

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) Publication number:

0 482 629 A1

(12)

EUROPEAN PATENT APPLICATION(21) Application number: **91118140.2**(51) Int. Cl.⁵: **F24F 1/02**(22) Date of filing: **24.10.91**

(30) Priority: **25.10.90 JP 285855/90**
30.10.90 JP 290708/90
30.11.90 JP 334109/90

(43) Date of publication of application:
29.04.92 Bulletin 92/18

(84) Designated Contracting States:
DE GB IT

(71) Applicant: **KABUSHIKI KAISHA TOSHIBA**
72, Horikawa-cho Saiwai-ku
Kawasaki-shi Kanagawa-ken 210(JP)

(72) Inventor: **Suzuki, Kazuo**
1-14-1-14, Tomiokanishi, Kanazawa-ku
Yokohama-shi, Kanagawa-ken(JP)
Inventor: **Sano, Tetsuo**

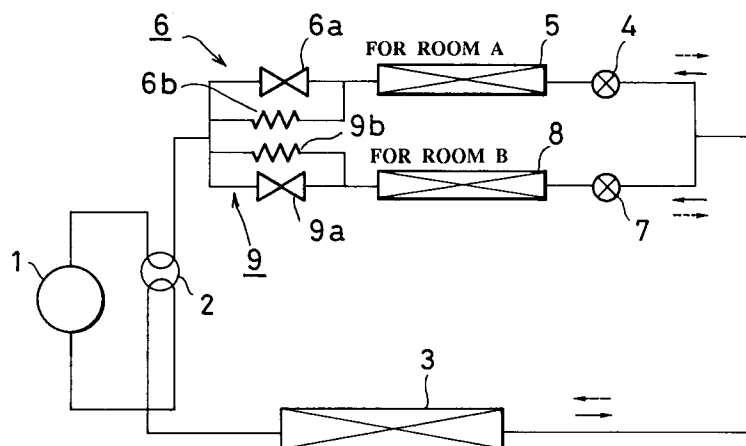
452, Nakazatohigashicho
Fujinomiya-shi, Shizuoka-ken(JP)
Inventor: **Oyabu, Yasunori**
1-20-31 Mutsumicho, Minami-ku
Yokohama-shi, Kanagawa-ken(JP)
Inventor: **Yamagishi, Katsuaki**
11-3-507, Kamicho, Isogo-ku
Yokohama-shi, Kanagawa-ken(JP)
Inventor: **Yamaguchi, Hiroichi**
1-10-14, Daigiri
Fujisawa-shi, Kanagawa-ken(JP)

(74) Representative: **Lehn, Werner, Dipl.-Ing. et al**
Hoffmann, Eitle & Partner Patentanwälte
Arabellastrasse 4
W-8000 München 81(DE)

(54) **Air-conditioning apparatus.**

(57) An air-conditioning apparatus comprises an outdoor unit having a compressor (1) and an outdoor heat exchanger (3); a plurality of indoor units connected in parallel to the outdoor unit and each hav-

ing an indoor heat exchanger (5, 8); and flow control device (6, 9) disposed between each of the indoor heat exchangers (5, 8) and the compressor (1), for adjusting the flow rate of coolant.

FIG. 3**EP 0 482 629 A1**

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a multiple-system air-conditioning apparatus that air-conditions a plurality of living spaces.

2. Description of the Prior Art

Figure 1 shows a conventional multiple-system air-conditioning apparatus for air-conditioning two rooms. In the figure, numeral 1 denotes a compressor, 2 a four-way valve, and 3 an outdoor heat exchanger. The compressor 1 and outdoor heat exchanger 3 constitute an outdoor unit to which two indoor units for rooms A and B are connected in parallel.

The indoor unit for the room A comprises an expansion valve 4 serving as a flow control valve, an indoor heat exchanger 5, and an open-close valve 13. Similarly, the indoor unit for the room B comprises an expansion valve 7 serving as a flow control valve, an indoor heat exchanger 8, and an open-close valve 14.

For cooling the rooms A and B, coolant is supplied in a direction indicated with continuous arrow marks, and for heating the rooms, in a direction indicated with dotted arrow marks.

When cooling the rooms A and B, the expansion valves 4 and 7 disposed on the liquid coolant side (the coolant inlet side during the cooling operation) of the indoor heat exchangers 5 and 8 are opened or closed in response to an increase or a decrease in air-conditioning loads of the indoor units, to adjust flow rates of the coolant to the indoor heat exchangers 5 and 8.

The open-close valves 13 and 14 disposed on the gaseous coolant side (the coolant outlet side during the cooling operation) of the heat exchangers 5 and 8 block the coolant from entering the heat exchangers 5 and 8 while they are out of operation, and have no function of adjusting the flows of the coolant.

When the indoor unit for the room A is required to operate at maximum (100%) heat exchanging capacity for cooling the room A and the indoor unit for the room B at 10% capacity for cooling the room B, the expansion valve 4 for the room A is opened to a full extent to feed the coolant at a maximum flow rate, and the expansion valve 7 for the room B is adjusted to feed the coolant to the room B at a flow rate of 10% of the maximum flow rate.

In this case, the flow rate of the coolant in the indoor unit for the room B is very small compared with its maximum capacity, so that the liquid coolant may exist only partly around the inlet of the

indoor heat exchanger 8, and the remaining part of the heat exchanger 8 may be occupied with superheated vapor.

Namely, as shown in Fig. 2, the inside of the indoor heat exchanger 8 may involve a part 17 where the liquid coolant exists and a part 16 where the superheated vapor exists. Room air that passes through the part 7 where the liquid coolant exists is cooled and dehumidified to provide dry air "a", while room air that passes through the part 16 where the superheated vapor exists is substantially not cooled or dehumidified to provide damp air "b". These air portions "a" and "b" are mixed together and supersaturated in the indoor unit 15, thereby forming dew "c" over structural components such as a casing, a nose, and a blow port disposed inside the indoor unit 15.

If there is a similar imbalance in the air-conditioning loads of the indoor units when heating the rooms A and B, the indoor heat exchanger 8 for the room B that receives a small quantity of the coolant may excessively condense the coolant and hold a large amount of liquid coolant in the piping thereof. This may cause a shortage of the coolant in a refrigeration cycle of the air-conditioning apparatus, and thus deteriorating the performance of the compressor 1 and overheating and breaking the compressor 1. To avoid this trouble, a ratio between the operating capacities of the indoor heat exchangers 5 and 8 must not be increased too large.

In this way, the conventional multiple-system air-conditioning apparatus has a problem that, if there is a big difference between loads required for the indoor units when cooling rooms, the structural components disposed inside the indoor unit operating under a light loads are bedewed. There is another problem that, when heating the rooms with the same large difference existing between loads required for the indoor units, an excessive quantity of liquid coolant stays in the piping of the indoor heat exchanger operating under a light load. The latter problem causes a shortage of coolant in the refrigeration cycle of the apparatus, thereby deteriorating, overheating, and breaking the compressor.

To supply a small quantity of coolant to the indoor unit operating under the light load, it may be possible to alternately supply and stop the coolant at a relatively large flow rate, instead of supplying the coolant at a very small flow rate. This, however, raises another problem to fluctuate a temperature in the room and give persons in the room an unpleasant feeling.

The conventional air-conditioning apparatus adjusts the opening of each flow control valve to control the flow rate of coolant supplied to a corresponding room.

The capacity of the outdoor unit is sometimes designed to be smaller than a total of capacities of the indoor units, to reduce the cost of the air-conditioning apparatus. This is made on an assumption that rooms to be air-conditioned will not simultaneously require a full load each. The outdoor unit, therefore, will be in a shortage of capacity if all rooms simultaneously require a full load each. If this happens, the conventional air-conditioning apparatus cannot deal with this situation.

When a ratio between capacities (air-conditioning loads) required for the two rooms in Fig. 1 involves a big difference, for example, 1:9, a ratio between flow rates of coolant supplied to the indoor units will not always be 1:9 even if a ratio between the openings of the flow control valves is set to 1:9. As a result, a ratio between actual performances of the indoor units will not be 1:9 so that a user may not obtain required air-conditioning performances.

The reason of this is partly because the coolant is in a two-phase flow of gas and liquid, and partly because the fitting conditions of flow dividers are different. Due to these reasons, the coolant is not always distributed according to a ratio between the openings of the flow control valves.

The air-conditioning apparatus of Fig. 1 for air-conditioning a plurality of rooms has only one outdoor heat exchanger with which heat of the coolant is discharged to atmosphere for cooling the rooms, or heat of atmosphere is absorbed by the coolant for heating the rooms. Namely, the single outdoor heat exchanger is able to carry out only one of the heat exchanging actions, and if the cooling and heating requirements simultaneously occur, it responds to only one of them.

In spring or fall in particular, different rooms may simultaneously require the cooling and heating actions due to differences in sunshine and individual temperature sensitivities in the rooms. To ensure comfortable air-conditioning in each room, these requirements must be satisfied. The conventional air-conditioning apparatus, however, is incapable of satisfying such simultaneous requirements.

SUMMARY OF THE INVENTION

An object of the invention is to provide an air-conditioning apparatus that does not produce dew over structural components disposed inside an indoor unit operating under a light load during a cooling operation, nor holds an excessive amount of coolant inside the piping of an indoor heat exchanger of an indoor unit operating under a light load during a heating operation, thereby improving the efficiency and reliability of a refrigeration cycle

of the apparatus and comfortably air-conditioning a plurality of rooms without fluctuating room temperatures even under light loads.

Another object of the invention is to provide an air-conditioning apparatus that accurately controls performances of a plurality of indoor units of the apparatus according to a ratio between air-conditioning loads required for the indoor units, and even if a total of capacities of the indoor units is greater than the capacity of an outdoor unit, properly controls the performances of the indoor units according to the required air-conditioning load ratio.

Still another object of the invention is to provide an air-conditioning apparatus that correctly responds to a simultaneous occurrence of opposing cooling and heating requirements.

