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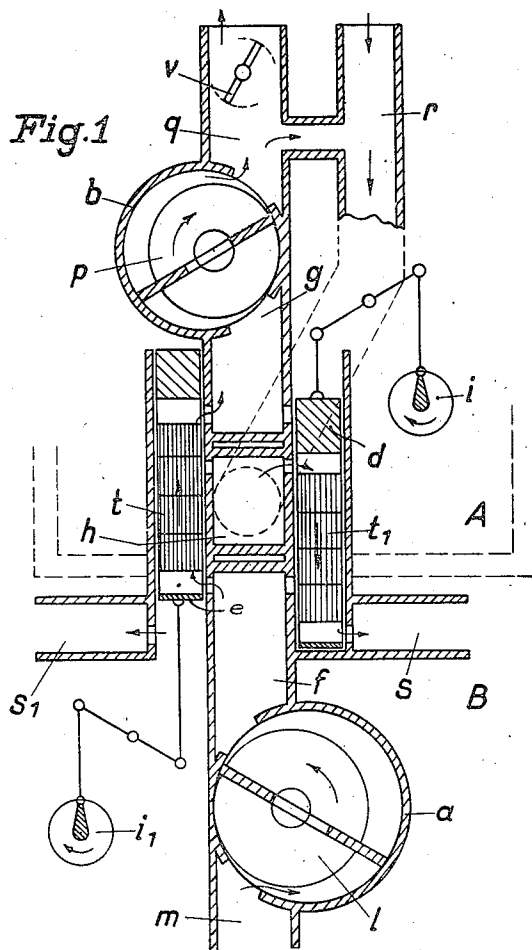
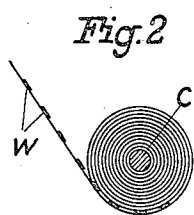
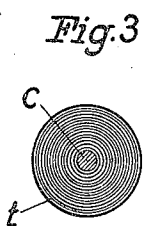
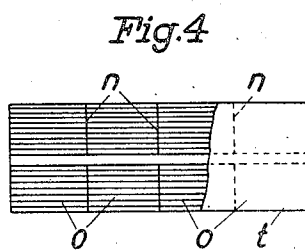
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2,044,330

AIR CONDITIONER

Filed March 6, 1933

2 Sheets-Sheet 1



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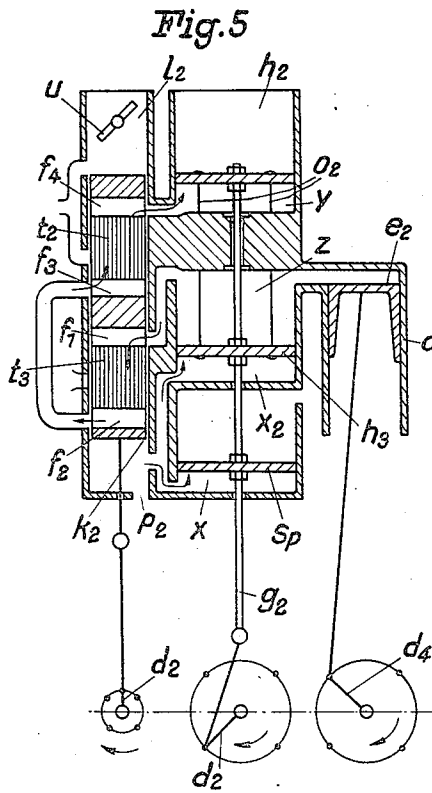
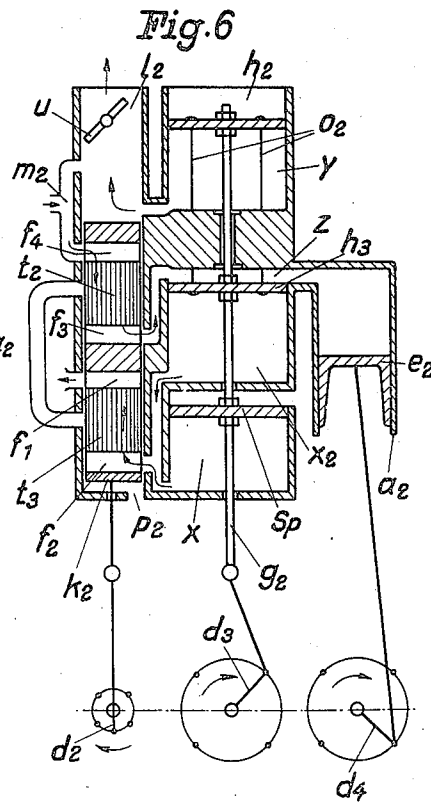
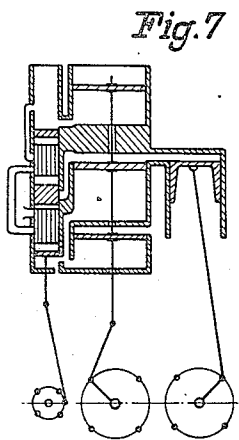
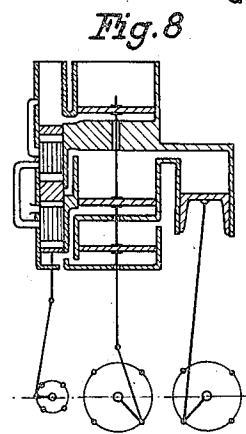
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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,044,330

