July 14, 1925. 1,545,587

C. L. A. M. LEBLANC

REFRIGERATING APPARATUS BASED UPON THE USE OF AIR

Filed April 18, 1923 2 Sheets-Sheet 1

Fig. 2.

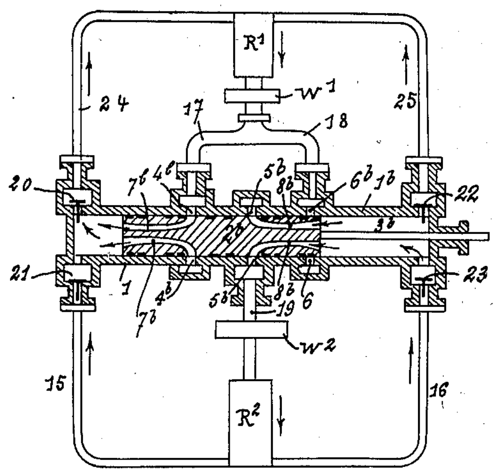
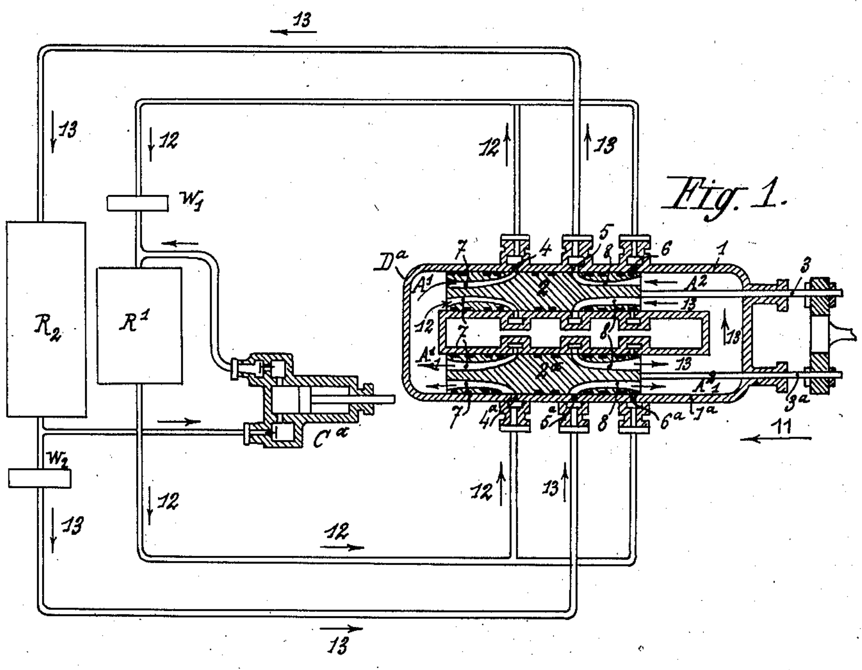


Fig. 1.



INVENTOR

Charles Leonard Armand Maurice Leblanc

By Green and McCallister

His Attorneys

C. L. A. M. LEBLANC

REFRIGERATING APPARATUS BASED UPON THE USE OF AIR

Filed April 18, 1923 2 Sheets-Sheet 2

Fig. 5.

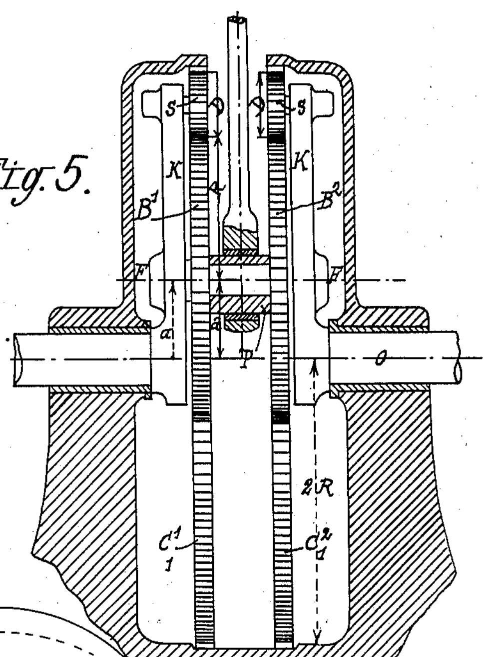


Fig. 4.