In order to accomplish the objects, a first aspect of the invention provides an air-conditioning apparatus involving an outdoor unit having a compressor and an outdoor heat exchanger, and a plurality of indoor units connected to the outdoor unit in parallel and each having an indoor heat exchanger. The air-conditioning apparatus comprises flow control means disposed between each of the indoor heat exchangers and the compressor, for adjusting the flow rate of coolant.

During a cooling operation, the flow control means reduces the flow rate of coolant to a corresponding one of the indoor heat exchangers according to at least one of a decrease in an evaporation temperature in the indoor heat exchanger, the degree of superheat of the coolant at an outlet of the coolant, and an increase in the temperature or humidity of air in the room.

During a heating operation, the flow control means adjusts the flow rate of coolant to a corresponding indoor heat exchanger according to a load on the indoor heat exchanger.

When the indoor heat exchanger of one of the indoor units is required to operate under a small load during the cooling operation, the corresponding flow control means adjusts the flow rate of coolant to a required small value at the outlet of the coolant. As a result, the evaporation capacity of the indoor heat exchanger is reduced, and liquid coolant is uniformly distributed through the indoor heat exchanger to equalize a temperature in the indoor heat exchanger, thereby equalizing the temperature and humidity of air passing through the indoor heat exchanger, without producing dew over structural components disposed in the indoor unit.

For a heating operation with a small flow rate of coolant, the coolant is adjusted to the required small flow rate at an inlet of the coolant of the corresponding indoor heat exchanger. As a result, a condensation temperature in the indoor heat exchanger acting as a condenser is reduced to weaken the heat exchanging capacity thereof, so that

the coolant may not be excessively condensed, nor held inside the indoor heat exchanger, thereby stabilizing a refrigeration cycle of the air-conditioning apparatus.

Even if there is a big difference in performances required for a plurality of the indoor units, the temperature of each of the air-conditioned rooms does not fluctuate, to realize comfortable air-conditioning.

According to a second aspect of the invention, there is provided an air-conditioning apparatus comprising a plurality of indoor units and control means for controlling coolant supplied to the indoor units in a time sharing manner according to a ratio between air-conditioning loads required for the indoor units.

This arrangement supplies the coolant to a plurality of the indoor units in the time sharing manner according to, for example, a time ratio corresponding to a ratio between air-conditioning loads required for the indoor units. Even if the ratio between the air-conditioning loads required for the indoor units is relatively large, the coolant is properly and accurately distributed to the indoor units according to the air-conditioning load ratio.

Even if a total of capacities of the indoor units is greater than the capacity of the outdoor unit, the coolant is properly distributed to the indoor units according to the air-conditioning load ratio.

A third aspect of the invention provides an air-conditioning apparatus involving a plurality of indoor heat exchangers connected to a coolant path in parallel. When cooling and heating requirements simultaneously occur, the air-conditioning apparatus alternately carries out cooling and heating operations, and supplies coolant to the indoor heat exchangers according to the cooling and heating requirements in synchronism of the alternate cooling and heating operations.

This arrangement alternately carries out the cooling and heating operations in a time sharing manner when the cooling and heating requirements simultaneously occur. During the cooling operation, this arrangement supplies coolant only to the indoor heat exchangers that have issued cooling requests, and during the heating operation, only to the indoor heat exchangers that have issued heating requests.

These and other objects, features and advantages of the present invention will be more apparent from the following detailed description of preferred embodiments in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a system diagram showing a refrigeration cycle of an air-conditioning apparatus according to a prior art;

Fig. 2 is a schematic view showing the inside of an indoor unit of the prior art of Fig. 1;

Fig. 3 is a system diagram showing a refrigeration cycle of an air-conditioning apparatus according to an embodiment of the invention;

Fig. 4 is a system diagram showing a refrigeration cycle of an air-conditioning apparatus according to a modification of the first embodiment;

Fig. 5 is a block diagram showing a control system of the air-conditioning apparatus of Fig. 3;

Fig. 6 is a system diagram showing a refrigeration cycle of an air-conditioning apparatus according to a second embodiment of the invention;

Fig. 7 is a block diagram showing a control system of the air-conditioning apparatus of Fig. 6;

Fig. 8 is a timing chart showing a first example of time sharing control for the embodiment of Fig. 6;

Fig. 9 is a timing chart showing a second example of time sharing control for the embodiment of Fig. 6;

Fig. 10 is a timing chart showing a third example of time sharing control for the embodiment of Fig. 6;

Fig. 11 is a timing chart showing a fourth example of time sharing control for the embodiment of Fig. 6;

Fig. 12 is a timing chart showing a fifth example of time sharing control for the embodiment of Fig. 6;

Fig. 13 is a timing chart showing a sixth example of time sharing control for the embodiment of Fig. 6;

Fig. 14 is a system diagram showing a refrigeration cycle of an air-conditioning apparatus according to a third embodiment of the invention;

Figs. 15 and 16 are time charts explaining operations of the third embodiment;

Fig. 17 is a time chart showing an operation of a modification of the third embodiment;

Fig. 18 is a view explaining a data table according to the third embodiment; and

Fig. 19 is a time chart showing an operation of another modification of the third embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Figure 3 shows an air-conditioning apparatus according to the first embodiment of the invention. This air-conditioning apparatus is used for air-conditioning two rooms. In Figs. 3 through Fig. 19, the same reference numerals as those shown in Fig. 1 represent like parts whose explanations will not be repeated.

In Fig. 3, the air-conditioning apparatus comprises flow control devices 6 and 9 connected to indoor heat exchangers 5 and 8 for rooms A and B, respectively. Each of the flow control devices 6 and 9 serves as flow control means for adjusting the flow rate of coolant and is disposed between the corresponding indoor heat exchanger and a compressor 1. The flow control device 6 (9) is at an outlet of gaseous coolant during a cooling operation. The flow control device 6 (9) comprises an open-close valve 6a (9a) and a thin pipe 6b (9b) that are connected in parallel with each other.

Each of the open-close valves 6a and 9a has a function of simply opening and closing a flow of the coolant between a 100% opened state and a 0% opened state. On the other hand, each of the thin pipes 6b and 9b has a function of reducing the flow of the coolant to, for example, 20%. This reduction ratio of the coolant flow by the thin pipe 6b or 9b is properly designed.

The flow control device 6 (9) is 100% open when the open-close valve 6a (9a) is opened, and reduces the flow of the coolant to, for example, 20% when the open-close valve 6a (9a) is closed.

If the indoor unit for the room B is required to operate at 10% of its maximum capacity, the expansion valve 7 is controlled to reduce the flow of the coolant to 50%, while the flow control device 9 is adjusted to reduce the flow to 20%, thereby adjusting the flow rate of the coolant passing through the indoor heat exchanger 8 for the room B to 10% in total.

An operation of the above air-conditioning apparatus will be explained.

For example, to cool the rooms A and B, the indoor unit for the room A is required to operate at 100% capacity and the indoor unit for the room B at 10% capacity. The expansion valve 4 for the room A is fully opened, and the open-close valve 6a of the flow control device 6 is also fully opened, so that the indoor heat exchanger 5 for the room A may receive coolant at the maximum flow rate.

On the other hand, the expansion valve 7 for the room B is opened 50%, and the open-close valve 9a of the flow control device 9 is closed to control the flow rate of the coolant to 20%. As a result, the indoor heat exchanger 8 for the room B may receive the coolant at the flow rate of 10% in

total. In this way, when reducing the flow rate of the coolant in the indoor unit for the room B, the flow control device 9 disposed at the outlet of the coolant more predominantly acts than the expansion valve 7 disposed at the inlet of the coolant.

Compared with the conventional technique of adjusting the flow rate of the coolant to 10% only with the expansion valve 7, this embodiment increases the quantity of liquid coolant supplied to the indoor heat exchanger 8 for the room B. As a result, the evaporation capacity of the indoor heat exchanger 8 is reduced, and the liquid coolant is uniformly distributed through the indoor heat exchanger 8 to equalize a temperature in the indoor heat exchanger 8. Unlike the conventional air-conditioning apparatus, the apparatus of this embodiment never causes unevenness in the temperature and humidity of air passing through the indoor heat exchanger 8, nor produces dew in the indoor unit.

If there is the same imbalance in loads required for the indoor units for the rooms A and B when heating the rooms, the flow control device 9 of the indoor unit for the room B reduces the flow rate of coolant at an inlet of the coolant in front of the indoor heat exchanger 8, so that the heat exchanging capacity of the indoor heat exchanger 8 serving as a condenser decreases due to a decrease in a condensation temperature. As a result, the coolant is not excessively condensed and held inside the indoor heat exchanger 8. This stabilizes a refrigeration cycle of the air-conditioning apparatus.

Figure 4 shows an air-conditioning apparatus according to a modification of the first embodiment.

This modification has flow control valves 11 and 12 serving as flow control means for linearly adjusting the flow rate of coolant. The flow control valves 11 and 12 are disposed between the compressor 1 and the indoor heat exchangers 5 and 8 for the rooms A and B, respectively. The opening of the flow control valve 11 (12) is adjusted by a control circuit 45 and an opening control circuit 52 (53) according to at least one of the evaporation temperature of the indoor heat exchanger 5 (8), the degree of superheat of coolant detected by a heat exchanger sensor 34 (39) at an outlet of the coolant, and the temperature and humidity of air in the room A (B) detected by a room temperature sensor 33 (38) and a humidity sensor 60, as shown in Fig. 5.

During a cooling operation, the opening of the flow control valve 11 (12) is controlled according to at least one of a decrease in the evaporation temperature of the indoor heat exchanger 5 (8), the degree of superheat of the coolant at the outlet of the coolant, and an increase in the temperature or humidity of air in the room A (B). The flow of the

coolant to the indoor heat exchanger 5 (8) is reduced in response to a capacity required for the corresponding indoor unit.

According to this modification, even if there is a big difference in loads on the indoor units for the rooms A and B, the flow rate of the coolant to the indoor heat exchanger of the indoor unit whose required load is smaller is adjustable only through a corresponding one of the flow control valves 11 and 12, so that the modification is more effective in producing no dew over structural components disposed inside the indoor unit of the smaller load during the cooling operation, and in holding no excessive liquid coolant in the piping of the indoor heat exchanger of the smaller load during the heating operation.