AIR CONDITIONER

Alfred Richter, Berlin-Reinickendorf-Ost,
GermanyApplication March 6, 1933, Serial No. 659,363
In Germany March 5, 1932

10 Claims. (Cl. 62-176)

(Granted under the provisions of sec. 14, act of
March 2, 1927; 370 O. G. 5)

The present invention consists in a process by which heat and atmospheric moisture can be conveyed in a simple manner from a room A of low temperature to a room B of higher temperature in such a way that room A is cooled and room B heated. Obviously, if desired, the exterior atmosphere may be used as a source of heat if the process is applied to cool or heat only one room.

The process is essentially based on the suitable use of an appropriate heat-exchanger for the transmission of heat of a cold air machine of "open" cycle type in such a way that for the heat-abstractation and absorption no special heating or cooling bodies are necessary; the heat-abstractation and absorption take place by means of mixing with the air of the room atmospheric air.

The process according to the invention furthermore is based on the fact that the steam contained in the air is also made effective for the transmission of heat, simultaneously avoiding reduction in efficiency of the cold air machine by the presence of atmospheric moisture.

In the drawings several embodiments are shown for carrying out the new process, in which:—

Fig. 1 is a diagrammatic vertical sectional view of one embodiment.

Fig. 2 is a cross sectional detail view through the piston-like body of the heat-exchanger in the course of formation.

Fig. 3 is a similar view showing the same when completed.

Fig. 4 is an enlarged side elevational detail partly in section of the same.

Figs. 5 and 6 are diagrammatic longitudinal sectional views of a further embodiment of the device for carrying out the process, and

Figs. 7 and 8 are similar views on a reduced scale corresponding respectively to Figs. 5 and 6 showing the parts at different cycles of their operation.

This heat-exchanger is adapted to absorb heat and moisture from an air-current and to transmit them later to another air-current. For this purpose it is desirable that the heat-exchanger offer a large surface of contact to the air-current. This is obtained by forming the heat-exchanger (t) of an aluminium foil of a thickness of about 0.1 to 0.2 mm. and by winding a long band of this foil spirally around the axis (c) as shown in Fig. 3. For this purpose any other metal may also be used which is adapted to be hammered or rolled to foils, such as tin, copper and the like. But aluminium is especially suitable in view of its

great thermal conductivity and heat capacity. Between the single windings, bands (w) made of any solid material are interposed in such a way that many small flat channels are built, through which air-currents are later led. Furthermore the heat-exchanger is divided by incisions (n) into several zones (o). By this device it is possible to put in a simple way a large surface of contact in a relatively small apparatus. Fig. 1 shows an air compressor (a) with rotating piston, an expansion cylinder (b) with rotating piston, and two valve housings (d and e), in each of which is placed a piston-like body (t), (t') constituting a heat-exchanger of the type as shown in Figures 3 and 4. The chambers (f, g and h) are connected by means of ports with the piston valve housings. The two piston valves (t and t') are coupled by means of a crank drive (i and i₁) in such a way that they reciprocate in opposite directions. The device represented in Fig. 1 is designed to cool a room A, which is shown by the dotted line. The other room B is to be taken as exterior atmosphere. Assuming that this atmosphere shows a temperature of +10° C., the mode of operation is the following:

The rotating piston (l) in the air compressor (a) draws atmospheric air through the channel (m) and compresses it into the chamber (f) under an increase of pressure of 0.5 atm. so that the total pressure of the air contained in the chamber (f) amounts to 1.5 atm. The temperature of this compressed air has been increased according to the effect of the compression from +10° C. to +45° C. This compressed and heated air passes in the direction of the arrow through a channel into the valve housing (e), then through the many small channels of the heat-exchanger (t) and enters the chamber (g). Assuming that this heat-exchanger (t) shows in the foremost zone a temperature of about +43° C. and in the last zone a temperature of about 0° C.: The air therefore, while passing through the heat-exchanger (t), will transfer a part of its heat to the material of the heat-exchanger in the single zones thereof and after attaining the saturation point will also precipitate atmospheric moisture in the form of dew. The material of the heat-exchanger (t) absorbs the heat abstracted from the air-current, thereby increasing its temperature in all zones to about 2° C. The compressed air has decreased its temperature from +45° C. to +2° C. while passing through the heat-exchanger due to the loss of heat and enters at this temperature the chamber

g. The pressure in the chamber *g* is only a little lower than in the chamber *f* (according to the resistance to flow) and amounts approximately to 1.5 atm. The air now passes into the expansion cylinder (*b*) and pushes the piston (*p*) forward in the direction of the arrow, whereby the air expands while performing work and passes in the direction of the arrow into the channel (*q*). When passing into the channel (*q*) the air is reduced to atmospheric pressure and as a result is reduced to a very low temperature, which—considering the losses in the walls and the like—amounts to about -25°C . This cold air passes from the channel (*q*) to the cooling room A, thereby again absorbing heat from the chilled products contained therein and from the walls and warming up to a temperature of about -2°C . By the absorption of the heat the purpose of the cooling has been attained, as the chilled products in the room A and the air of this room have been cooled accordingly. Of course the cold air which passes out has mixed with the air of the cooling room.

A corresponding part of the air of the cooling room now passes through the channel (*r*) to the chamber (*h*) as shown by the dotted lines, which represent the prolongation of the channel (*r*). From the chamber (*h*) the air passes in the direction of the arrow to the piston valve (*d*) and then through the heat-exchanger (*t₁*) into the channel (*s*) in order to reach the atmosphere. Assuming that the heat-exchanger (*t₁*) has a temperature of 0°C in the foremost chamber and a temperature of $+44^{\circ}\text{C}$ in the last chamber: The air therefore will absorb a part of the heat accumulated in the material of the heat-exchanger (*t₁*) while passing through it; thereby it is warmed up so that it passes out at a final temperature of about 42°C . On its way through the heat exchanger (*t₁*)—due to its warming up—the air shows a great saturation capacity, by which the moisture contained on the material of the heat-exchanger as dew evaporates and the steam-content of the air is increased.

At the above mentioned mode of operation the material of the heat-exchanger (*t*) naturally will warm up a little and the material of the heat-exchanger (*t₁*) will cool down a little. In order to avoid a further warming up or cooling down, which would reduce or annul the efficiency of the process, the two piston valves (*t* and *t'*) are brought into inverse position by turning the cranks (*i* and *i₁*). By this displacement the inlet and the outlet ports on the left as well as on the right side are exchanged accordingly so that in the further course the heat-exchanger (*t*) takes up the function of the heat exchanger (*t₁*) and vice versa. From this reversing results that the heated air is led through the valve housing (*d*) and the air leaving the cooling room A namely, the chamber (*b*) through the valve housing (*e*). By this reversing the direction of the air current in each heat-exchanger is inverted, the material of the heat-exchanger (*t*) is cooled down again and the material of the heat-exchanger (*t₁*) warmed up again accordingly. The reversing of these two piston valves is carried out continuously in short periods (about 30 times per minute). Therefore hot and cold air passes alternately in countercurrent through each heat-exchanger, the air of the two air-currents always coming into contact with the same surfaces of the heat-exchanger. This is of special importance as only by the described mode of operation the moisture precipitated by the air-current which is

cooled down is dried by the following air-current, which is warmed up.