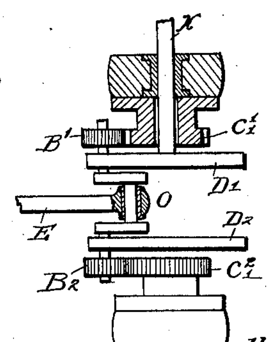
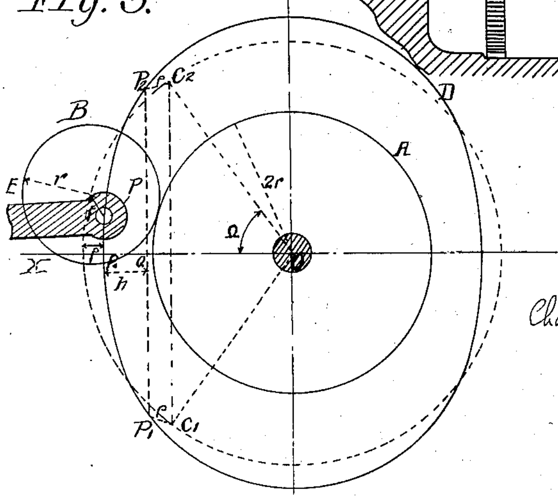


Fig. 3.



INVENTOR

Charles Leonard Armand Maurice Leblanc

By Green and McCallister

His Attorneys

Patented July 14, 1925. **1,545,587**

UNITED STATES PATENT OFFICE.

CHARLES LÉONARD ARMAND MAURICE LEBLANC, OF PARIS, FRANCE, ASSIGNOR TO SOCIÉTÉ ANONYME POUR L'EXPLOITATION DES PROCÉDÉS MAURICE LEBLANC-VICKERS, OF PARIS, FRANCE.

REFRIGERATING APPARATUS BASED UPON THE USE OF AIR.

Application filed April 18, 1923. Serial No. 632,929.

To all whom it may concern:

Be it known that I, Charles Léonard Armand Maurice Leblanc, a citizen of France, and a resident of Paris, France, have invented certain new and useful Improvements in Refrigerating Apparatus Based Upon the Use of Air, which is fully set forth in the following specification.

In his patent application filed in the United States of America on September 22, 1921, Serial No. 502,508, the applicant described a refrigerating apparatus based upon the use of air, in which cold is produced by means of air which is first compressed and then caused to expand in piston-operated machines combined with heat-exchanging devices termed cooling device and refrigerating apparatus whereof the first serves to cool the air after its compression and the second to utilize the cold produced by the air under expansion.

In the machine described in the said application, the air which is cooled by its expansion in a cylinder containing a piston, is exchanged, by scavenging by means of separate fans or pumps, for air at a like pressure which has yielded up its cold in the said refrigerating apparatus, and this air, during the succeeding stroke, is subjected in the same cylinder and by the same piston to a compression during which it becomes heated. At the end of the compression stroke it is exchanged in like manner, by means of independent fans or pumps, for air at a like pressure which has given up its heat in the said cooling device; this air is in turn caused to expand during the succeeding stroke, and so on.

The said method is carried into effect by means of a double acting cylinder and piston device, which is herein designated as the main compressor, this being used in connection with a compressor of known type, termed auxiliary compressor. The first device carries out exclusively the operations of compression and expansion, these taking place alternately at each end of the piston, the air being expelled from each chamber of the cylinder at the end of each piston stroke; the energy expended during the compression in the said compressor is equal to the energy recovered during the expansion.

