\ Wd}$$

Let

$$K_2=\frac{12}{45.6\ Wd}=\frac{.263}{Wd}$$

Then,

$$\frac{dT}{dx}=K_2Q \quad (2)$$

Differentiating equation (2),

$$\frac{d^2T}{dx^2}=K_2\frac{dQ}{dx} \quad (3)$$

Substituting equation (1) in equation (3)

$$\frac{d^2T}{dx^2}=-K_1K_2(T_2-T) \quad (4)$$

Let

$$a=K_1K_2=.125W\frac{.263}{Wd}=\frac{.0326}{d} \quad (5).$$

Then,

$$\frac{d^2T}{dx^2}-aT=-aT_2$$

The solution of this is,

$$T=C_1\cos(\sqrt{a}x+C_2)+T_2$$

The constants of integration, C_1 and C_2, can be determined from the conditions:

1. At $x=0$, $T=T_1$, the temperature of the edge of the wall of the cooling compartment.

2. At $x=l$, the middle of the far wall, the flow is zero, and therefore,

$$\frac{dT}{dx}=0$$

Substituting for the integration constants, the equation can be rearranged,

$$T_2-T_1=\frac{T_2-T_1}{\cos\sqrt{a}l} \quad (6)$$

Where T_2 is the temperature of the room; T_1 is the temperature of the edge of the wall of the brine tank or cooling compartment; T is the temperature of the metal lining at the farthest point from the cooling compartment. Substituting the value of (a) from equation (5) in equation (6),

$$T_2-T_1=\frac{T_2-T_1}{\cos\sqrt{\frac{.0326}{d}}l} \quad (7)$$

Consider now the refrigerator of the drawing, having the food compartments of the following dimensions: 24 inches high, 16 inches deep and 14 inches wide. Then the equivalent length, l, is 1.75 feet. Assume that T_2 is 90 degrees, that T_1 is 32 degrees and that T_1 is 50 degrees, and solving equation (7) for d, it is found that $d=\frac{1}{8}$ inch, that is the thickness of the lining of the food and cooling compartments should be at least ⅛ inch thick.

With the same dimensions of refrigerator, $T_2=90°$, $T_1=32°$ but $T_1=45$ degrees, (d) from equation (7) is 3/16 inches.

The cooling compartment has fastened in the front thereof, an ice compartment 9 having metal walls 10 in good thermal contact with the walls 5 of the cooling compartment. I preferably weld the walls 10 to the walls 5. The top, bottom and two sides of ice compartment 9 are exposed to the cooling effect of the cooling compartment and if pans of water are inserted through the door 11 of the ice compartment, and the temperature of the cooling compartment is below 32 degrees Fahrenheit, the water in the pans will be turned into ice.

The bottoms of the food compartments are shown as provided with grooves 12 therein sloping toward the back of the refrigerator. At the back of the refrigerator and communicating with the grooves 12 is a trap and drain 13 of usual construction. Any condensation forming on the walls of the food compartment adjacent said cooling compartment will flow down the walls into the grooves 12 and out through the trap and drain 13.

Any well known type of artificial refrigerating machine may be used in my refrigerator. I have illustrated the refrigerating machine shown in the application of Clark Orr, Ser. No. 393,888, filed July 3, 1920, which is assigned to the same assignee as the present application. The refrigerating machine is shown mounted on a cover 14 to which is secured the base 15 of the machine. The refrigerating machine comprises the base 15 forming a reservoir for condensed refrigerant, such as sulphur dioxide, a condensing chamber formed in casing 15 and a compression chamber formed in casings 16 and 17. Located in casing 16 is a compressor for compressing the refrigerant, and located in casing 17 is an electric motor for driving the compressor. The reservoir, condensing chamber and the motor in the compression chamber are cooled by a cooling medium such as water, which enters the machine by pipe 18 and leaves the machine by pipe 19. Secured to the underside of the cover 14 is the evaporator which consists of the receptacle 7 for receiving the liquid refrigerant and the evaporator coil 8. Inlet pipe 22 communicates with the receptacle 7 at the top and outlet pipe 23 connects the receptacle with the compression chamber. The ends of the evaporator coil 8 communicate with the bottom of the receptacle 7.

The refrigerant in a gaseous condition is drawn through the pipe 2 into the compressor, where it is compressed. After compression it passes into the compression chamber from whence it goes into the condensing chamber. In the condensing chamber it is cooled and liquefied by the cooling medium entering the machine through pipes 18 and collects in the reservoir. The liquid refrigerant passes through pipe 22 into the receptacle 7 and thence into the evaporator coil 8. As the liquid refrigerant is evaporated in the coil 8 it takes out heat from the cooling compartment and from the walls 5 thereof, thereby cooling the refrigerator. The liquid refrigerant in expanding again becomes a gas, which passes up through the liquid in the receptacle 7 and thence through pipe 23 to the compressor. The position of pipe 23 in the receptacle is such as to be slightly above the normal level of the liquid refrigerant in the receptacle.