As the hot current of compressed air is cooled down to about 0°C when leaving the heat-exchanger, it has only a small content of steam, about 5 grams/m.³; the greater part of the moisture originally contained in the atmospheric air (about 17 grams) has been delivered to the surface of the heat-exchanger as precipitate. As the steam content of the compressed air precooled to about $+2^{\circ}\text{C}$ is only very small, the drop in temperature caused by the release becomes nearly completely active at the following release for the effective refrigeration output because only a small part of the refrigeration output is consumed for the condensation of the rest of the existing steam.

The working of the compressor (*a*) and of the expansion cylinder (*b*) takes place continuously; only the air-current itself is led periodically through the valve housings (*e* and *d*) so that the released air-current leaving the cooling room through the valve housing (*d*) passes through the adjacent port into and through the channel (*s*) into the atmosphere while simultaneously the compressed air-current passes through the valve housing (*e*) and vice versa.

By the described mode of operation of the process heat and moisture have been brought from the cooling room (A) into the exterior atmosphere (B). As the temperature in the room (A) amounts to about -2°C it was necessary to raise the quantity of heat to the temperature of the exterior atmosphere. The expenditure of energy necessary for this purpose has been spent by the work done in driving the piston (*l*) in the air compressor (*a*). Naturally the expenditure of energy in the compressor (*a*) was still greater than it would have been necessary for the transmission, but a part of this spent energy is recovered by the output of the air in the expansion cylinder (*b*) so that only the difference of energy to overcome the drop in temperature was necessary. It is of advantage to mount the piston of the expansion cylinder on the same axis as the compression cylinder in order to get the best possible recovery of energy and to avoid all avoidable losses by friction.

In the above description of the function it has been assumed that the heat-exchangers (*t* and *t₁*) show a certain specific temperature in the single zones. In order to obtain this specific temperature the flap valve (*v*) is closed at the beginning of the process. Thereby the released air is forced to pass directly into the outlet channel (*r*).

Thereby the refrigeration effect appearing at the release is used completely to cool down the material of the heat exchangers (*t* and *t₁*) accordingly, as they showed in all zones the temperature of the exterior air, i. e. about $+10^{\circ}\text{C}$ before the start of the process. After short time the conditions of temperature provided will be attained in the single zones of the heat-exchangers; then the flap valve (*v*) is opened a little so that a part of the cold air passes into the cooling room (A) while only a part of the cold air directly into the channel (*r*). When the cooling room has reached the desired temperature (about 0°C) the flap valve (*v*) may be completely opened so that the total refrigeration output is available for the cooling room. The process of precooling is essential because the greater part of the moisture of the air is de-

posited inside the heat-exchanger only if the compressed air is precooled to about 0° C.

The heat abstracted from the cooling room (A) is conveyed to the exterior atmosphere as superheated air, which passes out through the channels (s and s_1). Therefore special bodies for the transmission of the heat are neither necessary in the cooling room (A) nor on the side (B). A further advantage consists in overcoming relatively high drops in temperature by small pressure differences of the air. Furthermore small tensions enable an easy making tight of the single moved parts and result in a high efficiency.

On account of the small pressure difference the desired results may also be obtained without using the adiabatic expansion for recovering of power, whereby the construction of the expansion cylinder is materially simplified. In this case the loss of power will be compensated for by the simplification of the design.

Apart from the two piston valves the whole process does not need any valves or control gears and it is easily possible to carry out the process up to the greatest outputs. Of course it is possible to use a turbo-blower or the like instead of the rotating pistons. The process is also applicable for lower temperatures with good efficiency. The omission of the transmission elements (cooling and heating bodies viz. condensers) is a further important advantage of the invention.

In the above description the process has been shown when carried out for the cooling of a cold storage room, which is used for keeping food or the like. The process and the described device can also be used for heating rooms. Then the provided room (A) takes the place of (B) and heated air enters the latter. The heat conveyed to the room then is taken from the exterior atmosphere. Thereby it is possible to carry out this process with materially increased heat outputs per kilowatt hour compared with the hitherto known resistance heaters. Especially will such a heating process as given by the invention yield better results when applied to vehicles such as railways where a source of electricity is available for heating.

Figs. 5 and 6 show a further device for applying the process; a combined system of cylinders with moving pistons is used for conveying the air. The piston valve housing (h_2) is subdivided and furnished with two heat-exchangers (t_2 and t_3).