As explained above, the first embodiment of the invention arranges flow control means on the compressor side of an indoor heat exchanger of each indoor unit, for adjusting the flow rate to coolant. During a cooling operation, the flow rate of coolant for the indoor heat exchanger of the indoor unit that requires a smaller cooling load is adjusted to a required small value at an outlet of the coolant. As a result, the evaporation capacity to the indoor heat exchanger is reduced, and the liquid coolant is uniformly distributed through the indoor heat exchanger to equalize a temperature in the heat exchanger. As a result, the temperature and humidity of air passing through the heat exchanger is equalized without producing dew over structural components disposed inside the indoor unit.

During a heating operation, the flow rate of coolant to the indoor heat exchanger of the indoor unit that requires a light load is adjusted to a required small value at an inlet of the coolant, so that the condensation temperature of the indoor heat exchanger is reduced to reduce the heat exchanging capacity of the indoor heat exchanger acting as a condenser, and condensed liquid does not excessively stay inside the heat exchanger. As a result, a refrigeration cycle of the air-conditioning apparatus is stabilized to increase the efficiency thereof, an overheat of the compressor prevented, the reliability of the apparatus improved.

Compared with the conventional air-conditioning apparatus that repeatedly starts and stops an indoor unit that requires a small load, the embodiment remarkably reduces fluctuations in a room temperature, thereby comfortably air-conditioning a room.

Figures 6 through 13 show an air-conditioning apparatus according to the second embodiment of the invention.

As shown in Fig. 7, the second embodiment has, in addition to the functions of the first embodiment, a function of supplying coolant in a time sharing manner.

The air-conditioning apparatus of the second embodiment for air-conditioning two rooms will be explained with reference to Figs. 6 and 7.

In Fig. 6, numeral 1 denotes a compressor, which is connected to an outdoor heat exchanger 3 through coolant piping and a four-way valve 2. The coolant piping extending from the outdoor heat exchanger 3 is divided into a plurality of paths (two in the figure) through a flow divider 23. The divided piping is connected to pressure reduction devices, e.g., flow control valves (electronic expansion valves) 4 and 7, indoor heat exchangers 5 and 8, and flow control valves 11 and 12 for rooms A and B. The piping is then collected by a flow divider 21 and connected again to the compressor 1 through the four-way valve 2, thereby completing a heat-pump-type refrigeration cycle.

In Fig. 6, continuous arrow marks indicate a flow of coolant for a cooling operation, and dotted arrow marks a flow of the coolant for a heating operation.

The above arrangement resembles to that of Fig. 4.

Figure 7 is a block diagram showing a control circuit according to the second embodiment.

In the figure, an operation control portion 32 for the room A is manipulated by a user to issue a start or stop instruction, a required room temperature, or a required wind volume. This operation control portion 32 comprises, for example, a remote control unit.

A room temperature sensor 33 measures the temperature of the room A, and a heat exchanger sensor 34 measures the temperature of the indoor heat exchanger 5. These sensors 33 and 34 are used for, for example, preventing a cold wind during a heating operation.

A fan motor 35 blows a wind for cooling or heating the room A.

A difference between the room temperature measured by the room temperature sensor 33 and a temperature set through the operation control portion 32 is calculated in a temperature difference calculation circuit 36 and transferred to an air-conditioning load calculation circuit 42.

Similarly, the room B has an operation control portion 37, a room temperature sensor 38, a heat exchanger sensor 39, and a fan motor 40. Functions of these components are the same as those for the room A. A difference between the room temperature of the room B and a set temperature is calculated in a temperature difference calculation circuit 41 and transferred to an air-conditioning load calculation circuit 43.

The air-conditioning load calculation circuits 42 and 43 provide information to an air-conditioning load ratio calculation circuit 44, which calculates a ratio between air-conditioning loads of the rooms A

and B. The air-conditioning load of each room is determined according to the difference between the room temperature and the set temperature for the room, an ambient temperature outside the room, insulation of the room, etc. If these conditions except the temperature difference are substantially identical for all rooms, the air-conditioning load may be calculated according to only the temperature difference. A signal corresponding to an ambient temperature provided by an ambient temperature sensor 57 may be used to calculate the air-conditioning load.

According to the ratio between the air-conditioning loads of the rooms A and B calculated in the air-conditioning load ratio calculation circuit 44, a time sharing control circuit 46 for time-sharing coolant flow rates drives opening control circuits 50, 51, 52, and 53 for the rooms A and B. Namely, the openings of the flow control valves 4 and 11 for the room A and of the flow control valves 7 and 12 for the room B are controlled in a time sharing manner according to the air-conditioning load ratio.

A total of capacities of the rooms A and B is prepared by changing the rotational speed of a compressor motor 1M with a frequency variable circuit 47. Cooling and heating operations are switched from one to another by turning ON and OFF the four-way valve 2 with a switching circuit 48.

A fan motor 54 is employed for an outdoor heat exchanger 3.

A current sensor 55 detects a current flowing to the compressor motor 1M and controls not to supply an over-current thereto. A discharge temperature sensor 56 measures a coolant discharge temperature, and reduces an operation frequency of the compressor if the discharge temperature is too high, thereby protecting a coil of the compressor.

A suction temperature sensor 58 and a suction pressure sensor 59 detect the degree of superheat of the coolant. Controlling the degree of superheat is important for safely and efficiently operating the refrigeration cycle but not particularly explained here.

The time sharing control of the flow rates of coolant in the air-conditioning apparatus of the above arrangement will be explained with reference to timing charts of Figs. 8 and 13.

Figure 8 shows a first example of the time sharing control. The air-conditioning apparatus air-conditions two rooms A and B in which coolant is supplied to one of the rooms and not supplied to the other according to the time sharing control. A ratio between air-conditioning loads of the rooms A and B calculated in the air-conditioning load ratio calculation circuit 44 is supposed to be 2:1.

According to this air-conditioning load ratio, the time sharing control circuit 46 controls the flow control valves 4 and 11 for the room A and the flow control valves 7 and 12 for the room B in a time sharing manner as shown in Fig. 8.

At first, the flow control valves 4 and 11 for the room A are fully opened, while the flow control valves 7 and 12 for the room B are kept completely closed. This is done for a period of $2T$ which is two times a unit period T . After this period, the flow control valves 4 and 11 for the room A are completely closed, while the flow control valves 7 and 12 for the room B are fully opened. This is done for the unit period T . As a result, the coolant is distributed at the ratio of 2:1 corresponding to the air-conditioning load ratio for the rooms A and B.

Figure 9 shows a second example of the time sharing control, which is a modification of the first example. While the flow control valves for one room are fully opened, those for the other room are not completely closed but slightly opened to pass a small quantity of coolant. In this case, if the room A receives the coolant, the openings of the flow control valves 4 and 11 are controlled as explained in the first embodiment. The second example also distributes the coolant to the indoor units at the ratio of 2:1 corresponding to the air-conditioning load ratio for the rooms A and B.

Figure 10 shows a third example of the time sharing control. A ratio between air-conditioning loads of the indoor units is relatively large, for example, 8:1. The openings of the flow control valves for the indoor unit of larger air-conditioning load are kept at predetermined extent, while the openings of the flow control valves for the indoor unit of smaller air-conditioning load are controlled in a time sharing manner to precisely distribute the coolant according to the air-conditioning load ratio.

When the ratio between air-conditioning loads of the rooms A and B is 8:2, the coolant is properly distributed to the rooms only by adjusting the openings of the flow control valves. While the ratio becomes 8:1, the coolant is hardly distributed by only adjusting the openings of the flow control valves. In this case, a ratio between the openings of the flow control valves 4 and 11 for the room A to the openings of the flow control valves 7 and 12 is firstly set to 8:2 for a period of $4T$. During the next period of $4T$, the flow control valves 7 and 12 for the room B are closed. As a result, a ratio between flow rates of the coolant for the rooms A and B for a total period of $8T$ becomes 8:1. With this time sharing method, the coolant is properly distributed to the indoor units of the rooms A and B even if the air-conditioning load ratio is relatively large, and the capacities of the indoor units are precisely adjusted according to the air-conditioning load ratio.

Figure 11 shows a fourth example of the time sharing control, which is a modification of the third example. The flow control valves 7 and 12 for the room B are opened and closed alternately every unit time T. During a period of 8T, the coolant is supplied for 4T and not supplied for 4T to provide the same result as in the third example.

Figure 12 shows a fifth example of the time sharing control. This example controls three rooms A, B and C at an air-conditioning load ratio of 2:1:3. Time sharing control is carried out by supplying coolant to the indoor unit of the room A for a period of twice (2T) a unit time T, to the indoor unit of the room B for the unit time (1T), and to the indoor unit of the room C for a period of three times (3T) the unit time. As a result, the coolant is supplied to the rooms A, B and C according to the required air-conditioning load ratio of 2:1:3.

Figure 13 shows a sixth example of the time sharing control, which is a modification of the fifth example. Coolant is sequentially supplied to each of the rooms A, B, and C for a unit time T. Since it is necessary to supply the coolant to the room A for a period of 2T, the coolant is further supplied to the room A for another unit time T. As a result, the room A receives the coolant for a period of 2T in total. At this time, the coolant is not supplied to the room B because the room B requires the coolant only for the unit time T. Since the room C requires the coolant for a period of 3T, the coolant is further supplied to the room C for another unit time T. At this time, the rooms A and B have already received necessary quantities of the coolant, so that only the room C receives the coolant for the unit time T, i.e., for a period of 3T in total. In this way, in one cycle, the rooms A, B and C receive the coolant at the time ratio of 2:1:3 similar to the fifth example.

In each of the fifth and sixth examples, the closed flow control valves may receive a small quantity of coolant as in the second example.

Similar to the first embodiment, the second embodiment has a flow control valve on each side of each indoor heat exchanger. This flow control valve may be disposed on one side of each indoor heat exchanger.

As explained above, the second embodiment of the invention carries out time sharing control when supplying coolant to a plurality of indoor units according to a required air-conditioning load ratio. Even if this ratio is relatively large, the coolant is properly and precisely distributed to the indoor units according to the ratio. Even if a total of capacities of a plurality of the indoor units is greater than the capacity of an outdoor unit, the coolant is properly distributed to the indoor units according to the ratio.

