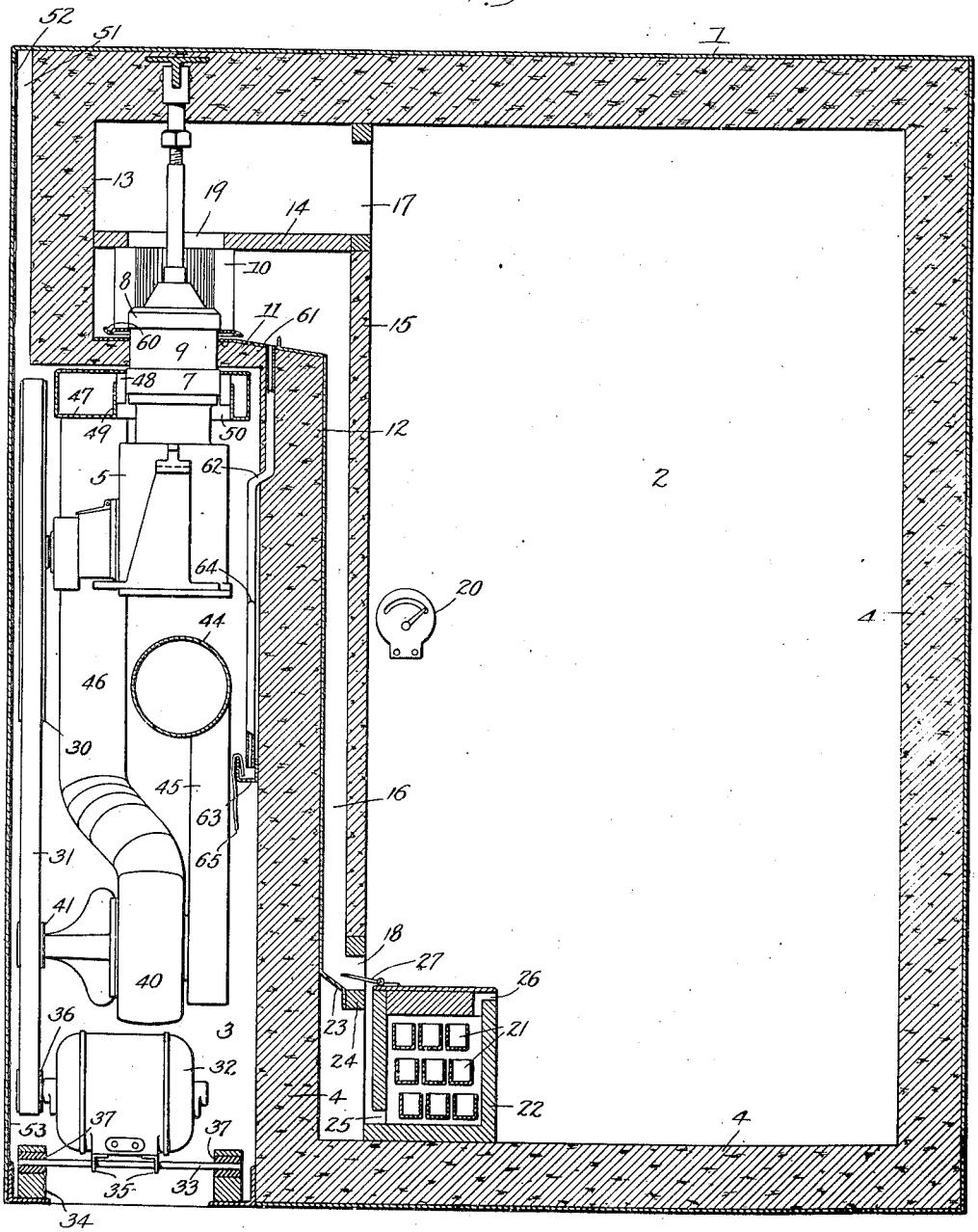
June 18, 1929. I. LUNDGAARD 1,717,459

REFRIGERATOR

Filed May 22, 1922 2 Sheets-Sheet 1

Fig. 1.



WITNESSES

Oliver W. Holmes

INVENTOR

Ivar Lundgaard

BY Knight Bros

ATTORNEYS

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Fig. 2.