The refrigerator is maintained at a temperature substantially lower than that of the room in which it is placed. Heat therefore flows through the insulating casing 3 thereof into the walls 4 of the food compartments, through these walls to the walls 5 of the cooling compartment from which it is transmitted to the walls of the evaporator. If desired the cooling compartment may be filled with brine, in which case the brine because of its good thermal conductivity will reduce the resistance of the thermal path between the walls of the cooling compartment and the evaporator and thus will assist in transferring heat from the former to the latter.

Under certain conditions, it may be desirable to make more ice than can be made in the ice compartment 9, and my construction of refrigerator lends itself to this purpose. In order to do this, cans of water may be placed in the cooling compartment by suspending them in a rack across the top of the cooling compartment. Such cans would be put in and taken out through a suitable opening provided in the cover 14.

I desire it to be understood that my invention is not limited to the particular arrangement shown and described, and I aim in the appended claims to cover any modifications which do not depart from the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:—

1. In combination, a refrigerator comprising a casing of heat insulating material having a food compartment and a cooling compartment therein provided with metal walls, the adjacent walls of the two compartments being in good thermal relation to each other, an artificial refrigerating machine mounted in proximity to said refrigerator and having an evaporator, said evaporator being located in said cooling compartment and being in good thermal relation with the walls of said compartment, the walls of the food compartment being of such thickness that the heat entering said refrigerator through the casing thereof flows substantially solely by conduction through the metal walls of the food compartment to the cooling compartment and thence to said evaporator.

2. In combination, a refrigerator comprising a casing of heat insulating material having a cooling compartment and a food compartment therein provided with metal walls, said cooling compartment being completely separated from said food compartment, said walls of said compartments being made of a material having good thermal conductivity, and an artificial refrigerating machine mounted in proximity to said refrigerator and having an evaporator, said evaporator being located in said cooling compartment and being in good thermal contact with the walls of said cooling compartment, said walls of said food compartment having a direct thermal connection with the walls of said cooling compartment, said walls of said food compartment being of such thickness that the heat entering said refrigerator through the casing thereof flows substantially solely by conduction through the walls of the food compartment to the adjacent walls of said cooling compartment and thence to said evaporator.

3. In combination, a refrigerator comprising a casing of heat insulating material having a food compartment and a cooling compartment therein provided with metal walls, said cooling compartment being completely separated from said food compartment, the adjacent metal walls of said food and cooling compartments having good thermal contact with each other, and an artificial refrigerating machine mounted in proximity to said refrigerator and having an evaporator, said evaporator being located in said cooling compartment, the walls of said evaporator being in good thermal contact with said walls of said cooling compartment, said metal wall of the food compartment being of such thickness that the heat entering said refrigerator through the casing thereof flows substantially solely by conduction through the metal walls of the food compartment to the adjacent walls of the cooling compartment to said evaporator.

4. In combination, a refrigerator comprising a casing of heat insulating material having a plurality of food compartments and a cooling compartment therein, provided with metal walls, said cooling compartment being located between said food compartments, said cooling compartment being completely separated from said food compartments, metal walls for said food compartments having good thermal contact with the metal walls of said cooling compartment, and an artificial refrigerating machine mounted in proximity to said refrigerator and having an evaporator, said evaporator being located in said cooling compartment and being in good thermal contact with said walls of the cooling compartment, said metal walls of the food compartments being of such thickness that the heat entering said refrigerator through the casing thereof flows substantially solely by conduction through the metal walls of the food compartments to the adjacent metal walls of said cooling compartment and thence to said evaporator.

5. In combination, a refrigerator comprising a casing of heat insulating material having a plurality of food compartments and a cooling compartment therein provided with metal walls, said cooling compartment being located between said food compartments, said cooling compartment being completely separated from said food compartments, said walls of said food compartments having good thermal contact with said walls of the cooling compartments and an artificial refrigerating machine mounted in proximity to said refrigerator and having an evaporator, said evaporator being located in said cooling compartment, the walls of said evaporator being in good thermal contact with said walls of the cooling compartment, said walls of the food compartments being of such thickness that the heat entering said refrigerator through the casing thereof flows substantially solely by conduction through the walls of the food compartment

to the adjacent walls of the cooling compartment and thence to said evaporator.