An air-conditioning apparatus according to the third embodiment of the invention will be explained. This embodiment alternately carries out cooling and heating operations to deal with cooling out heating requirements that simultaneously occur.

Figure 14 shows an air-conditioning apparatus according to the third embodiment of the invention. In the figure, numeral 1 denotes a compressor; 3 an outdoor heat exchanger; 70 an expansion valve; 71, 73 and 75 indoor heat exchangers disposed for rooms A, B and C, respectively; 77, 79 and 81 operation portions each for setting a cooling or heating request and a target temperature for the corresponding room; 83, 85, 87, 89, 91, and 93 two-way valves for controlling the supply of coolant to the indoor heat exchangers 71, 73, and 75; and 2 a four-way valve for changing the flow of coolant in a coolant path and thus changing cooling and heating operations from one to another. Numeral 97 is a control circuit for controlling an overall operation of the air-conditioning apparatus.

When heating the rooms, the control circuit 97 controls the four-way valve 2 to guide gaseous coolant of high temperature from the compressor 1 toward the indoor heat exchangers 71, 73, and 75. The gaseous coolant passes through the indoor heat exchangers 71, 73, and 75 to discharge heat to air in the rooms, thereby heating the rooms and reducing the temperature of the gaseous coolant. The coolant then passes through the expansion valve 70 and the outdoor heat exchanger 3 to absorb heat from air outside the rooms.

When cooling the rooms, the control circuit 97 controls the four-way valve 2 to guide the gaseous coolant from the compressor 1 toward the outdoor heat exchanger 3, which discharges heat of the coolant to outside air, thereby liquefying the coolant. The liquid coolant is fed to the indoor heat exchangers 71, 73, and 75 in which the coolant absorbs heat from air in the rooms to cool the rooms.

Figure 15 is a time chart showing an operation of the third embodiment which deals with simultaneous cooling and heating requests.

The indoor heat exchangers 71, 73 and 75 air-condition the rooms A, B, and C, respectively.

During a period t1, only the room A is cooled.

Thereafter, the room B issues a heating request. The control circuit 97 then switches the four-way valve 2 to alternately carry out cooling and heating operations in a time sharing manner for a period t2. In synchronism of the alternating operations, the two-way valves 83 and 85 of the indoor heat exchanger 71 for the room A and the two-way valves 87 and 89 of the indoor heat exchanger 73 for the room B are alternately opened and closed. As a result, the room A is cooled, and the room B is heated. In this alternating operations, the num-

bers of rooms cooled and heated are each one so that a time ratio between cooling and heating operations (A:B) is 1:1.

Thereafter, the room C issues a heating request. The number of rooms to be heated then becomes twice the number of rooms to be cooled. Namely, the time ratio between the cooling and heating operations becomes 1:2, and with this time ratio, the alternating operations are continued for a period t3.

In this way, the third embodiment alternately carries out heating and cooling operations according to a time ratio corresponding to the numbers of cooled and heated rooms, to deal with simultaneous cooling and heating requests. Unlike the conventional air-conditioning apparatus, the third embodiment can deal with all of such simultaneous cooling and heating requests.

In the third embodiment, the time ratio between the alternating operations is changed when the numbers of rooms to be cooled and heated are changed, thereby properly air-conditioning the rooms. To deal with the changes in the numbers of rooms to be cooled and heated, a modification shown in Fig. 16 changes the rotational speed of the compressor 1 with the time ratio (A:B) being unchanged.

Figure 17 is a time chart showing another modification of the third embodiment. According to this modification, the alternating cooling and heating operations are carried out according to not only the time ratio based on the numbers of rooms to be cooled and heated but also differences between target temperatures and room temperatures as well as an ambient temperature.

More precisely, according to a cooling request from the room A and a heating request from the room B, the cooling and heating operations are alternately carried out at a time ratio of 1:1 for a period t4.

Thereafter, a decreased target temperature is entered through the operation portion 77 of the room A. It is then necessary to increase the flow rate of coolant for the room A. To deal with this, with the same number of rooms, the time ratio (A:B) is changed to 2 for cooling and 1 for heating, and the cooling and heating operations are alternately carried out for a period t5.

During a period t6, on ambient temperature decreases so that cooling efficiency increases and heating efficiency decreases. To cope with this, the time ratio (A:B) is returned to 1:1 and the alternating operations are continued for this period t6.

The control circuit 97 may store a data table shown in Fig. 18 containing various time ratios. According to this table, a proper time ratio is selected to more precisely air-conditioning the individual rooms.

In the above embodiment, the time ratio (A:B) between the alternating operations is changed to properly air-condition the individual rooms according to the numbers of rooms to be cooled and heated, differences between target temperatures and room temperatures, and a change in an ambient temperature. It is possible to change the rotational speed for the compressor 1 with the time ratio (A:B) being unchanged, as shown in Fig. 19.

Similar to the first embodiment, the third embodiment may have a flow control valve on each side of each indoor heat exchanger.

As mentioned above, the third embodiment of the invention alternately carries out cooling and heating operations in a time sharing manner to deal with simultaneous cooling and heating requests. During the cooling operation, the third embodiment supplies coolant only to indoor heat exchangers that have issued the cooling requests, and during the heating operation, supplies the coolant only to indoor exchangers that have issued the heating requests. In this way, the third embodiment correctly air-conditions the individual rooms even if rooms simultaneously issue the opposing cooling and heating requests.

Various modifications will become possible for those skilled in the art after receiving the teachings of the present disclosure without departing from the scope thereof.

Claims

1. An air-conditioning apparatus comprising:
 - (a) an outdoor unit having a compressor and an outdoor heat exchanger;
 - (b) a plurality of indoor units connected in parallel to said outdoor unit and each having an indoor heat exchanger; and
 - (c) flow control means disposed between each of the indoor heat exchangers and the compressor, for adjusting the flow rate of coolant.
2. The apparatus according to claim 1, further comprising an expansion valve disposed between each of the indoor heat exchangers and the outdoor heat exchanger, for controlling the flow rate of the coolant.
3. The apparatus according to claim 1, wherein, when the indoor heat exchanger of any one of said indoor units is requested to operate at a small capacity during a cooling operation, a corresponding one of said flow control means adjusts, at an outlet of the coolant, the flow rate of the coolant for the indoor heat exchanger in question to a required small value, thereby reducing the evaporation capacity of

- the indoor heat exchanger, uniformly distributing the liquid coolant through the indoor heat exchanger, equalizing a temperature in the indoor heat exchanger as well as the temperature and humidity of air passing through the indoor heat exchanger, and producing no dew over structural components disposed inside the corresponding indoor unit. 5
4. The apparatus according to claim 1, wherein when the indoor heat exchanger of any one of said indoor units is requested to operate at a small capacity during a heating operation, a corresponding one of said flow control means adjusts, at an inlet of the coolant, the flow rate of the coolant for the indoor heat exchanger in question to a required small value, thereby decreasing the condensation temperature and heat exchanging capacity of the indoor heat exchanger acting as a condenser, holding no excessive condensed liquid coolant inside the indoor heat exchanger, and stabilizing a refrigeration cycle of the air-conditioning apparatus. 10 15 20
5. The apparatus according to claim 1, wherein, for a cooling operation, said flow control means reduces the flow rate of the coolant to the corresponding indoor heat exchanger according to at least one of a decrease in the evaporation temperature of the indoor heat exchanger, the degree of superheat of the coolant at an outlet of the coolant, and an increase in the temperature or humidity of room air. 25 30
6. The apparatus according to claim 1, wherein, for a heating operation, said flow control means reduces the flow rate of the coolant when a heating load on the corresponding indoor heat exchanger has decreased. 35 40
7. An air-conditioning apparatus comprising:
 (a) an outdoor unit having a compressor and an outdoor heat exchanger;
 (b) a plurality of indoor units connected in parallel to said outdoor unit and each having an indoor heat exchanger; and 45
 (c) time sharing control means for controlling coolant supplied to said indoor units according to a ratio between air-conditioning loads of the indoor units in a time sharing manner. 50
8. The apparatus according to claim 7, further comprising flow control means disposed between each of the indoor heat exchangers and the compressor, for adjusting the flow rate of the coolant. 55
9. An air-conditioning apparatus comprising:
 (a) on outdoor unit having a compressor and an outdoor heat exchanger;
 (b) a plurality of indoor units connected in parallel to said outdoor unit and each having an indoor heat exchanger; and
 (c) control means for alternately carrying out cooling and heating operations according to simultaneous cooling and heating requests, and controlling, in synchronism of the alternating cooling and heating operations, coolant supplied to the indoor heat exchangers that have issued the cooling and heating requests.
10. The apparatus according to claim 9, further comprising flow control means disposed between each of the indoor heat exchangers and the compressor, for adjusting the flow rate of the coolant.

