

High EER Air Conditioning Apparatus with Special Heat Exchanger

The present invention is related to an air conditioning apparatus having a high EER (energy efficiency ratio), particularly to an air conditioning apparatus which uses energy of air to cool or heat working
5 medium circulated in the apparatus.

Air conditioners are now widely used for conditioning the air within a building (for example, a house or an office, etc.). However, the conventional air conditioners have the disadvantages of high noise, low efficiency and not always introducing fresh air into the space for which
10 the conventional conditioner is used.

The present invention therefore is aimed at providing an improved air conditioning apparatus to mitigate and/or obviate the aforementioned problems.

An air conditioner incorporating the air conditioning apparatus in
15 accordance with the present invention is characterized in that it consists of an air-energy evaporating portion, an air-energy condensing portion, a low compression-ratio compressor and an auxiliary water pump. The other components of the air conditioner are similar to those of a conventional conditioner.

20 Since the present invention is related to using the energy of air to heat or cool the working medium, fresh air can be introduced into the space during each operating cycle of the present invention. Furthermore, since the heat flow rate per unit area of the condensing portion and the evaporating portion is relatively high, the evaporating portion together
25 with the condensing portion constitutes a high-efficiency heat exchanger. Thus, the thermal efficiency of the present invention is very high. This means that the air conditioner incorporating the air conditioning apparatus in accordance with the present invention has an EER which is much higher than that of the conventional air conditioner.

An objective of the present invention is to provide an air conditioning apparatus which has a high EER (energy efficiency ratio).

Another objective of the present invention is to provide an air conditioning apparatus which always introduces fresh air into the space
5 during each operating cycle of the apparatus.

A further objective of the present invention is to provide an air conditioning apparatus which will generate low noise during operation.

Other objectives, advantages, and novel features of the invention will become more apparent from the following detailed description in
10 conjunction with the accompanying drawings.

IN THE DRAWINGS:

Fig. 1 is a diagrammatical view showing the constituting elements for an air conditioning apparatus in accordance with the present invention wherein the apparatus is used for cooling purpose;

15 Fig. 2 is a partial cross-sectional view as taken from line 2-2 of Fig. 1;

Fig. 3 is a partial cross-sectional view as taken from line 3-3 of Fig. 1;

Fig. 4 is a diagrammatical view showing that the air conditioning
20 apparatus in accordance with the present invention is used as a room air conditioner;

Fig. 5 is a layout showing a working medium circulation system in accordance with the present invention;

Fig. 6 is a perspective view showing a condenser in accordance with
25 the present invention; and

Fig. 7 is a partially cross-sectional view showing the details of a portion of a condenser coil of the condenser of Fig. 6.

A working medium in a heat exchanger of an air conditioning apparatus in accordance with the present invention has the following four

processes for each cycle:

(1) a continuously heat-absorbing process so that the temperature of the working medium is increased from the lowest temperature (T1) to a high temperature (T2) wherein this process is proceeded under the same
5 low pressure (P1);

(2) a compression and temperature-increasing process so that the temperature of the working medium is increased from the temperature (T2) to a higher temperature (T3);

(3) a continuously heat-releasing process so that the temperature of
10 the working medium is lowered from the temperature (T3) to a low temperature (T4), wherein this process is proceeded under the same high pressure (P2); and

(4) an expansion and temperature-decreasing process so that the temperature of the working medium is lowered from the temperature (T4)
15 to the lowest temperature (T1).

Fig. 1 is related to a diagrammatic view showing the main structure of an air conditioning apparatus in accordance with the present invention, wherein the apparatus is used as an air cooler.

In Figs. 1 and 2, an evaporating portion (J1) is seen wherein the
20 working medium flowing through the evaporating portion (J1) is heated by the energy of air via a plurality of parallel, heat-conductive and metallic plates (5). A first area (A) and a second area (B) are defined respectively beside one of the flat heat conductive plates (5), wherein the area (A) is constituted by the heat conductive plate (5) and a
25 differential insulation plate (20) and the area (B) is constituted by the heat conductive plate (5) and a wave-like heat conductive plate (7). The area (A) defines a first passage for the working medium to pass through, wherein the working medium is under the continuously heat absorbing process so that its temperature is increased from the lowest temperature

(T1) to the high temperature (T2). The area (B) defines a second passage for the air to pass through wherein the air is under a continuously heat-releasing process so that the temperature of the air is lowered from the high temperature (T2) to the lowest temperature (T1).