An investigation of the cycle of the air in the said machine shews that the main compressor takes more air from the cooling device than it returns to it, and delivers to the refrigerating apparatus more air than it removes therefrom. The object of the auxiliary compressor is to constantly deliver from the refrigerating apparatus to the cooling device this excess of air which is sent into one device to the detriment of the other. The auxiliary compressor constantly absorbs energy and does not restore the same.

In application No. 502,508 of September 22, 1921, a machine is described which is based upon this principle, employing a main compressor in which the distribution of air, at the end of each stroke, between the cylinder chambers and the circuits of the heat exchanging devices is effected by means of clack valves.

The present invention relates to a machine which is based upon the same principle, but comprising a main compressor wherein the fluid distribution and the operation of the piston are carried out by the use of new mechanical combinations whereby a combined apparatus of a very simple construction can be obtained.

The following description and the appended drawings which are given by way of example set forth the said invention.

Fig. 1 is a diagrammatic general view of the machine.

Fig. 2 is a modification of the same.

Fig. 3 is a diagrammatic view showing the manner of pivoting the connecting rods to the crankshaft.

Fig. 4 is a plan view partly in section showing the manner of mounting the connecting rods on the crankshaft.

Fig. 5 is a modification of Fig. 4.

In Fig. 1, the auxiliary compressor is shewn at C^a, and the main compressor at D^a, the cooling device at R_1, the refrigerating apparatus at R_2, and the scavenging fans at W_1 and W_2. The auxiliary compressor withdraws the air issuing from the refrigerating apparatus and delivers it to the inlet of the cooling device. The main compressor comprises two like cylinders 1 and 1^a whose left hand ends A^1 and A^1_1 communicate with each other, as also the right hand ends A^2 and A^2_1. Within the said cylinders are respectively movable the pistons 2, and 2^a whose rods 3, 3^a are connected together outside the machine and are actuated by a common mechanism, so that the two pistons move in the same manner. The wall of each cylinder has three ports 4, 5, 6 each pair of ports being oppositely situated upon the cylinder; the ports 4 and 6 of each cylinder are connected together by a conduit. Piping starts from the outer ports 4 and 6 of the cylinder 1, forming part of a circuit which comprises the fan W_1 and the cooling device R_1 and ends at the ports 4^a and 6^a of the cylinder 1^a.

Each piston has two circular ports, the left hand port is in constant communication with the left hand of the corresponding cylinder, through an annular conduit 7 formed in the body of the piston; in like manner the right hand port is in constant communication, with the right hand end of the corresponding cylinder through the annular conduit 8.

The piston controls the movement of the fluids, as will be further set forth, by the coincidence of the ports of the cylinder and piston.

When the piston moves to the left, or in the direction of the arrow 11, Fig. 1, it effects the compression of the air upon its front face and the expansion of air at its rear face; at the end of the stroke, or in the position shewn in Fig. 1, the left hand ports of the piston have now opened the cylinder ports, thus connecting the left hand cylinder chambers with the circuit of the cooling device R_1. At the end of the piston stroke, the air has the pressure P_1 and the temperature T_4; during the whole time of opening of the ports 4, the fan W_1 whose speed has been calculated for the purpose, will drive the air from the cylinder into the cooling device R_1 and will replace it by a like volume of air at the same pressure but at a lower temperature T_1 obtained from R_1, the air flows as indicated by the arrows 12 of Fig. 2. Since the air from the cooling device is colder than the air from the cylinder, the scavenging action takes from the cooling device a greater volume of air than it returns to the latter.

While these effects are taking place upon the left hand face of the piston, the air at the right hand face of the piston is caused to expand from the pressure P_1 to the pressure P_2; with the piston in the end position, Fig. 1, its right hand ports have now opened the ports 5 of the cylinders whereby their right hand chambers are connected with the circuit of the refrigerating air R_2, the ports 6 remaining closed. While the ports 5 are open, the fan W_2 drives the air from the cylinders, which has the temperature T_2, into the refrigerating apparatus, and replaces it by an equal volume of air at the same pressure but at a higher temperature T_3, proceeding from R_2. The air flows according to the arrows 13. Since the air from the refrigerating apparatus has a higher temperature than the air from the cylinders, this scavenging delivers to the refrigerating apparatus a larger amount of air than it withdraws therefrom.