FIG. 1

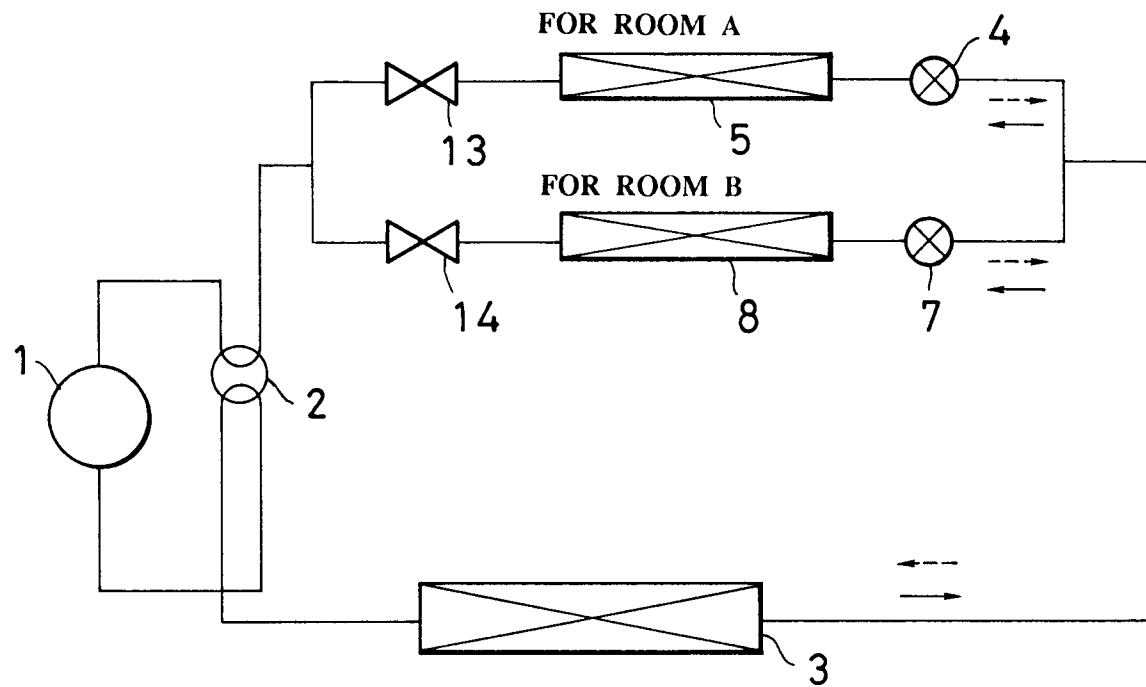


FIG. 2

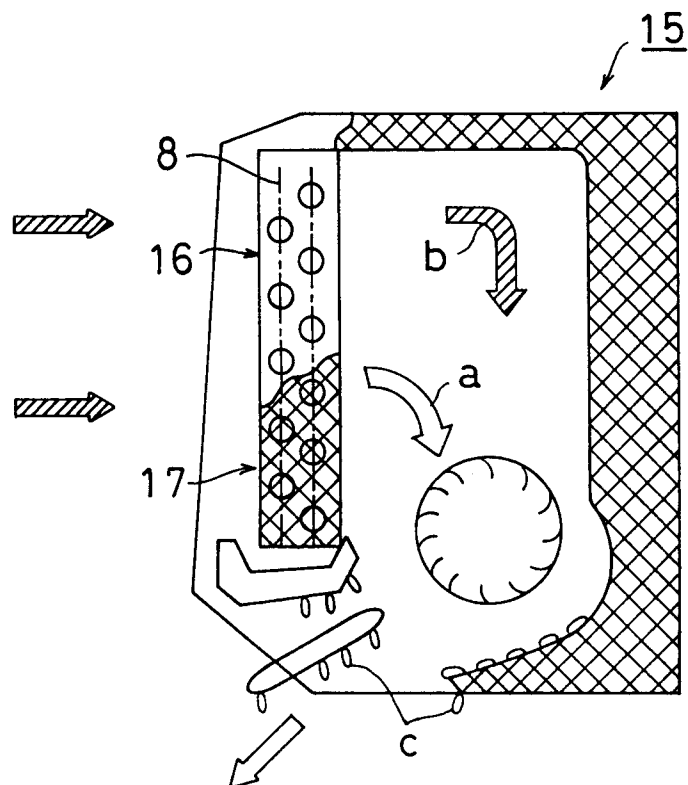


FIG. 3

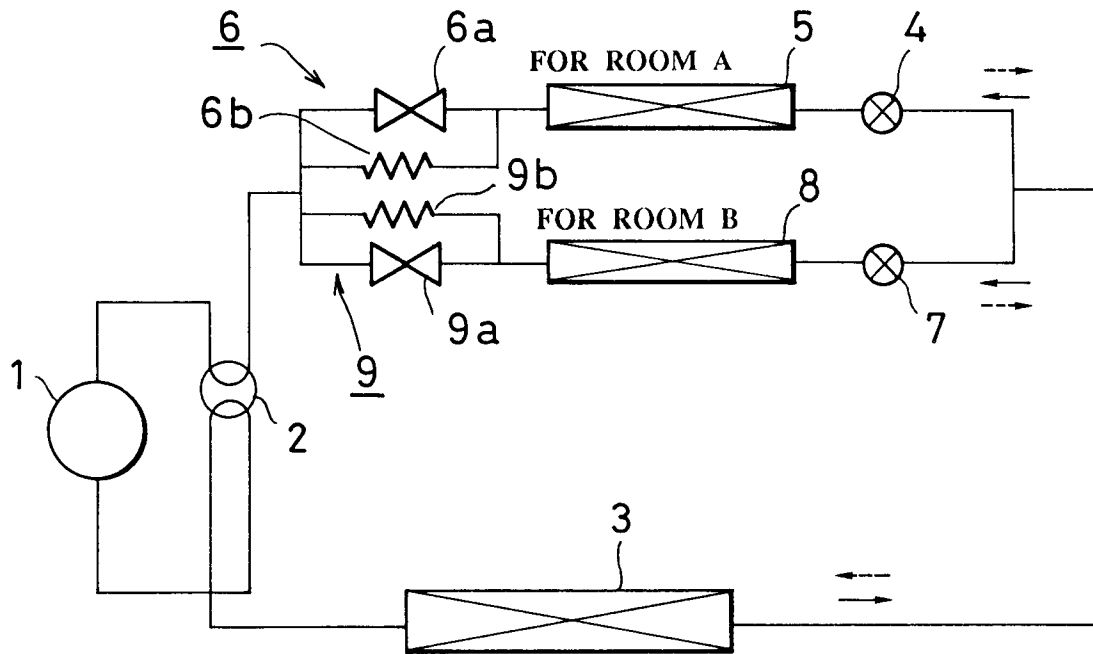
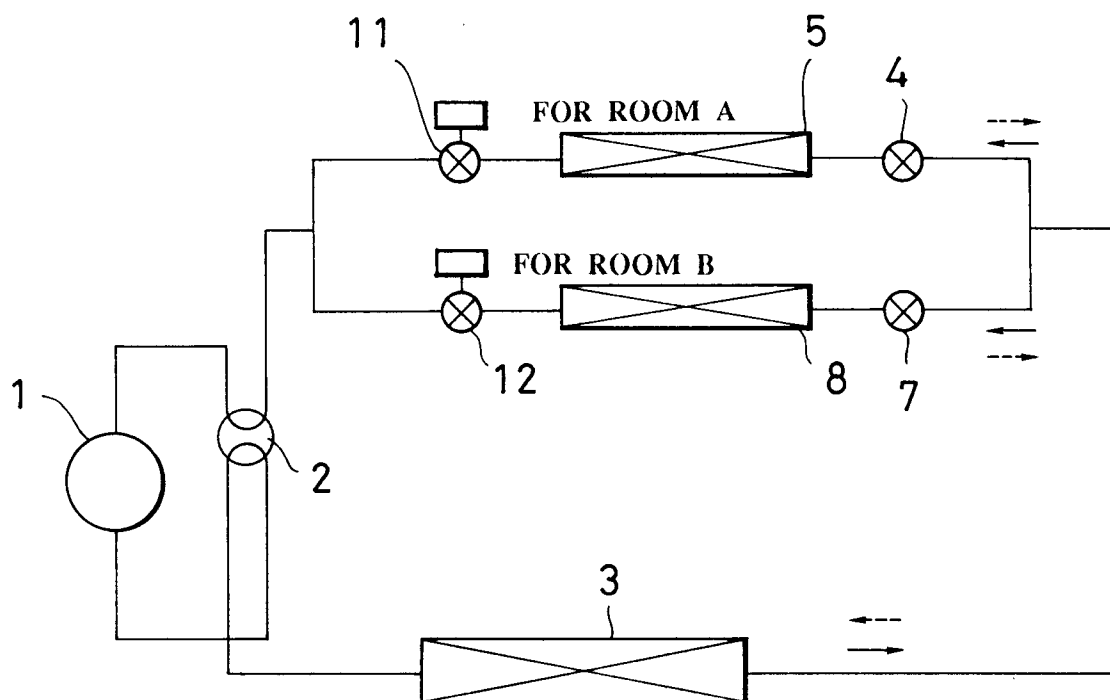