5 The differential insulation plate (20) is a wave-type heat-dividing plate made of non-metallic material which has a large coefficient of heat resistance. The differential insulation plate (20) divides the heat exchange area of the heat conductive plate (5) along the flow direction of the working medium. The wave-like heat conductive plate (7) has a
10 plurality of wave-type sub-wings formed by pressing a thin, metallic plate material. The heat conducting amount of the wave-like heat conductive plate (7) along the flow direction of the air can be deemed as zero. The wave-like heat conductive plate (7) can adiabatically divide the conductive plate (5) along the flow direction of the air into a plurality of
15 heat-exchanging sub-areas and increase the heat-exchanging area between the heat conductive plate (5) and the air to be cooled so that the conductive plate (5) is adiabatically divided into an indefinite number of micro isothermal surfaces. Each micro isothermal surface (for example: dx_n , dy_n) has a temperature different from (but very close to) its
20 neighboring micro isothermal surfaces. Thus, the temperature increasing curve of the working medium plotted in a Cartesian coordinate system wherein the X-axis representing time and the Y-axis representing temperature, is substantially a mirror image of the temperature decreasing curve of the air plotted therein, which releases heat, wherein
25 the air releases heat to the working medium and the working medium absorbs heat from the air. This means that the temperature-increasing and heat-absorbing process of the working medium is correspondent to the temperature-decreasing and heat-releasing process of the air.

When the above situation happens, the temperature of the air, which

is originally located outside the space to be cooled by the air conditioning apparatus and has the temperature of (T2) and now is drawn into the air passage defined by the area (B) by a fan (12), is continuously and sufficiently lowered. The air releases heat which heats the
5 conductive plate (5) to increase the temperature of the working medium in the area (A). The heat released by the air is removed by the working medium until the temperature of the air is lowered to a degree slightly higher than the initial temperature (T1) of the working medium; then, the air is introduced into the space to be cooled via louvers (14) mounted
10 in an air outlet of the air conditioning apparatus.

Regarding the flowing of the working medium in the evaporating portion (J1), a description thereof is followed.

The evaporating portion (J1) defines a plurality of inlets and outlets both respectively connected to a working medium distribution tube (3)
15 which has a plurality of working medium distribution holes (not labeled) defined therein. After all of the outlets of the evaporating portion (J1) are connected together, they are then connected to a vapor-liquid delivery pipe (13). After all of the inlets of the evaporating portion (J1) are connected together, they are then connected to a liquid delivery pipe
20 (16). Partitions (not labeled) are used to separate the working medium passages. A returning tube (11) is provided on turning corners of each of the working medium flowing passages. The working medium flows through two sides of each of the partitions by a U-shaped path.

When the working medium in the liquid delivery pipe (16), which is
25 in the form of a thin liquid (g1) consisting of heat absorbent and coolant and has the pressure (P2), flows through a regulating valve (17), the pressure of the working medium is lowered to be the pressure (P1). Then, the working medium is uniformly distributed into the working medium distribution tubes (3) on the inlets of the evaporating portion

(J1). After that, the working medium is injected into the parallel working medium passages from a top side thereof. During the flowing of the working medium downwardly through the working medium passages, the working medium (g1) is continuously and sufficiently heated by the air flowing through the air passages, wherein the air is required to be cooled. Thus, the air in the air passages is cooled from the outdoor temperature (T2) to the required low temperature (T1) and then drawn into the spaced to be cooled. The working medium, which has been heated, is joined on the working distribution tubes (3) on the outlets of the evaporating portion (J1). Thereafter, the working medium is delivered to the vapor-liquid delivery pipe (13) and compressed by a compressor (M) to have the pressure (P2) and finally delivered to the inlets of the condensing portion (J2).

Since the heat exchanging process is proceeded on micro isothermal surfaces, and each micro isothermal surface has an effect enabling the cooling working medium and the cooled air located beside the heat conductive plate (5) to have a sufficient heat exchange, the final difference of temperature between the working medium and the air after the heat exchanging process is accomplished tends to be zero. Actually, the difference of temperature between the working medium and the air after the heat exchanging process in the evaporating portion (J1) in accordance with the present invention is accomplished is about 0.1 to 0.5 °C.

As shown in Fig. 3, the condensing portion (J2) also uses the heat conductive plates (5) to exchange heat between the working medium and air. Each of the parallel extending heat conductive plates (5) defines a (C) area and a (D) area therebeside. The area (C) consists of the heat conductive plate (5) and the differential insulation plate (20) and defines a passage for the working medium to pass therethrough, in which

the working medium releases heat since it is continuously cooled from the temperature (T3) to the temperature (T4). Opposite to the area (C) is the area (D). The area (D) consists of the heat conductive plate (5) and another differential insulation plate (21) and defines a passage for the air
5 in the space to be cooled to be drawn therethrough, in which the air continuously absorbs moisture and the heat from the working medium. A moisture evaporating film (6) which is made of porous, hygroscopic material is attached on a side of the heat conductive plate (5) facing the area (D). The film (6) has a good water holding ability and hygroscopic
10 effect and a large surface area exposed to the air.