In this manner, the main compressor will constantly transfer air from the cooling device to the refrigerating apparatus, but when the standard conditions are once established, this air is brought from the refrigerating apparatus to the cooling device by the auxiliary compressor, the latter being a known piston compressor actuated by the main motor.

When the pistons of the main compressor start towards the right, the ports 4, 5 of the two cylinders will close while the ports 6 remain closed; the air expands in the left hand chambers and is compressed in the right hand chambers; when the piston reaches the end of the stroke, the ports 4 still remain closed, but the ports 5, 6 are open, so that the scavenging takes place exactly as before while the said ports are open.

The fans W_1, W_2 may be of a known type, and are driven for example by independent electric motors in constant rotation.

It should be observed that the currents of air produced by the scavenging will enter the chambers which are subjected to scavenging at one end and will be discharged at the other, so that the whole volume of air in said chambers is expelled and is replaced by air obtained from the heat-exchanging apparatus. It is for this reason that a pair of like cylinders are employed.

On the same principle as above set forth, a machine can be constructed in which the single compressor serves the same purpose as the auxiliary and the main compressors, as shewn in Fig. 2.

The double-acting cylinder 1^b has three sets of ports at the sides, as before; the ports 4^b and 6^b, connected together on each side, cause the two ends of the cylinder to communicate in turn with the cooling device R_1 and the scavenging fan W_1, through the conduits 17, 18; the middle port 5^b serves for alternate connection between the cylinder ends and the refrigerating apparatus R_2 and the fan W_2 through the conduit 19.

The piston 2^b, actuated by the rod 3^b, is constructed as in Fig. 1, and it has a reciprocating motion in the cylinder; as before, the fluid is controlled by the ports 7^b, 8^b of the said piston which communicate respectively with each of the cylinder chambers. The cylinder has at the left a discharge clack valve 20 and a suction clack valve 21, and in like manner at the right are disposed the discharge valve 22 and the suction valve 23. The orifices controlled by the discharge valves are connected through the pipes 24, 25 with the cooling device R_1 which is at the pressure P_1. The orifices controlled by the suction valves communicate through the conduits 15, 16 with the refrigerating apparatus R_2 which is at the pressure P_2.

In this case, the operation is as follows. Considering the action which takes place in the left hand part of the cylinder, with the piston moving to the right, all the ports will be closed, and the piston will cause the expansion of the air, which was at first at the pressure P_1, to the pressure P_2 which prevails in the refrigerating apparatus R_2; at this time the suction valve 21 will open, while the valve 20 remains closed, and from this time onwards the pressure cannot descend below P_2.

It is supposed, as is always the case in practice, that the refrigerating apparatus has a sufficient capacity that the pressure therein shall remain unaffected by the variations in the output of air, and in this event the volume of air in the left hand end of the cylinder is V_2; the piston continues to move to the right until the volume becomes V_3; the pressure remains constant during this movement, since air withdrawn from the refrigerating apparatus by the piston is admitted into the cylinder; when the volume attains the value V_3, the piston will open the port 5^b and places it in communication with the left hand portion of the cylinder. A circuit is thus opened which connects this part of the cylinder, through the conduit 7^b and the port 5^b, with the fan W_2 and the refrigerating apparatus R_2, returning thence to the cylinder through the pipe 15 and valve 21. The fan W_2 then acts throughout the whole time of the opening of the port 5^b to ensure the exchange between the air in the cylinder and the air in the refrigerating apparatus.