FIG. 4



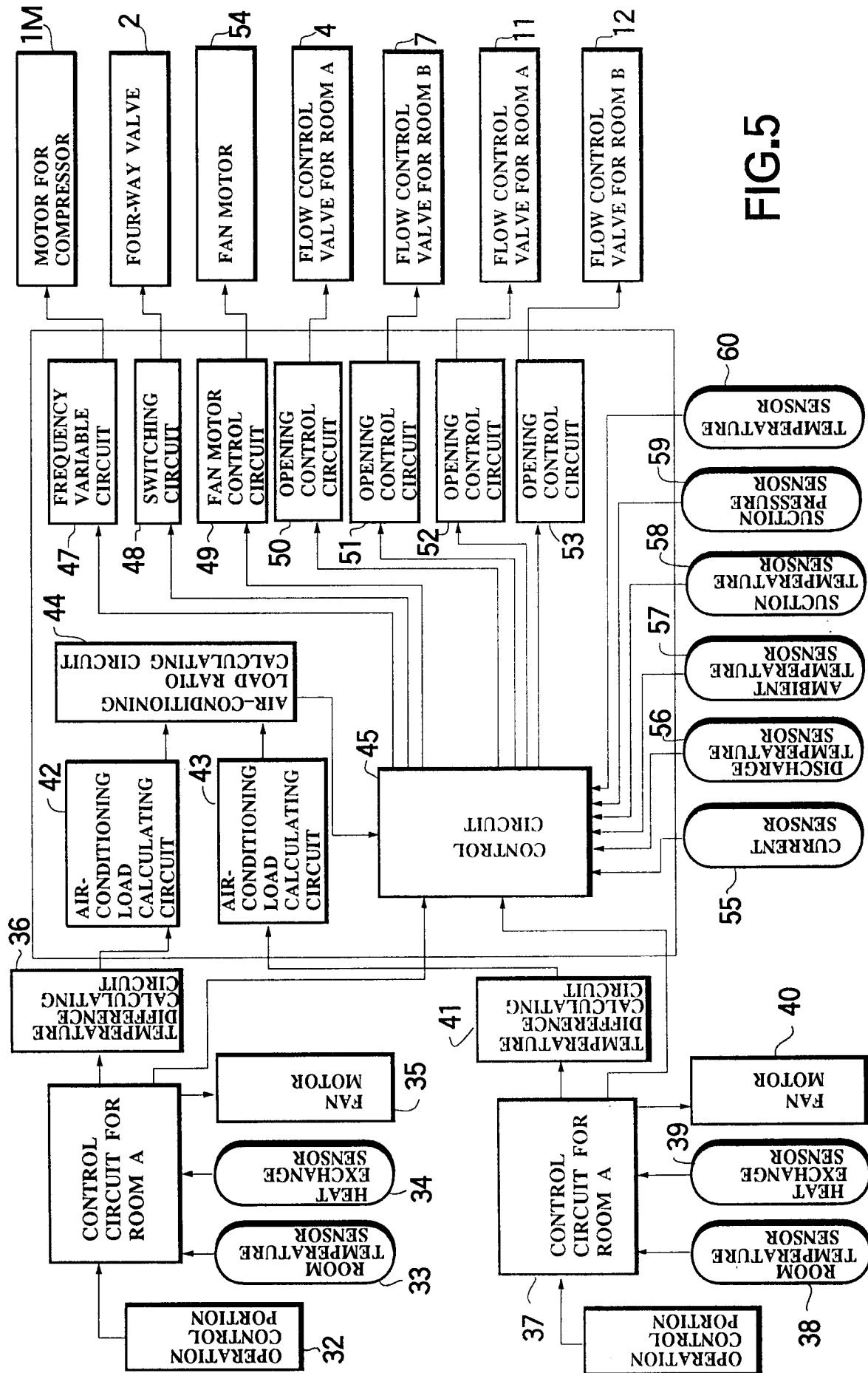
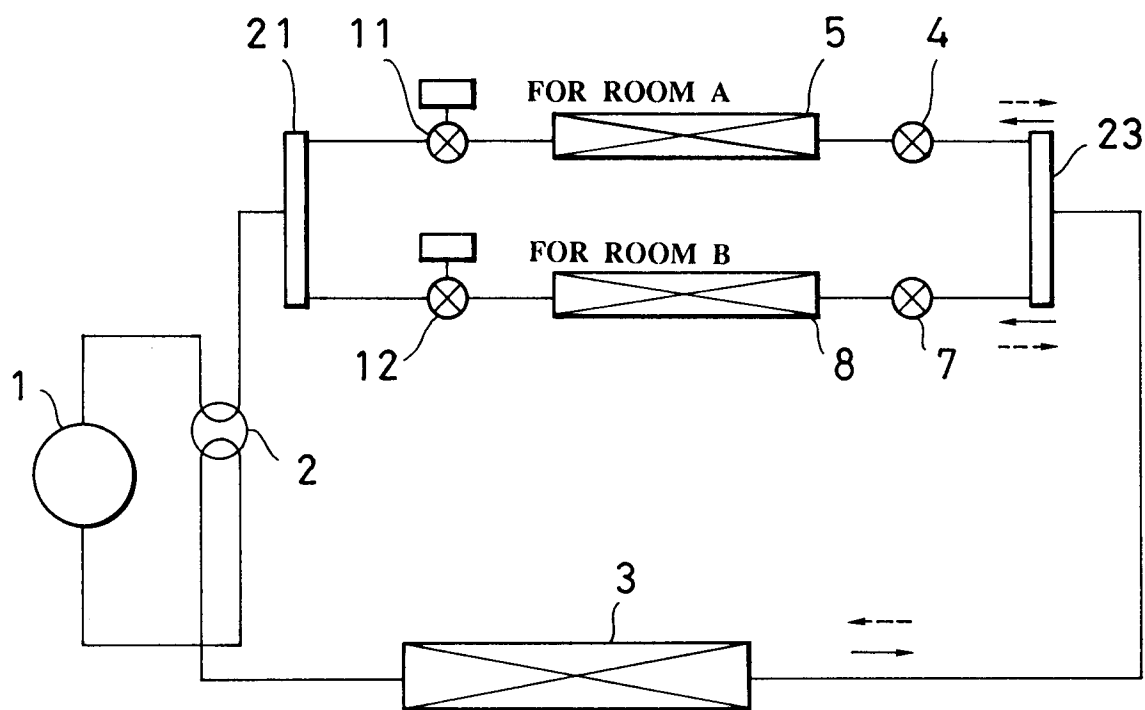