The mode of operation on an average is the same as described in connection with Fig. 1. The subdivision of the piston valve and the corresponding other position of the air channels are new and carried out in such a way that only the compressed and superheated air flows through both heat-exchangers (t_2 and t_3) successively, the air leaving the cooling room passing only through the heat-exchanger (t_2). The re-cooling of the heat-exchanger (t_3) takes place in such a way that atmospheric air is sucked in by a special purging piston and is pressed again through the heat-exchanger (t_3). The device substantially consists of a chamber (2) in which atmospheric air is contained. To this chamber (2) a compressor (a) is mounted. Furthermore the device consists of a chamber (x) and the expansion chamber (y).

The mode of operation of the process with this device is the following:

In Fig. 5 the piston valve controlled by the crank (d_2) has reached the uppermost position.

The cranks (d_2 , d_3 , d_4) are mounted on a common axis and move in the direction of the arrows. The crank (d_4) has driven the compressor piston (e_2) upward and thereby compressed the air enclosed in the chamber (2) to about 1.5 atm. The chamber (2) communicates through the channels (f_1 , f_2 , f_3 and f_4 as shown by the arrows) with the chamber (y) in such a way that also in the chamber (y) there exists a pressure of 1.5 atm. By the further rotation of the crank-shaft the piston-rod (g_2) is driven upward and the compressed air contained in the chamber (2) is pressed through the channels (f_1 to f_4) into the chamber (y). Apart from the friction there is no special power required, as the piston (h_2) has the same speed as the piston (h_3) and the volume of the chamber (y) increases proportionately to the decrease of the volume in the chamber (2). The compressed air has cooled down accordingly on the way through the heat-exchangers (t_2 and t_3).

In Fig. 7 the final state of the above described period is represented, that is, the greater part of the compressed air has passed from the chamber (2) into the chamber (y). At the next rotation of the crank the channels (f_1 to f_4) for the chambers (2, y) are closed by the piston valve (b_2).

In Fig. 6 the further period after the rotation of the crank is represented. The piston valve (b_2) has now reached its lowermost position. A further rotation of the crank-shaft results in moving the piston rod (g_2) downward, whereby the volume of the chamber (y) is reduced and the air contained therein, which has already been released through the opened channel, passes into the outlet branch (12).

By moving the piston (h_3) downward air from the cooling room is sucked in through the channels (m_2 , f_4 , f_3) into the chamber (2). The cylinder space of the compressor (h_2) is filled with air from the cooling room. Due to the passage of the cooling room air through the heat-exchanger (t_2), the cooling room air entering the chamber (2) has warmed up from about 0° C. to about +10°.

From Fig. 8 the further course of the piston position is evident. The chamber (2) then has attained its greatest volume and the released air is removed to a large extent from the chamber (y). It follows now the period shown in Fig. 5, in which by the moving upward of the piston (e_2) in the compressor the air in the chamber (2) is compressed to about 1.5 atm., a new action of the pistons being started. After compressing the air in the chamber (2) it is pressed into the chamber (y) and released there, finally leaving for the cooling room. During the action in the chambers (2, y) the following process has taken place simultaneously in the chamber (x).

At the period represented in Fig. 5 the piston rod (g_2) is moving upward. The chamber (x) is filled with atmospheric air through the channel opening (p_2). In order to enlarge the chamber (x) the room (x_2) placed beneath the piston (h_3) has been made available; by moving the piston (h_3) upward also the volume of the chamber (x_2) is increased. The chamber (x_2) communicates with the chamber (x) by means of a connecting channel. By the downward movement of the piston rod (g_2) (as shown in the period according Fig. 6) the atmospheric air contained in the chambers (x and x_2) (called rinsing air) is pressed through the channel (f_2) to the channel (f_1) and further into the free atmosphere. Whilst

passing through the heat-exchanger (t_3) the atmospheric rinsing air has cooled down the material of the heat-exchanger according to the requirements of the present invention so that during the following period the heat-exchanger is capable of again absorbing heat, which has to be abstracted from the hot compressed air current.