When the piston returns to the left, the port 5^b is closed and the compression commences, and the valve 21 closes. When the pressure returns to the initial value P_1, the valve 20 which connects the end of the cylinder with the cooling device R_1, which is at the pressure P_1, will now open. From this time onward, the pressure cannot rise above P_1; the volume of air is V_4; the final movement of the piston to the left will take place at a constant pressure equal to P_1; the piston delivers air into the cooling device. When the volume of the cylinder has been reduced to the initial value V_1, the piston opens the port 4^b; a circuit is then opened which by means of the conduit 7^b, the port 4^b and the pipe 17, connects the left hand end of the cylinder with the fan W_1 and the cooling device R_1, thence returning to the cylinder through the pipe 24 and the valve 20. The fan W_1 performs the scavenging of the compressed air in the cylinder, and replaces this air by cold air supplied from R_1, during the time when the port 4^b remains open. The piston then moves to the right, the port 4^b and the valve 20 are closed, and the cycle proceeds as before.

The operation is the same, as concerns the other face of the piston.

In spite of its apparent simplicity, this second arrangement is in general less advantageous than the first. In the same cylinder it is in fact necessary to perform the successive scavenging operations while the piston is close to the end of the stroke, and then to circulate the air through the clack valves. In order to carry out the scavenging in the proper manner, that is to say without losing a great amount of kinetic energy when traversing the ports, and without unduly reducing the speed of the machine, it is preferable to stop the piston at the ends of the stroke and to maintain the valves fully open during a considerable part of the piston stroke, for instance about two-thirds. This result can be obtained, as will be set forth hereunder. But the valves must open for a very short time in relation to this time of the piston stroke, so that it becomes preferable to control the valves by special gear.

In the first arrangemet, on the contrary, the power compressor is the only one to be fitted with clack valves, and there is no inconvenience in allowing them to open and close automatically; in this case the main compressor can be provided with any suitable arrangements for facilitating the scavenging operation.

In both types of machines described, the air expands at one face of the piston of the main compressor whilst it is compressed at the other face, during any one piston stroke from one dead centre to another. The energy of expansion is in the first place greater than the energy of compression, and the piston thus supplies energy; then the energy of compression becomes greater than that of expansion, and the piston absorbs energy until the end of the stroke. The energy of expansion supplied during the first part of the stroke is stored up in a flywheel mounted on the driving shaft which operates the piston rod; the said flywheel will give back this energy during the second part of the stroke.

Further, in these machines, the heat exchanged between the air and the cylinder walls is very small; on the contrary to what takes place in refrigerating machines using saturated steam, the efficiency of a small cylinder is about the same as for a large cylinder, by reason of this small action of the cylinder walls. To obtain high power machines, these can now be constructed with multiple cylinders whose pistons are mounted on a common crankshaft as for internal combustion engines, and combinations can thus be had which are powerful as well as light and compact.

In the preceding considerations, the piston is supposed to be actuated simply by a crank and piston rod, and this has the advantage of simple construction.

A drawback is however observed in this case. The time of opening of the ports is a rather small fraction of the time of the piston stroke; but it would be most advantageous to increase to the maximum the time during which the said ports remain open, and conversely to accelerate the movement of the piston from one dead centre to the other, thereby reducing the speed to be given to the air to enable it to clear the said ports during the scavenging and thus reduce the speed of scavenging, which is proportional to the square of the speed of the air; or otherwise, should the scavenging speed be predetermined, one may increase the speed of the machine, other factors being equal, and thereby augment the power.

In order to increase the duration of the scavenging by slowing up the piston when near the ends of the stroke, use can be made of the kinematic arrangement shewn diagrammatically in Fig. 3.