FIG.5

FIG. 6



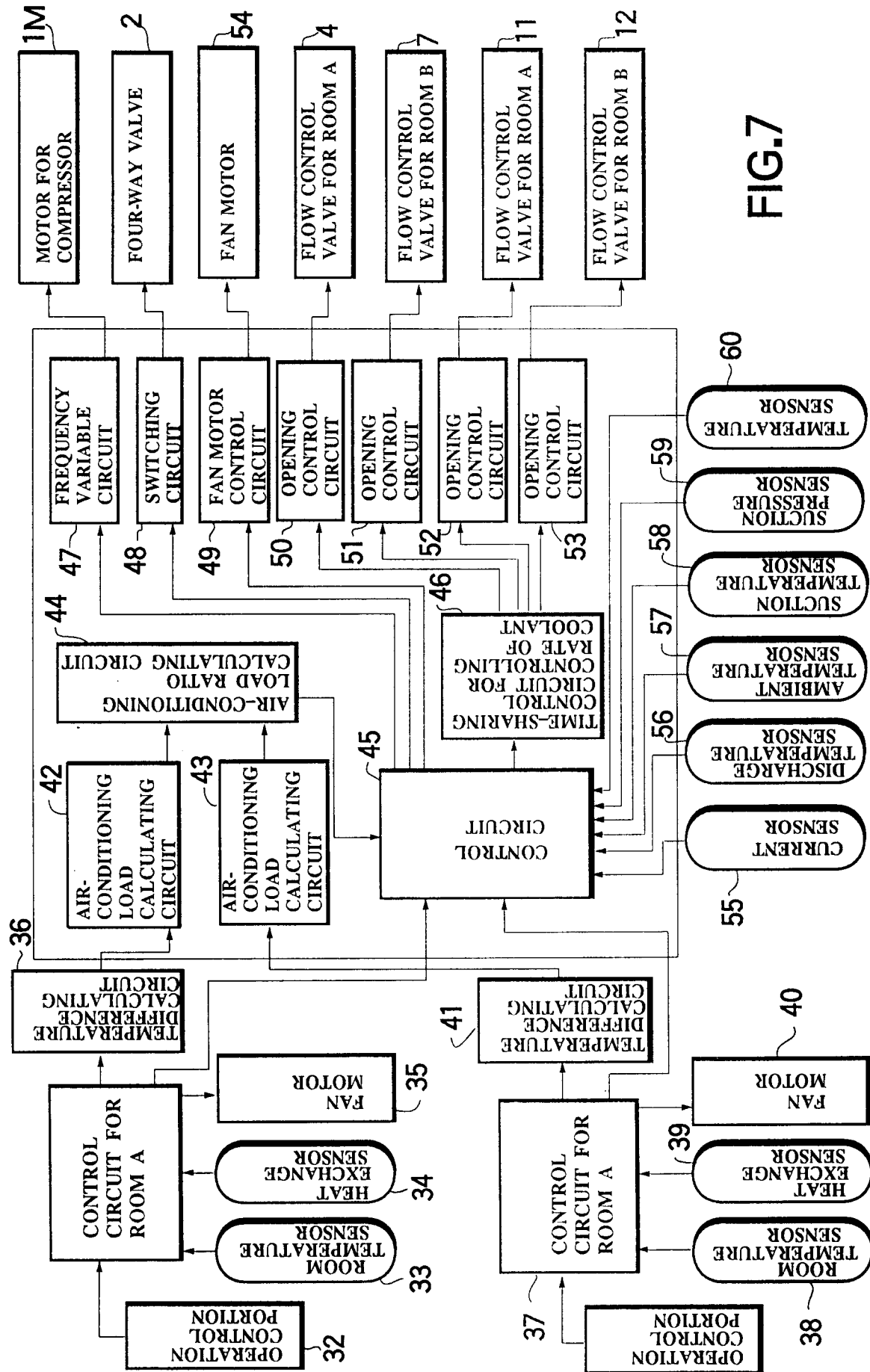


FIG. 7

FIG. 8

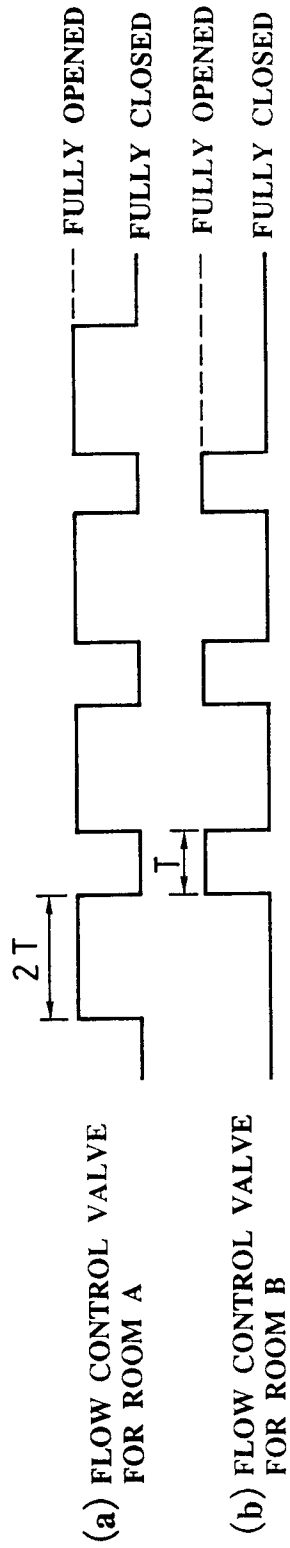


FIG. 9

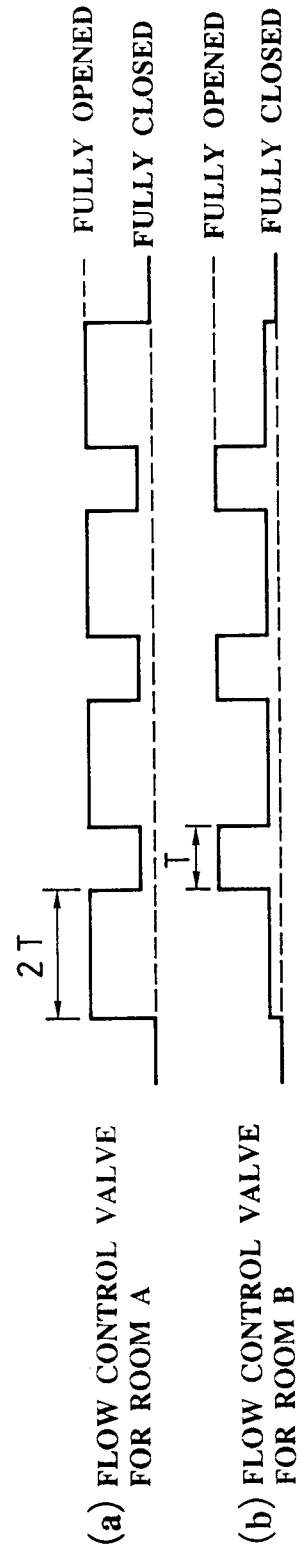


FIG. 10

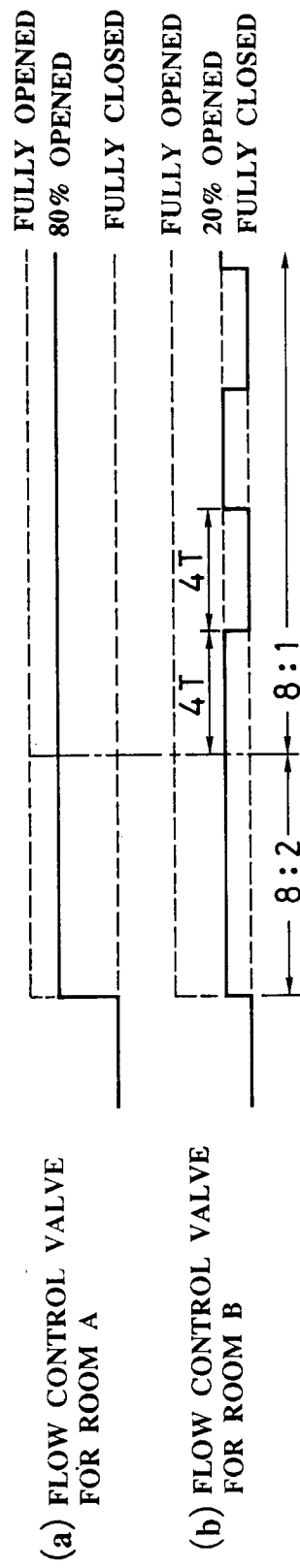


FIG. 11

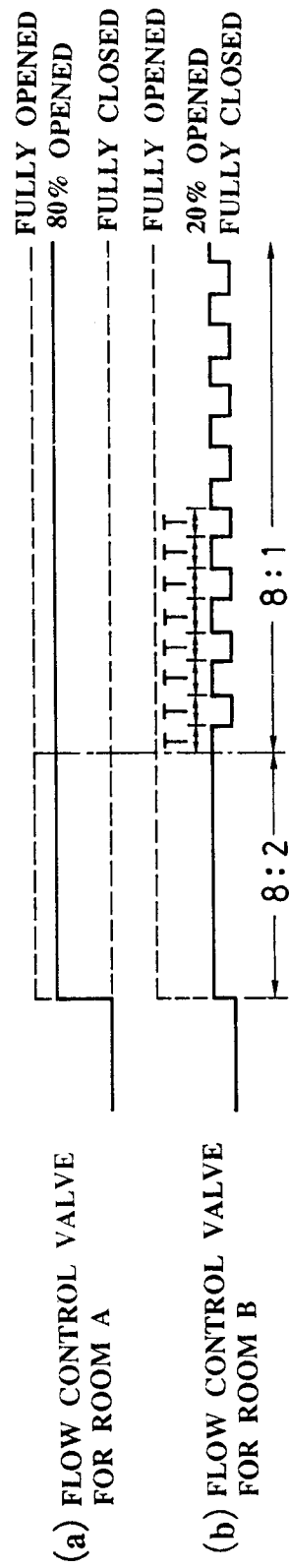


FIG. 12