The flap valve (u) has the same function as the flap valve (v) already described in Fig. 1. In the same way also the other proceedings concerning the giving off and taking up of the heat and the moisture according to the invention are given. Also this form of embodiment of the device can be used for heating rooms, as shown when explaining Fig. 1. The pistons (h_2 , h_3) are connected to each other by several tie rods (o_2) in order to increase the stability of the pistons, because both pistons are charged equally only from the interior side with the pressure of the compressed air.

For a better understanding the compressed air is shown also in Figs. 5-6 by arrows.

As evident from the modes of operation described above in Fig. 1 for carrying out the cyclic process, fresh atmospheric air and a corresponding quantity of cooling room air have been exchanged continuously in such a way that simultaneously with the cooling an intensive ventilation of the cooling room takes place without needing a special refrigeration output for this purpose.

If a ventilation is undesirable the mode of operation as shown in Figs. 5 and 6 may be used, as then only cooling room air is working in the cyclic process and the atmospheric air is used as so-called rinsing air only for abstracting heat.

To sum up: The invention concerns a cooling and heating process which is based on the recognition that the energy lost by the condensation of the steam contained in the air to be cooled can be recovered (to a large extent) by changing periodically the ways of the two air currents passing between the cold and the warm room, thereby recovering for the purpose of heating the energy lost by condensation while cooling. The invention furthermore concerns devices for carrying out this process and more especially a heat-exchanger, which is built in a special way of suitable material.

I claim:

1. Process for cooling and heating air in an open cycle, one air-volume being cooled and another air-volume separated from the first one being heated, which comprises compressing air from the volume to be heated, cooling the compressed air, thereby condensing the moisture contained therein, expanding this air when entering the other volume, simultaneously leading from the cooled volume into the volume to be heated air which is heated by contact with condensed water of higher temperature and periodically changing the direction of flow of the air currents in such a way that the directions of flow of the two air currents are altered periodically, so that the moisture deposited by one air current is absorbed by the subsequent air current.

2. Process for cooling and heating air in an open cycle, one air volume being cooled and another air volume separated from the first one being heated, which comprises periodically compressing air from the volume to be cooled and cooling the compressed air, thereby condensing the moisture contained therein, expanding the air when entering the volume to be cooled, subsequently drawing in air from the volume to be

cooled which takes up part of the heat deposited by the first air current and simultaneously providing current of air from the volume to be heated flowing again into this volume, which current takes up the rest of the heat and the moisture deposited by the first air current.

3. A device of the character described comprising at least one compressor cylinder, an expansion cylinder, two heat-exchangers including a housing having inlet and outlet ports and a piston body in the housing and composed of a metal foil wound into a cylindrical form and spacing elements between each single winding to provide a plurality of small channels therein, the piston body being adapted to be shifted axially in the said housings thereby governing the ports in the housings, means for shifting the piston bodies in their housings, pipes establishing communication between the compressor cylinder and the ports in the heat-exchanger housings and between the latter and the expansion cylinder, pipes establishing communication between the room to be heated and the ports in the heat-exchanger housings and between the latter and the room to be cooled.

4. A device of the character described comprising at least one compressor cylinder, an expansion cylinder, two heat-exchangers including a housing having inlet and outlet ports and a piston body in the housing and composed of a metal foil wound into a cylindrical form and spacing elements between each single winding to provide a plurality of small channels therein, the piston body being adapted to be shifted axially in the said housings thereby governing the ports in the housings, means for shifting the piston bodies in their housings, pipes establishing communication between the compressor cylinder and the ports in the heat-exchanger housings and between the latter and the expansion cylinder, pipes establishing communication between the room to be heated and the ports in the heat-exchanger housings and between the latter and the room to be cooled, and a valve in the outlet of the expansion cylinder.

5. A device of the character described comprising at least one compressor cylinder, an expansion cylinder, two heat-exchangers including a housing having inlet and outlet ports and a piston body in the housing and composed of a metal foil wound into a cylindrical form and spacing elements between each single winding to provide a plurality of small channels therein, each body having incision cuts forming an angle of 90° with the axis of the windings, the piston body being adapted to be shifted axially in the said housings thereby governing the ports in the housings, means for shifting the piston bodies in their housings, pipes establishing communication between the compressor cylinder and the ports in the heat-exchanger housings and between the latter and the expansion cylinder, pipes establishing communication between the room to be heated and the ports in the heat-exchanger housings and between the latter and the room to be cooled.