The water holding ability of the film (6) can greatly improve the heat conductivity between the film (6) and the heat conductive plate (5). The porosity of the film (6) enables the film (6) to have a large surface area for evaporating moisture, which causes the cooling process of the
15 working medium to become a heat releasing process under a lower temperature.

The differential insulation plates (20) and (21) respectively for constituting the working medium passage and the air passage are both made of non-metallic material having a large coefficient of heat
20 resistance. The differential insulation plates (20), (21) can respectively divide two sides of the conductive plate (5) into an infinite number of micro isothermal heat conductive surfaces (for example, dx_n , dy_n). Thus, each side of the conductive plate (5) of the condensing portion (J2) can be formed into a continuously varied-temperature heat conductive
25 surface.

After the cool air flows out of the evaporating portion (J1) (as indicated by (a3) in Fig. 1) and absorbs the heat and moisture in the space to be cooled, the cool air will have a temperature and humidity which can make occupants of a room feel comfortable (as indicated by

(a4) in Fig. 1). Then, the air is drawn into the area (D) by a fan (19). In the area (D), the air sufficiently absorbs the moisture evaporated from the film (6) and the temperature thereof is increased from (T4) to (T3). Thereafter, the air is exhausted outside the space to be cooled.

5 The working medium, which flows out of the evaporating portion (J1) and has the pressure (P1), is compressed by the compressor (M) to have the pressure (P2). Then, the working medium is injected into each of the working medium passages defined by the area (C) via the distribution holes defined in the working medium distribution tubes (3). In the
10 working medium passages, the working medium continuously releases heat and the temperature thereof is continuously lowered so that the working medium is gradually liquefied to become cool, thin liquid (g1). Thereafter, the liquid (1) is delivered into the evaporating portion (J1) via the liquid delivery pipe (16) and the regulating valve (17). Then, the
15 circulation of the working medium is repeated through the present invention.

Regarding the variation of the humidity in the air, a description thereof is set forth below.

Referring to Fig. 1, the air (as indicated by (a1) in Fig. 1), which is
20 outside the space to be cooled, has an initial humidity (X1). After the air is drawn through the evaporating portion (J1) as indicated by (a2) to enter the place to be cooled, the air releases heat and the temperature thereof is lowered to be the temperature (T1) (as indicated by (a3) in Fig. 1), in which the air has a humidity (X2). Thus, when the air is moved
25 from (a1) to (a3), its humidity has a variation of (*X1) equal to (X1) minus (X2). Then, the air is drawn from a position as indicated by (a4) in the space to be cooled to enter the condensing portion (J2) as indicated by (a5), in which the air has a humidity (X3). Thereafter, the air in the condensing portion (J2) absorbs the moisture from the film (6) to have a

humidity (X_4). Finally, the air, which has the humidity (X_4), is exhausted outside of the condensing portion (J2) (as indicated by (a6)). Thus, when the air is moved from (a4) to (a6), its humidity has a variation of ($*X_2$) equal to (X_4) minus (X_3). The moisture in the air
5 passing through the evaporating portion (J1) is condensed to water drops which is collected in a water tank (not shown in Fig. 1) via a hose (not shown) connecting the water tank and a water collecting pan (10). The water in the water tank is quantitatively pumped by a water pump (not shown in Fig. 1) to be sprayed onto the evaporating film (6) via a
10 plurality of nozzles (18). The condensing of the working medium is accomplished by the moisture in the film (6), which absorbs heat from the working medium to become vapor. Since the air input amount and output amount through the present invention per time unit is the same, when the ($*X$) is equal to ($*X_2$), an equilibrium of the variation of the
15 humidity can be obtained. However, since the humidities respectively of the air outside and inside the space to be cooled fluctuate, when the ($*X_2$) > ($*X_1$), the water in the water tank should be supplemented to the evaporating film (6) by an automatic water supplying device; alternatively, when the ($*X_2$) < ($*X_1$), the water in the water tank
20 automatically overflows out of the water tank, thereby enabling the present invention to obtain an optimum operating effectiveness.

As shown by Fig. 4, the present invention can be used as an integral-type room air conditioner.