The crank is provided with an eccentric which turns about the crank by means of the gearing A, B; in the figure, the gear wheels are shewn only by their pitch-circles. The gear set comprises a stationary wheel with radius 2 r mounted coaxially upon the driving shaft O which actuates the piston, and a gear wheel B with radius r which rolls upon A. The end of the piston rod, which is mounted upon the said eccentric, pivoted at the point P of the gear wheel B which is situated at the distance ρ from the centre C of said wheel. The arrangement is operated so that the centre P of the end of the piston rod shall approach the axis of rotation when passing through the dead centres. In these conditions, by suitably selecting the eccentricity ρ, the end of the piston rod P will describe a shortened epicycloid D. Let P_0 Q represent the height h of the cylinder ports, and P_1 P_2 the points at which the line perpendicular to O x drawn through the point Q intersects the curve D; the ports will remain open at one end of the stroke, while the end of the piston rod covers the distance P_1 P_2 upon the curve D. When the end of the rod is at P_1, the centre of the wheel B is at C_1, and when the end of the rod is at P_2, the centre of the wheel is at C_2; it is thus observed that the ports will remain open during the time in which the shaft O rotates through the angle 2 Ω.

It is shewn in the figure that this angle is great, and that the ports will thus remain open during a considerable fraction of the half revolution of the shaft C.

As shewn in the plan view, Fig. 4, the driving shaft x o y is provided with the stationary gear wheels C^1_1, C^2_1 and is divided so as to form a combination which is symmetrical with respect to O X; the said shaft carries two cranks discs D_1 D_2 having respectively a pinion B_1 rolling upon C^1_1 and a pinion B_2 rolling upon C^2_1; to the said pinions is connected the eccentric rod E which communicates the motion to the piston rod.

The preceding arrangement can be used when the trunnion of the crank is in the overhang position, but the usual crankshaft cannot be employed; this would however represent a serious drawback in the case of multicylinder machines, analogous to internal combustion engines. Use can here be made of the arrangement shewn in end view in Fig. 5. The driving shaft O is provided with a crankshaft of known type, mounted in two bearings, and on either side are disposed the stationary gear wheels C^1_1, C^2_1 with internal teeth having a radius of 2 R, the said wheels being secured to the bearings; a indicates the radius of the crank; upon the trunnion or axle of the said crank is mounted an eccentric P serving as the end of a connecting rod which is connected with two gear wheels B^1 B^2 having the radius R, centered upon the said trunnion or axle and revoluble thereon. The said gear wheels are not in direct engagement with the wheels C^1_1, C^2_1, as in this case they would turn in contrary direction to the crank and not in the same direction, as in the preceding case; the planetary gears s of diameter D are therefore interposed between the wheels B^1 B^2 and the wheels C^1_1, C^2_1, said planetary gears being mounted upon axles disposed upon extensions K K of the arms of the crankshaft, and they engage the wheels C^1_1 C^2_1 as well as the wheels B^1 B^2, so that the wheels B^1 B^2 will turn in the same direction as the crank and through an angle 2 ω when the crank turns through ω.

Obviously, the arrangements hereinbefore set forth are susceptible of all desired modifications in detail without departing from the principle of the invention.

What I claim is:—

1. In an apparatus for accomplishing refrigeration by means of air, an air cooler, a refrigerator, a compressor and expander having ports communicating with said air cooler, and other ports communicating with said refrigerator, and a reciprocating piston in said compressor and expander adapted to control the opening and closing of said ports.

2. In an apparatus for accomplishing refrigeration by means of air, an air cooler, a refrigerator, a compressor having ports communicating with said air cooler, and ports communicating with said refrigerator, and a piston adapted to reciprocate in said

compressor so as to control the operation of said ports and to simultaneously compress air to the pressure prevailing in the air cooler and expand air to the pressure prevailing in the refrigerator.

3. In an apparatus for accomplishing refrigeration by means of air, an air cooler, a refrigerator, a compressor having ports communicating with said air cooler and ports communicating with said refrigerator, and a piston adapted to reciprocate in said compressor so as to compress air to the pressure prevailing in the air cooler and to simultaneously expand air to the pressure prevailing in the refrigerator, said piston having conduits adapted to permit the passage of said compressed air to said air cooler, and conduits adapted to permit the passage of said expanded air to said refrigerator.