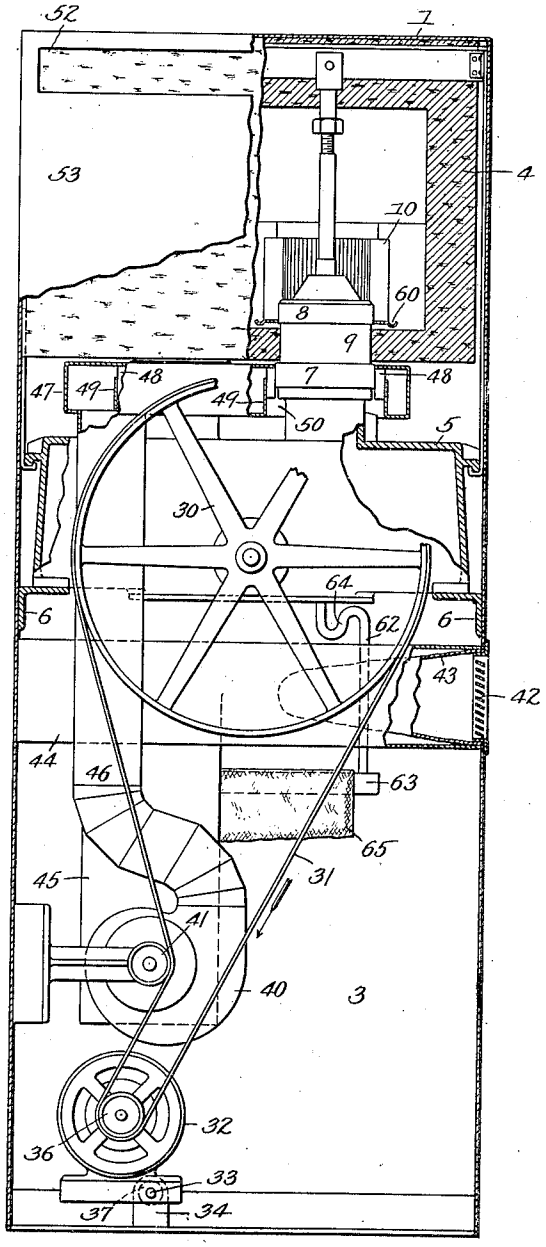
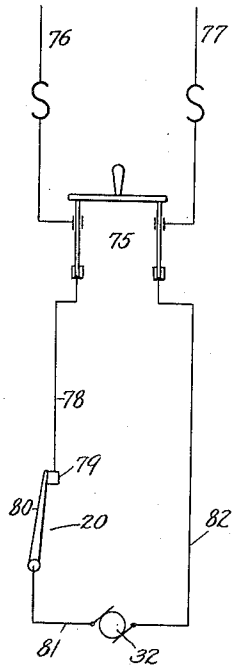


Fig. 3.



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Oliver W. Holmes.

INVENTOR

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BY

Knight Bros

ATTORNEYS

Patented June 18, 1929. 1,717,459

UNITED STATES PATENT OFFICE.

IVAR LUNDGAARD, OF HARTFORD, CONNECTICUT, ASSIGNOR, BY MESNE ASSIGNMENTS, TO DEVON MANUFACTURING COMPANY, OF BOSTON, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS.

REFRIGERATOR.

Application filed May 22, 1922. Serial No. 562,906.

My invention relates to household refrigerators in which mechanical refrigeration is used to maintain the food compartment at the desired temperature and in some cases also to produce ice. More particularly, it relates to a self-contained unit comprising a food compartment, an air refrigerating machine and the driving motor therefor, together with automatic means for regulating the temperature.

The purpose and utility of the invention will be better appreciated if I first review briefly the conditons to be met in such apparatus.

The requirements of a refrigerating machine to be used primarily for domestic purposes are quite different from the requirements of such machinery used for commercial purposes inasmuch as the former may not be expected to receive even ordinary mechanical attention or care. Domestic refrigerators are essentially of small capacity and it has proved difficult to adapt mechanical refrigerating equipment, based on the use of a condensable gas, to this purpose. During the operation of a compressor using such a gas, there develops more or less "foul" gas which must be, from time to time, eliminated from the system in order to maintain operating efficiency. Furthermore, most systems employing condensable gases must operate at a high pressure and the gases used are either noxious or flammable, which makes their use dangerous. It is also impossible to absolutely prevent leakage of the gas employed so that in time the system becomes depleted to such an extent that it no longer efficiently gives the required amount of refrigeration. There are many mechanical difficulties encountered in the construction of small compressors for high pressures, among them the making of valves that will be tight and pistons that will not leak.