The fresh air outside a room to be cooled is drawn to pass through
25 the air passages in the evaporating portion (J1) by the action of the fan (12), whereby the temperature of the air is cooled to temperature (T_1) (as indicated by (a3) in Fig. 4), and, then, the cooled air is discharged into the room. The air in the room (as indicated by (a4)) is driven to flow through the louvers (28) and the air passages in the condensing portion

(J2) by the action of the fan (19), whereby the air can absorb the moisture and heat from the evaporating film (6), and, then, the heated air is exhausted outside the room. Partitions in the evaporating portion (J1) and cooling portion (J2) are used to separate the working medium passages
5 therein to cause the working medium to flow in the heating and condensing portions (J1), (J2) by a U-shaped flowing path.

When the air conditioner is used as an air cooler, the nozzles (18) regularly and quantitatively spray water droplets to the evaporating film (6) to timely wet the evaporating film (6). A water pump (23) is
10 controlled by a solenoid (24) to regularly and intermittently supply water. When the air conditioner is used as an air cooler, the solenoid (24) controls the water pump (23) to supply water to the nozzles (18) for spraying water into the condensing portion (J2). When the air conditioner is used as an air heater, the solenoid (24) controls the water pump (23) to
15 simultaneously supply water to the nozzles (18) and the nozzles (26) for simultaneously spraying water into the evaporating portion (J1) and the condensing portion (J2). A water filter (22) is used for preventing dirt from entering the water supplying system.

When the present invention is used as an air heater, the function of
20 the evaporating portion (J1) is the same. However, the flowing direction of the air through the evaporating portion (J1) should be reversed. Similarly, the flowing direction of the air through the condensing portion (J2) also needs to be reversed. The operating steps for converting the present invention from functioning as an air cooler to an air heater are
25 detailedly described below:

1. Switching the inlets for the working medium to be outlets and outlets to be inlets and the outlets for the air to be inlets and the inlets to be outlets so that the working medium and the air will flow in an opposite direction through the evaporating portion (J1) and the

condensing portion (J2) in a manner which is just reversed from that when the room air conditioner in accordance with the present invention is used as an air cooler;

2. Reversing the operating direction of the fan (12) so that it will
5 draw the air inside the room to flow through the evaporating portion (J1) to reach a place outside thereof; and reversing the operating direction of the fan (19) so that it will draw the air outside the room to flow through the air passages in the condensing portion (J2) to absorb heat and moisture and then enter the room; and
- 10 3. Regularly and intermittently driving the pump by the solenoid to spray water into the evaporating portion (J1) and the condensing portion (J2) via the nozzles (18) and (26) to wet the evaporating film (6) in the condensing portion (J2) and timely melt the frost accumulated in the air passages in the evaporating portion (J1), in which a glycerol solution or
15 an ethylene glycol solution can be added into the water tank (9) to enhance the heat exchanging ability of the present invention and to prevent the forming of ice blocks in the air passages of the evaporating portion (J1).

Since the difference of temperature between the air and the working
20 medium after heat exchange in the evaporating portion (J1) is relatively small, and the working medium is condensed from a relatively low temperature and the increase of temperature of the air in the condensing portion (J2) is relatively small, in comparison with the conventional air conditioner, the air conditioning apparatus in accordance present inven-
25 tion can have a much higher energy efficiency ratio (EER).

Fig. 5 shows a circulation system for the working medium in the present invention when it is used as an air cooler. Figs. 6 and 7 show the details of a condenser and a portion of a condenser coil. The circulation system comprises a low pressure compressor (M), a condenser (32), a

water pump (33) for supplying water to the condenser (32), an expansion valve/capillary (36) and an evaporator (31).

The working medium in the evaporator (31) absorbs the heat in the space to be cooled. Then, the working medium is driven by the low pressure compressor (M) to reach the condenser (32), which generally is located outside the space to be cooled. The function of the condenser (32) is to use the heat carried by the working medium from the space to be cooled to evaporate the water supplied to the condenser (32) by the water pump (33). This means that the condenser (32) utilizes the change of latent heat in the air to achieve the evaporation of the water in the condenser (32) thereby to cause the water to absorb heat from the working medium; thus, the condensing of the working medium can be effected.

The operating pressure of the working medium in the high pressure side of the circulation system of the present invention is only about 12-13 kgf/cm². Thus, the present invention only needs a compressor with a low compression ratio for driving the working medium to circulate in the circulation system. The compression ration of the compressor (M) of the present invention is about 2, which is smaller than that of the conventional compressor. Thus, the present invention can reduce the needed power of the compressor and lower the noise generated when running the compressor.