4. In an apparatus for accomplishing refrigeration by means of air, an air cooler, a refrigerator, a compressor having ports communicating with said air cooler and ports communicating with said refrigerator, a piston adapted to reciprocate in said compressor so as to compress air to the pressure prevailing in the air cooler and to simultaneously expand air to the pressure prevailing in the refrigerator, said piston having conduits adapted to permit the passage of said compressed air to said air cooler and conduits adapted to simultaneously permit the passage of said expanded air to said refrigerator, and means for driving said piston so as to cause it to dwell at each end of its stroke.

5. In an apparatus for accomplishing refrigeration by means of air, an air cooler, a refrigerator, a combined double acting compressor and expander having ports communicating with said air cooler and ports communicating with said refrigerator, a piston adapted to reciprocate in said compressor and expander so as to compress air on one side thereof to the pressure prevailing in the air cooler and to simultaneously expand air on the other side thereof to the pressure prevailing in the refrigerator, said piston having conduits in each end adapted to alternately communicate with the ports communicating with said air cooler and the ports communicating with said refrigerator so as to permit the passage of said compressed air to said air cooler and the passage of said expanded air to said refrigerator.

6. In an apparatus for accomplishing refrigeration by means of air, an air cooler, a refrigerator, a combined double acting compressor and expander having ports communicating with said air cooler and ports communicating with said refrigerator, a piston adapted to reciprocate in said compressor and expander so as to compress air on one side thereof to the pressure prevailing in the air cooler and to simultaneously expand air on the other side thereof to the pressure prevailing in the refrigerator, said piston having conduits in each end adapted to alternately communicate with the ports communicating with said air cooler and with the ports communicating with said refrigerator so as to permit the passage of said compressed air to said air cooler and the simultaneous passage of said expanded air to said refrigerator, means for impelling the compressed air from said compressor by air at the same pressure from said air cooler, and means for simultaneously impelling expanded air from said compressor by air at the same pressure from said refrigerator.

7. In an apparatus for accomplishing refrigeration by means of air, an air cooler, a refrigerator, a combined double acting compressor and expander having ports communicating with said refrigerator, a piston adapted to reciprocate in said compressor and expander so as to compress air on one side thereof to the pressure prevailing in the air cooler and to simultaneously expand air on the other side thereof to the pressure prevailing in the refrigerator, said piston having conduits in each end adapted to alternately communicate with the ports communicating with said air cooler and the ports communicating with said refrigerator so as to permit the passage of said compressed air to said air cooler and the simultaneous passage of said expanded air to said refrigerator, means for impelling the compressed air from said compressor by air at the same pressure from said air cooler, means for simultaneously impelling expanded air from said compressor by air at the same pressure from said refrigerator, and an auxiliary compressor adapted to withdraw excess air from said refrigerator and transfer it to said air cooler.

8. In an apparatus for accomplishing refrigeration by means of air, an air cooler, a refrigerator, a compressor having ports communicating with said air cooler and ports communicating with said refrigerator, a piston adapted to reciprocate in said compressor so as to compress air to the pressure prevailing in the air cooler and to simultaneously expand air to the pressure prevailing in the refrigerator, said piston having conduits adapted to permit the passage of said compressed air to said air cooler and conduits adapted to permit the passage of said expanded air to said refrigerator, a crankshaft for driving said piston, and means for connecting said piston to said crankshaft so as to cause said piston to dwell at each end of the stroke.

9. In an apparatus for accomplishing refrigeration by means of air, an air cooler,

a refrigerator, a compressor having ports communicating with said air cooler and ports communicating with said refrigerator, a piston adapted to reciprocate in said compressor so as to compress air to the pressure prevailing in the air cooler and to simultaneously expand air to the pressure prevailing in the refrigerator, said piston having conduits adapted to permit the passage of said compressed air to said air cooler and conduits adapted to permit the passage of said expanded air to said refrigerator, a crankshaft for driving said piston, a connecting rod and means for pivoting the connecting rod to said crankshaft so that the end of said rod is moved in an epicycloidal path, whereby said piston is caused to dwell at each end of its stroke.

In testimony whereof I have signed this specification.

CHARLES LÉONARD ARMAND MAURICE LEBLANC.