In refrigerating machine using water as a cooling fluid, an adequate supply of water is not always available and the water is subject to freezing with consequent possible damage to the machine. Furthermore scale-forming materials and dirt are usually contained in water supplies and these tend to collect on the cooling surfaces, impairing the efficiency of heat transfer and requiring periodic cleaning out.

The use of brine as a circulating medium for cooling the refrigerated space necessitates additional apparatus, which occupies space in the compartment to be cooled. The brine is subject to loss by leakage and is a corrosive agent which make its use objectionable, as loss by leakage requires replenishment, and hence attention, while corrosion shortens the life of the equipment.

One object of my present invention is to provide a mechanical, domestic refrigerating unit that will require no condensable gases or liquids in its operation, that will be of low first cost and economical to operate, that will require a minimum of attention, that will automatically maintain a desired temperature, that will be perfectly safe and that will be noiseless. Other objects will appear from the detailed specification.

In attaining these objects, I use an air refrigerating machine under thermostatic control and so construct the refrigerator that it will have a food compartment and a machine compartment, with proper passages to cause natural circulation of the air in the food compartment over the cold end of the refrigerating machine and means within the machine compartment for circulating atmospheric air over the hot end of the air refrigerating machine.

In order that my invention may be fully understood, it will be described in connection with the accompanying drawings, in which

Figure 1 is a longitudinal vertical section through a refrigerator embodying the invention, showing the air refrigerating machine and its driving motor in elevation.

Figure 2 is an end view of the refrigerator, taken from the machine end, with the end sheet removed for the greater part, and certain portions of the machine broken away.

Figure 3 is a diagram of the electrical connections to the driving motor showing the thermostat control.

Like numerals refer to similar parts throughout the several views.

Referring more particularly to the drawings, refrigerator 1 comprises a food compartment 2 and a machine compartment 3. Food compartment 2 is insulated from the surroundings by suitable insulating material 4, such as pressed cork. An air refrigerating machine 5 is mounted in compartment 3 on angles 6. The air refrigerating

machine 5 may operate for example according to the principles set forth in my Patent No. 1,240,862 and is shown as having two cylinders. In such machines a confined body of mediating air is transferred back and forth between a compression chamber and an expansion chamber, in which it is alternately compressed and expanded. Adjacent to the compression chamber there is provided a heat exchanger 7 for absorbing heat from the compressed air and transferring it to a cooling fluid which rejects the heat from the system. The heat-exchanger 7 and the parts of the machine below it constitute the hot end. Adjacent to the expansion chamber, a heat exchanger 8 is provided for absorbing heat, by means of the leaves 10, from the fluid to be refrigerated and delivering the heat to the mediating air. Heat exchanger 8 and contiguous parts constitute the cold end. Between the two heat exchangers there is provided a regenerator 9 for maintaining a difference of temperature between them. A high pressure is neither necessary nor desirable in air refrigerating machines of this type, a difference of ten pounds per square inch, between the highest pressure and lowest pressure during the cycle, being sufficient to produce the refrigeration required. Hence, bursting of the machine is hardly possible.

A heat-insulating partition 11 extends across the top of machine compartment 3 from wall 12 to wall 13, snugly encircling regenerators 9. The heat insulating walls of the regenerator form the mechanical connection between the hot or compression and the cold or expansion cylinders as well as a container for the regenerative checker work as shown in my patent above referred to. A second partition 14 of heat-insulating material extends across the tops of leaves 10 from wall 13 to partition 15, which in turn extends across the refrigerator from wall to wall so as to leave a narrow passage 16 between it and wall 12, as well as an opening 17 at its top and an opening 18 at its lower end. An opening 19 is provided in partition 14 for each cylinder of the air refrigerating machine. Thus a path for the natural circulation of the air contained within the refrigerator is afforded. When the machine is in operation leaves 10 are cold and lower the temperature of the air surrounding them. The air, therefore, moves down passage 16 and through opening 18 into the food compartment 2. At the same time the warmer air in compartment 2 flows through opening 17 and downwardly through openings 19 over leaves 10. The natural circulation continues until the temperature in food compartment 2 is sufficiently low to cause thermostat 20 to stop the air refrigerating machine 5, as will be described later.