6. In combination, a refrigerator comprising a casing of heat insulating material having a plurality of food compartments and a cooling compartment therein and an ice compartment formed in said cooling compartment, said compartments having metal walls, said cooling compartment being completely separated from said food compartments, said walls of said food compartments having good thermal contact with said wall of said cooling compartment, an artificial refrigerating machine mounted in proximity to said refrigerator having an evaporator, said evaporator being located in said cooling compartment and being in good thermal contact with the walls of said cooling compartment, said walls of the food compartments being of such thickness that the heat entering said refrigerator through the casing thereof flows substantially solely by conduction through the walls of the food compartments to the adjacent walls of said cooling compartment and thence to said evaporator, said walls of said ice compartment being in good thermal contact with said walls of said cooling compartment.

7. In combination, a refrigerator comprising a casing of heat insulating material having a plurality of food compartments and a cooling compartment therein and an ice compartment formed in said cooling compartment, said compartments having metal walls, said cooling compartment being completely separated from said food compartments, said walls of said food compartments having good thermal contact with said walls of said cooling compartment, an artificial refrigerating machine mounted in proximity to said refrigerator having an evaporator, said evaporator being located in said cooling compartment, the walls of said evaporator being in good thermal contact with the metal walls of said cooling compartment, said walls of said food compartments being of such thickness that the heat entering said refrigerator through the casing thereof flows substantially solely by conduction through the walls of the food compartments to the adjacent walls of said cooling compartment and thence to said evaporator, said walls of said ice compartment being in good thermal contact with the said walls of said cooling compartment.

In witness whereof, I have hereunto set my hand this 24th day of June, 1924.

ALBERT L. GIVENS.

to the adjacent walls of the cooling compartment and thence to said evaporator.

6. In combination, a refrigerator comprising a casing of heat insulating material having a plurality of food compartments and a cooling compartment therein and an ice compartment formed in said cooling compartment, said compartments having metal walls, said cooling compartment being completely separated from said food compartments, said walls of said food compartments having good thermal contact with said wall of said cooling compartment, an artificial refrigerating machine mounted in proximity to said refrigerator having an evaporator, said evaporator being located in said cooling compartment and being in good thermal contact with the walls of said cooling compartment, said walls of the food compartments being of such thickness that the heat entering said refrigerator through the casing thereof flows substantially solely by conduction through the walls of the food compartments to the adjacent walls of said cooling compartment and thence to said evaporator, said walls of said ice compartment being in good thermal contact with said walls of said cooling compartment.

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In witness whereof, I have hereunto set my hand this 24th day of June, 1924.

ALBERT L. GIVENS.

Certificate of Correction.

It is hereby certified that in Letters Patent No. 1,533,646, granted April 14, 1925, upon the application of Albert L. Givens, of Fort Wayne, Indiana, for an improvement in "Refrigerators," errors appear in the printed specification requiring correction as follows: Page 3, line 124, for the equation

$$T=C_1 \cos (\sqrt{ax}+C_2)+T_2$$

read

$$T=C_1 \cosh (\sqrt{ax}+C_2)+T_2;$$

page 4, line 10, for the equation

$$T_2-T_1=\frac{T_2-T_1}{\cos \sqrt{al}} \quad (6)$$

read

$$T_2-T_l=\frac{T_2-T_1}{\cosh \sqrt{al}} \quad (6);$$

same page, line 14, for "T" read T_l, and line 20, for the equation

$$T_2-T_1=\frac{T_2-T_1}{\cos \sqrt{\frac{.0326}{d}}\,l} \quad (7)$$

read

$$T_2-T_l=\frac{T_2-T_1}{\cosh \sqrt{\frac{.0326}{d}}\,l} \quad (7);$$

same page, line 29, for "T_1 is 50 degrees" read —*T_l is 50 degrees* and line 35, for "T_1 is 45 degrees" read —*T_l is 45 degrees;* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 26th day of May, A. D. 1925.

Certificate of Correction.

It is hereby certified that in Letters Patent No. 1,533,646, granted April 14, 1925, upon the application of Albert L. Givens, of Fort Wayne, Indiana, for an improvement in "Refrigerators," errors appear in the printed specification requiring correction as follows: Page 3, line 124, for the equation

$$T = C_1 \cos (\sqrt{ax} + C_2) + T_2$$

read

$$T = C_1 \cosh (\sqrt{ax} + C_2) + T_2;$$

page 4, line 10, for the equation

$$T_2 - T_1 = \frac{T_2 - T_1}{\cos \sqrt{al}} \quad (6)$$

read

$$T_2 - T_l = \frac{T_2 - T_1}{\cosh \sqrt{al}} \quad (6);$$

same page, line 14, for "T" read T_l, and line 20, for the equation

$$T_2 - T_1 = \frac{T_2 - T_1}{\cos \sqrt{\frac{.0326}{d}} l} \quad (7)$$

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Signed and sealed this 26th day of May, A. D. 1925.

[SEAL.]

KARL FENNING,
Acting Commissioner of Patents.