6. A device of the character described comprising at least one compressor cylinder, an expansion cylinder, two heat-exchangers including a housing having inlet and outlet ports and a piston body in the housing and composed of a metal foil wound into a cylindrical form and spacing elements between each single winding to provide a plurality of small channels therein, each body having incision cuts forming an angle of 90° with the axis of the windings, the piston body being

adapted to be shifted axially in the said housings thereby governing the ports in the housings, means for shifting the piston bodies in their housings, pipes establishing communication between the compressor cylinder and the ports in the heat-exchanger housings and between the latter and the expansion cylinder, pipes establishing communication between the room to be heated and the ports in the heat-exchanger housings and between the latter and the room to be cooled, and a valve in the outlet of the expansion cylinder.

7. A device of the character described, comprising a compressor cylinder, an expansion cylinder, two surface heat-exchangers having a large surface, channels and valves at the inlet and outlet ends of the said heat-exchangers adapted for the communication of the outlet ends of the said heat-exchangers with the inlet of the said expansion cylinder and alternately with the space into which the outlet end of the said expansion cylinder opens, and for the communication of the inlet ends of the said heat-exchangers with the outlet of the said compressor cylinder and alternately with the space from which the said compressor cylinder sucks, the said valves being adapted to form alternately one of the said heat-exchangers as communicating channel between the compression space of the said compressor and the expansion space of the said expansion cylinder while the other heat-exchanger simultaneously serves as communicating channel between the outlet chamber of the expansion cylinder and the inlet chamber of the compressor cylinder.

8. A device of the character described, comprising a compressor cylinder, an expansion cylinder, two surface heat-exchangers having a large surface, channels and valves at the inlet and outlet ends of the said heat-exchangers adapted for the communication of the outlet ends of the said heat-exchangers with the inlet of the said expansion cylinder and alternately with the space into which the outlet end of the said expansion cylinder opens, and for the communication of the inlet ends of the said heat-exchangers with the outlet of the said compressor cylinder and alternately with the space from which the said compressor cylinder sucks, the said valves being adapted to form alternately one of the said heat-exchangers as communicating channel between the compression space of the said compressor and the expansion space of the said expansion cylinder while the other heat-exchanger simultaneously serves as communicating channel between the outlet chamber of the expansion cylinder and the inlet chamber of the compressor cylinder.

cylinder, three devices for reversing the said heat-exchangers and a throttle in the outlet channel of the said expansion cylinder.

9. A device of the character described, comprising a compressor cylinder, an expansion cylinder, two surface heat-exchangers having a large surface, channels and valves at the inlet and outlet ends of the said heat-exchangers adapted for the communication of the outlet ends of the said heat-exchangers with the inlet of the said expansion cylinder and alternately with the space into which the outlet end of the said expansion cylinder opens, and for the communication of the inlet ends of the said heat-exchangers with the outlet of the said compressor cylinder and alternately with the space from which the said compressor cylinder sucks, the said valves being adapted to form alternately one of the said heat-exchangers as communicating channel between the compression space of the said compressor and the expansion space of the said expansion cylinder while the other heat-exchanger simultaneously serves as communicating channel between the outlet chamber of the expansion cylinder and the inlet chamber of the compressor cylinder, each of the said heat-exchangers including a body composed of a metal foil wound spirally and spacing elements between all the windings for forming a plurality of narrow channels therein.

10. A device of the character described, comprising a compressor cylinder, an expansion cylinder, two surface heat exchangers having a large surface, channels and valves at the inlet and outlet ends of the said heat-exchangers adapted for the communication of the outlet ends of the said heat-exchangers with the inlet of the said expansion cylinder and alternately with the space into which the outlet end of the said expansion cylinder opens, and for the communication of the inlet ends of the said heat-exchangers with the outlet of the said compressor cylinder and alternately with the space from which the said compressor cylinder sucks, the said valves being adapted to form alternately one of the said heat-exchangers as communicating channel between the compression space of the said compressor and the expansion space of the said expansion cylinder while the other heat-exchanger simultaneously serves as communicating channel between the outlet chamber of the expansion cylinder and the inlet chamber of the compressor cylinder, the said valves consisting of piston valves which are adapted to receive the said heat-exchangers.

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