In certain cases it may be desired to manufacture ice for table or other purposes. To this end I provide containers 21 which may be filled with water. These are placed in an auxiliary compartment 22, installed in the bottom of food compartment 2 and constructed of heat-insulating material. Passage 16 terminates at its lower end in sheet 23 and strip 24. Compartment 22 is constructed to leave a narrow opening 25 at one lower edge and another opening 26 at the diagonally opposite upper edge. An adjustable damper 27 is mounted on compartment 22 so that any desired portion of the cold air passing through passage 16 may be deflected through the passage between strip 24 and compartment 22, through opening 25, over containers 21 and through opening 26 into the food compartment. Damper 27, after its first adjustment may be left in that position indefinitely. It is to be noted that compartment 22 receives air directly from the refrigerating machine and consequently the air is at its lowest temperature, which is sufficiently low to freeze water; also that, when circulation through passage 16 stops, due to the machine not being in operation, compartment 22 forms a cold-air pocket and, therefore, the ice will remain for a considerable period of time, although the food compartment may be above freezing.

The moving parts of air refrigerating machine 5 are driven through pulley 30 and belt 31 by pulley 36 of motor 32. Motor 32 is mounted in the machine compartment on supports 34 so that it may pivot about rod 33 which passes through angles 35 attached to the motor frame. Rod 33 is parallel to the shaft of motor 32 and is so located with reference to the shafts of motor 32 and refrigerating machine 5 that a component of the weight of the motor will act to cause the proper belt tension. Yielding bushings 37 are provided in supports 34 around rod 33 to absorb vibration and afford silent operation of the motor. The direction of rotation of the motor is selected, as indicated by the arrow, so that the reaction between the rotating and stationary parts of the motor will tilt the motor about rod 32 and cause an increase in belt tension at starting.

A blower 40, preferably of the sirocco or other silent type, is mounted within the machine compartment and is driven by belt 31 through pulley 41, which also serves as an idler to increase the angle of contact of belt 31 on pulley 36 of motor 32. Air is drawn to the blower from without the refrigerator through removable louvers 42, dust-bag 43, duct 44 and duct 45. Louvers 42 and dust-bag 43 may be applied at either end of duct 44, or at both ends. Dust-bag 43 prevents lint and dust from entering the duct and may be periodically cleaned by removing louvers 42 and turning bag 43 inside out, without interfering with the operation of the machine.

From blower 40 the air passes through duct 46 to distributor 47, where it divides to pass over a plurality of leaves 48 of heat exchangers 7, arranged on the hot end of the refrigerating machine similarly to leaves 10 of heat exchanger 8. Distributor 47 is supplied with circular flanges 49 closely surrounding leaves 48 for a part of their height and forming annular openings 50 around the cylinders through the bottom of distributor 47. Thus the air entering distributor 47 passes through the circular openings at the top of flanges 49, down over the leaves 48, through openings 50 and into the machine compartment. This air serves to carry away the heat of compression and to reject it from the system, and consequently is at a temperature above the air entering louvers 42. After circulating through the machine compartment, the warm air leaves it by passage 51 and is discharged into the atmosphere through opening 52. Passage 51 is provided between insulating wall 13 and the sheet metal casing 53 of the refrigerator, and opening 52 is at the top of sheet 53.

In designing the refrigerator, I proportion the air refrigerating machine to the amount of refrigeration required so that it will be required to operate only periodically. During the operating periods of the air refrigerating machine, any moisture in the air within the food compartment will tend to collect on the cold leaves 10 of the machine in the form of frost, as the temperature of the air falls. By so designing the apparatus that the average temperature of the food compartment is above freezing (which is desirable in a domestic refrigerator) the frost formed during operating periods will melt during idle periods, since leaves 10 will quickly assume the temperature of air circulating over them, after the machine has been stopped. A drip pan 60 is provided to catch the melted frost. From pan 60 the collected water flows over sheet 61 into pipe 62 through which it is led into a trough 63 in the machine compartment. A trap 64 is provided in pipe 62 to seal the cold compartment from the warm machine compartment. A wick 65 is placed with one edge dipping into trough 63 and the major portion of its surface exposed to the warm air delivered by blower 40 into machine compartment 3. Wick 65 distributes any moisture collected in trough 63 over its surface by capillary action and the water is evaporated by the warm air passing over it. Hence, all water collecting on the cold surfaces of the air refrigerating machine is evaporated by the heat rejected into the atmosphere by the machine. This automatic frost removal is a great advantage in the practical application of the machine as it makes it unnecessary to provide drains to take water away from the refrigerator and keeps the interior surfaces of the food compartment dry, in addition to keeping the cooling surfaces in a condition of efficient heat transfer.