The water pump (33) is used to pressurize water to flow through nozzles (34) so that the water can be formed into fine water droplets. The fine water droplets are sprayed onto wave-like radiating fins (321) and attach on a surface thereof. When the surface of the radiating fins (321) is completely coated with water, the water will slowly flow onto a condenser coil (42) and a hydroscopic material (41) located between the coil (42) to afford the moisture needed for absorbing the heat from the

condenser coil (42).

From the above descriptions, it is understood that the present invention at least has the following advantages: energy saving, low noise, and enabling the room to be conditioned to always have fresh air.

5 The present invention can also be constructed as a separate-type room air conditioner. The working medium for heat exchange therefor can use the conventional cooling agent, i.e., freon. The inventor has sent a separator-type room air conditioner incorporating an air conditioning apparatus in accordance with the present invention to TAIWAN
10 ELECTRIC RESEARCH & TESTING CENTER to test its performance. The test report (not attached herewith) shows that the average EER obtain by the present invention is about 4.235, the cooling ability thereof is about 3665 Kcal/hour, and the power consumption thereof is about 866 Watts.

15 When having the same cooling ability, the conventional separate-type room air conditioner, which has the highest EER of about 2.4, consumes a power of about 1527 Watts. In comparison with the conventional air conditioner, the present invention can save 661 Watts. This means that in comparison with the conventional air conditioner the
20 present invention can save about 43.5% of electrical energy. Such a test report can sufficiently demonstrate the high heat efficiency achievable by the present invention.

 The above test is conducted when the present invention is merely using the conventional cooling agent as the working medium. When the
25 present invention uses other new types of cooling agent as the working medium which have a better heat conductivity, the present invention can obtain an even better heat efficiency.

 Although this invention has been described with a certain degree of particularity, it is to be understood that the present

disclosure has been made by way of example only and that numerous changes in the detailed construction and the combination and arrangement of parts may be resorted to without departing from the spirit and scope of the invention as hereinafter claimed.

CLAIM:

1. An air conditioning apparatus for conditioning the air in a space, comprising:

a working medium circulation system for a working medium to flow
5 therethrough, comprising:

an evaporating portion;

a compressor;

a condensing portion;

an expansion valve; and

10 a water pump for supplying water to be sprayed onto at least the condensing portion;

said evaporating portion and condensing portion constituting a heat exchanger which accomplishes a heat exchange cycle between the working medium and air when the working medium has a circulating
15 cycle in the circulation system and the air is introduced from an outside of the space to be conditioned to flow through the air conditioning apparatus to enter the space and then exhausted outside the space through the apparatus;

said circulating cycle of the working medium in the circulation
20 system comprising a continuously heat-absorbing process in the evaporating portion, a compression and temperature-increasing process in the compressor, a continuously heat-releasing process under a high pressure in the condensing portion, and an expansion and temperature-decreasing process in the expansion valve;

25 said air having a heat-absorbing process in the condensing portion and a heat releasing process in the evaporating portion;

the evaporating portion and condensing portion of the heat exchanger being so designed that they can achieve a very high efficiency of heat conductivity whereby all of the energy in the air flowing



through the evaporating and condensing portions can be sufficiently utilized to achieve the heat exchange between the air and the working medium whereby the pressure of the working medium in the high pressure side of the circulation system only needs to have a pressure of
5 12-13 kgf/cm² so that the compressor can be a compressor with a low compression ration of about 2, which causes that the compressor can have a low operating noise and low electrical consumption.

2. The air conditioning apparatus in accordance with Claim 1, wherein the air conditioning apparatus can be used in an integral-type
10 room air conditioner, a separate-type room air conditioner and a central air conditioning system.

3. The air conditioning apparatus in accordance with Claim 1 or 2, wherein the air conditioning apparatus can be used as an air cooler, an air heater or an air cooler and heater.

15 4. The air conditioning apparatus in accordance with claim 1, wherein the condensing portion comprises a condenser coil and wherein an outer surface of the condenser coil is coated with a water evaporating film which is made of a porous material with a good water holding ability thereby to enhance the water holding and absorbing
20 ability and increase the evaporating area of the surface of the condenser coil so that the heat conductivity of the condenser coil can be enhanced, and, thus, the condenser coil can sufficiently conduct heat between the working medium in the condensing portion and the air flowing therethrough even when the working medium and the air have a very
25 little difference of temperature thereby to improve the heat exchanging efficiency of the condensing portion.

5. The air conditioning apparatus in accordance with Claim 4, wherein the heat exchanger can also be used for refrigerating equipment.