The temperature control and operating circuits are extremely simple as illustrated in Figure 3. A switch 75, mounted in a convenient place, serves to connect motor 32, under control of the thermostat 20 to mains 76, 77. Thermostat 20 is mounted within the food compartment of the refrigerator, and as indicated in Figure 3, is of any well-known type that will close a circuit at a predetermined upper temperature, keep it closed until the temperature has been lowered to a predetermined lower temperature, open it at the lower temperature and keep it open until the temperature has again risen to the higher temperature. A wire 78 extends from switch 75 to contact 79 of thermostat 20. Switch arm 80 of the thermostat is shown in contact with contact 79, the position corresponding to the upper temperature, and completes a circuit through wire 81, motor 32 and wire 82 back to switch 75. Motor 32 will, therefore, start and will operate the refrigerating machine 5 until the temperature has been sufficiently reduced, when thermostat 20 will open the motor circuit.

I have found that a refrigerator constructed according to my invention and having a food compartment of 15½ cubic feet may be maintained at a temperature of approximately 40° F. with a power consumption of 2½ k. w. hours per day of twenty-four hours, when the room temperature is 72° F. Under such conditions, the air refrigerating machine was in operation approximately one-third the time in periods of about two hour's duration. I also found that no attention was required and no repairs necessary during long continued operation.

Having now described in detail my domestic refrigerating unit, I desire to point out that it is noiseless in operation and economical to operate both as to power consumption and maintenance. Furthermore, it is perfectly safe as it involves neither the use of chemicals nor high pressures. Air is used as the mediating fluid and any leakage is automatically made up from the surrounding medium which is also air. Air is also used as the refrigerating fluid and circulates directly over the cooling surfaces of the machine, through the food compartment and over products to be refrigerated. Air is also used to cool the hot end of the refrigerating machine and thus rejects into the atmosphere the heat abstracted from the food compartment as well as the heat developed by mechanical losses within the machine. In addition, air also carries away into the atmosphere all moisture collected on the cold portions of the machine.

I regard it as broadly new and of great practical importance to provide a mechanical refrigerating system in which no liquid is

used for effecting any of the thermal changes. Other novel features have been pointed out and it will be understood that various forms of construction may be used without departing from the scope of the invention.

I claim:—

1. A mechanical domestic refrigerator comprising in combination, a refrigerating compartment, a closed cycle refrigerating machine using a gaseous mediating fluid having a cold cylinder and a hot cylinder, each of said cylinders being adapted to be surrounded by a circulating gaseous medium, thermo-siphonic means for circulating a body of air over said cold cylinder and through said refrigerating compartment to remove heat therefrom, and means for circulating a body of air over said hot cylinder to remove heat from the system.

2. In a mechanical domestic refrigerator in combination, a food compartment, a closed cycle refrigerating machine using a gaseous mediating fluid having a cold end and a hot end, thermo-siphonic means for circulating the air contained within the food compartment over said cold end, an auxiliary compartment having water containers in said food compartment, and means for passing at least a portion of the circulating air at low temperature through said auxiliary compartment before entering the food compartment to freeze the water in said containers.

3. A mechanical refrigerating system comprising in combination, a closed cycle refrigerating machine using a gaseous mediating fluid operating intermittently and having a cold cylinder and a hot cylinder, thermo-siphonic means for circulating air over said cold cylinder, means for collecting water condensed out of said circulating air on said cold cylinder, and means for re-evaporating said water and discharging the same into the atmosphere.

4. A domestic refrigerating unit comprising in combination, a food compartment, a machine compartment, a closed cycle refrigerating machine using a gaseous mediating fluid having a hot cylinder and a cold cylinder, means for utilizing natural circulation to circulate the air within said food compartment over said cold cylinder to produce the required refrigeration, means located in said machine compartment for circulating atmospheric air over said hot cylinder to reject the heat abstracted from the food compartment into the atmosphere, means for collecting water condensed on said cold cylinder and means for transferring the condensed water to the air circulating over the hot cylinder.

5. A domestic refrigerating unit, comprising in combination, a food compartment, a machine compartment, a closed cycle refrigerating machine using a gaseous mediating fluid, having a hot cylinder and a cold cylinder, means for utilizing natural circulation to circulate the air within said food compartment over said cold cylinder to produce the required refrigeration, means located in said machine compartment for circulating atmospheric air over said hot cylinder to reject the heat abstracted from the food compartment into the atmosphere, and means for exposing the water condensed on said cold cylinder to said circulating atmospheric air to re-evaporate said water.

6. The combination in a mechanical domestic refrigerator of a refrigerating compartment, a closed cycle refrigerating machine using a gaseous mediating fluid having a cold end and a hot end each comprising a cylinder and attached conducting plates, means for causing a thermo-siphonic circulation of air over the cold end and mechanical means for forcing air over the hot end.

7. A domestic refrigerator comprising in combination a food compartment, a machine compartment, a heat insulating dividing wall between them having an opening through it, a closed cycle refrigerating machine using a gaseous mediating fluid having a compression cylinder and an expansion cylinder, with a heat insulating connection between them, the expansion cylinder being located in the food compartment, the compression cylinder and the driving mechanism being located in the machine compartment, the said heat insulating connection occupying the said opening through the heat insulating dividing wall, means for utilizing natural circulation to circulate the air within said food compartment over said cold cylinder, and means in the machine compartment for circulating atmospheric air over said hot cylinder and to reject the heat abstracted thereby into the atmosphere.

8. A domestic refrigerator comprising in combination a food compartment, a machine compartment, a heat insulating dividing wall between them having an opening through it, a closed cycle refrigerating machine using a gaseous mediating fluid having a compression cylinder and an expansion cylinder, a piston common to both cylinders, with a heat insulating connection between them, the expansion cylinder being located in the food compartment, the compression cylinder and the driving mechanism being located in the machine compartment, the said heat insulating connection occupying the said opening through the heat insulating dividing wall, means for utilizing natural circulation to circulate the air within said food compartment over said cold cylinder and means in the machine compartment for circulating atmospheric air over said hot cylinder and to reject the heat abstracted thereby into the atmosphere.

9. The method of removing condensed moisture from a refrigerating chamber, which

consists in collecting the condensed moisture, feeding the resulting drip out of the said chamber and forcing air into contact with the moisture of the drip outside the chamber so as to cause the said moisture to be absorbed by the air.

10. The method of removing condensed moisture from a refrigerating chamber, which consists in collecting the condensed moisture, feeding the resulting drip out of the chamber, and inducing a forced circulation of air over the moisture of the drip outside of said chamber so as to cause said moisture to be absorbed by the air.

11. The herein described method of removing moisture from a refrigerating chamber, which consists in removing moisture from the refrigerating chamber and collecting the same outside of said chamber, and inducing a current of air over the collected moisture so that said moisture will be absorbed by the air.

12. A domestic refrigerator comprising in combination a food compartment, a machine compartment, a heat insulating dividing wall between them having an opening through it, a closed cycle refrigerating machine having a compression cylinder and an expansion cylinder, with a heat insulating connection between them, the expansion cylinder being located in the food compartment, the compression cylinder and the driving mechanism being located in the machine compartment, the said heat insulating connection occupying the said opening through the heat insulating dividing wall, and means in the machine compartment for cooling said hot cylinder.

13. A domestic refrigerator comprising in combination a food compartment, a machine compartment, a heat insulating dividing wall between them having an opening through it, a closed cycle refrigerating machine having a compression cylinder and an expansion cylinder with a heat insulating connection between them, a piston common to both cylinders, the expansion cylinder being located in the food compartment, the compression cylinder and the driving mechanism being located in the machine compartment, the said heat insulating connection occupying the said opening through the heat insulating dividing wall, and means in the machine compartment for cooling said hot cylinder.

IVAR LUNDGAARD.