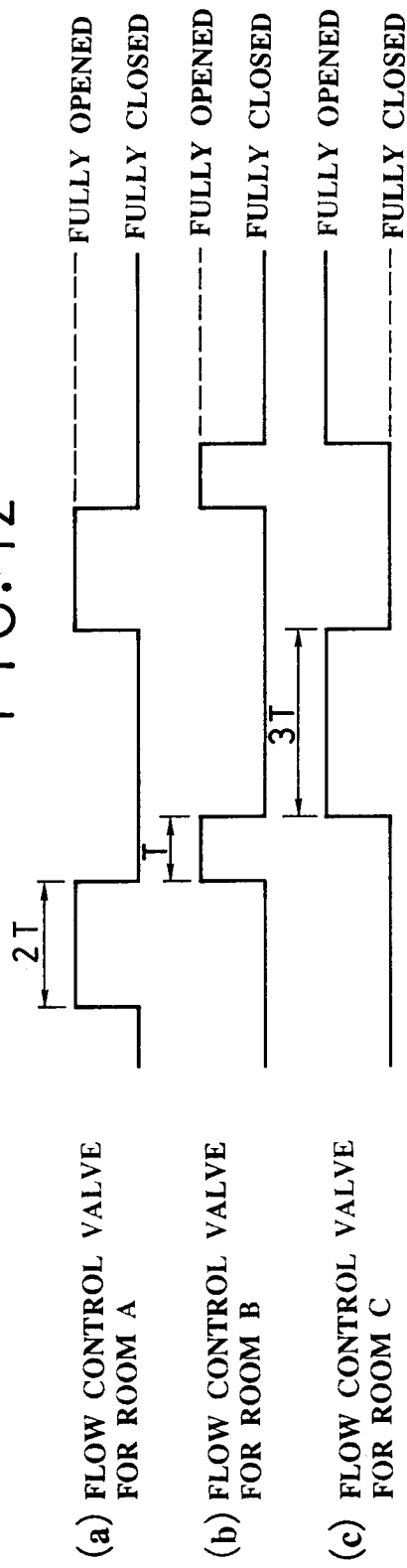


FIG. 13

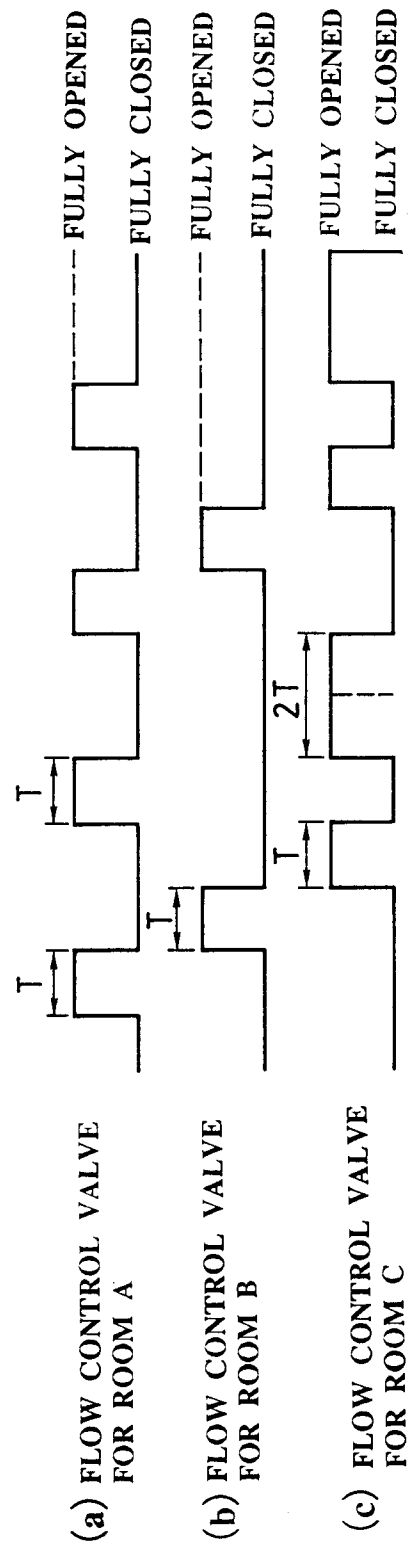


FIG. 14

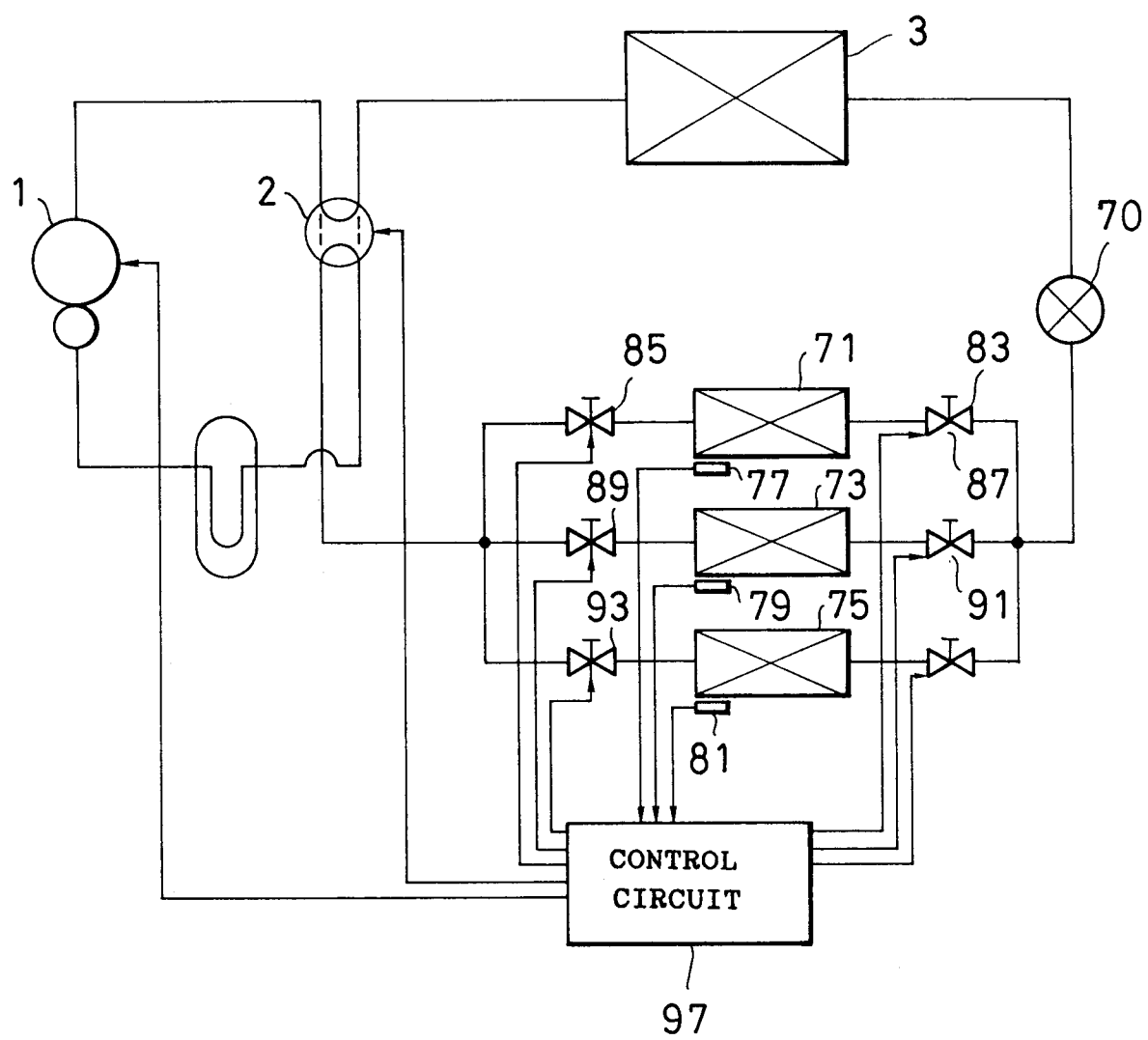


FIG. 15

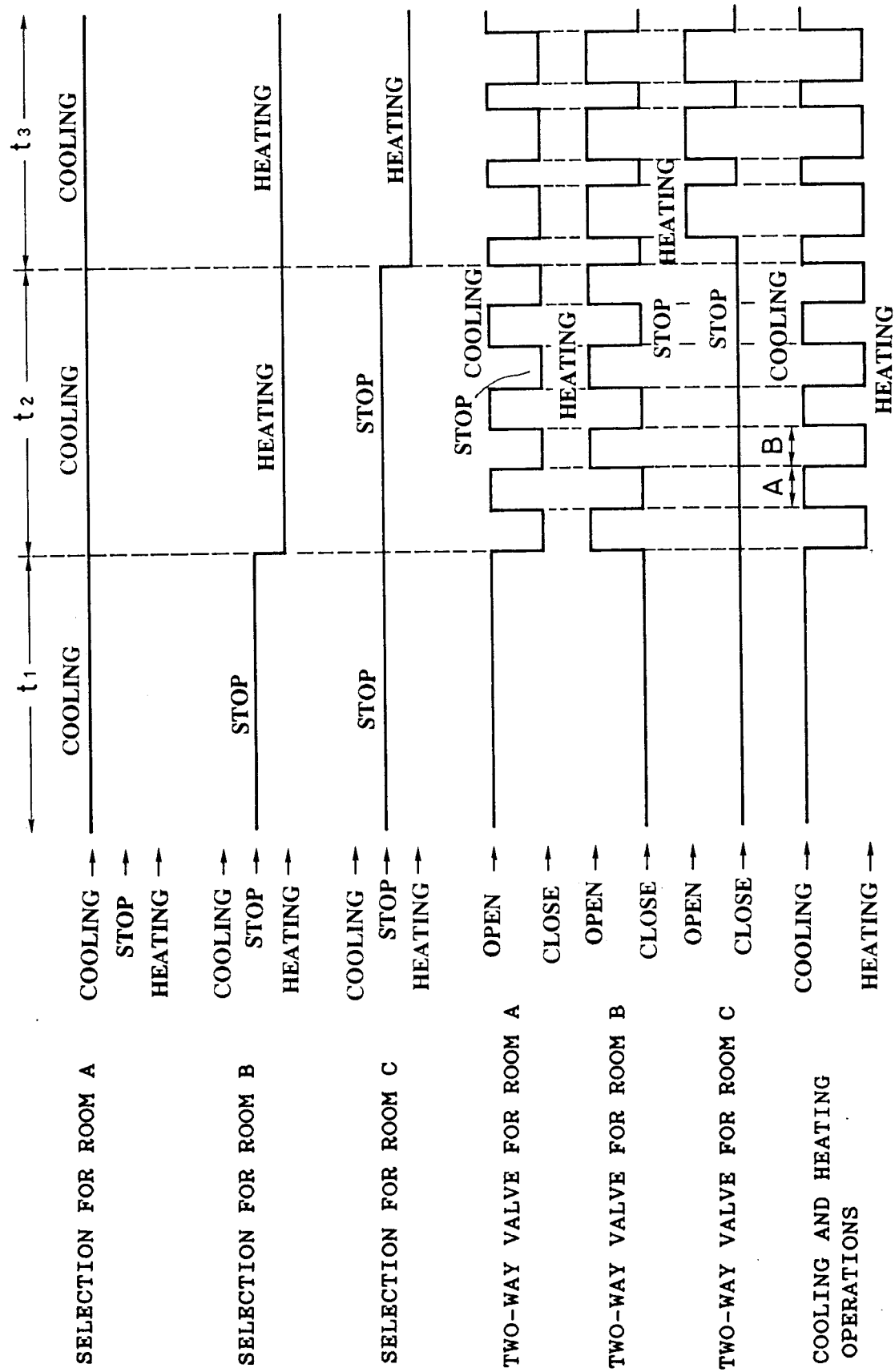


FIG.16

FIG.16A
FIG.16B

FIG.16A

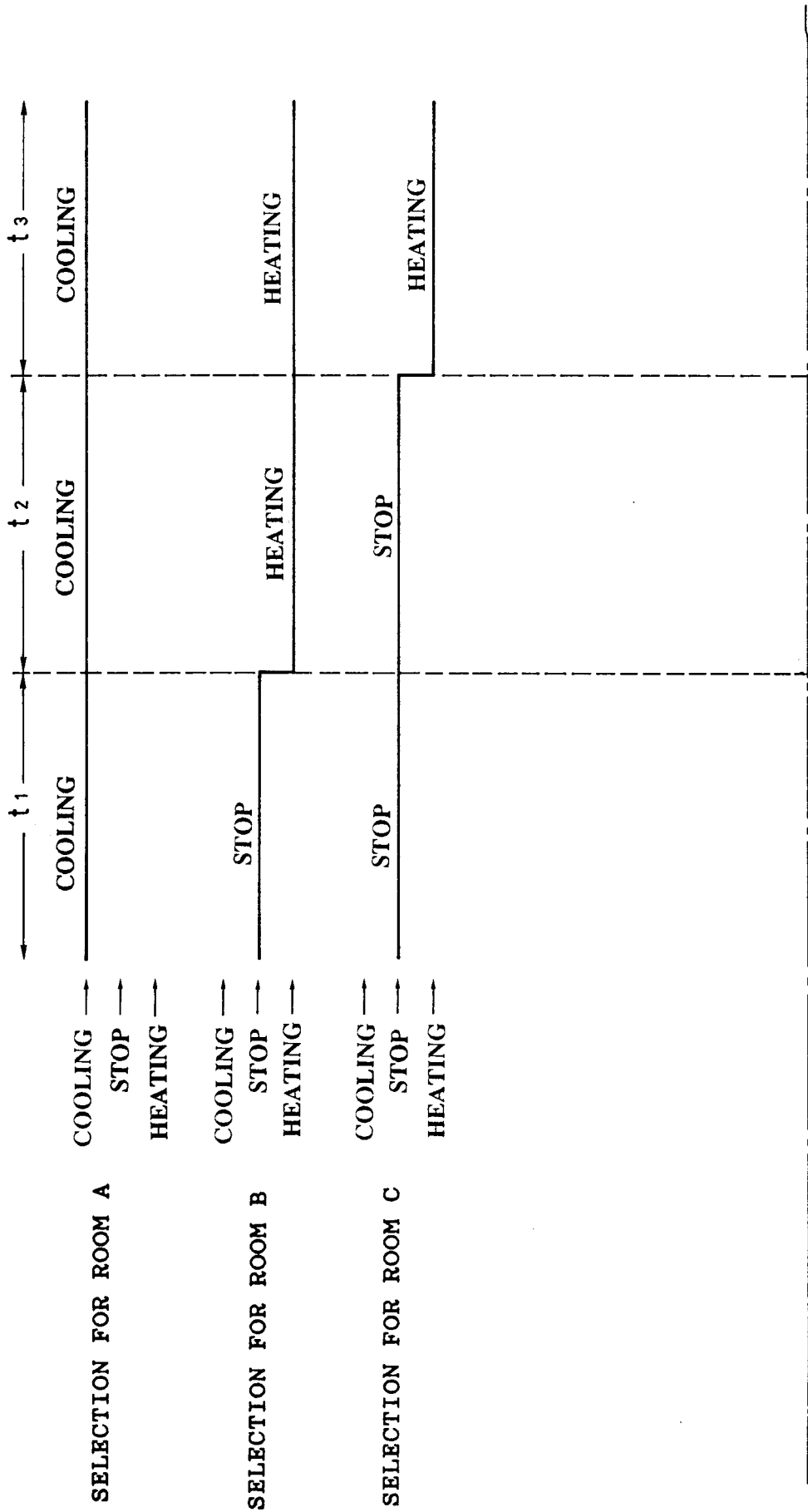


FIG. 16B

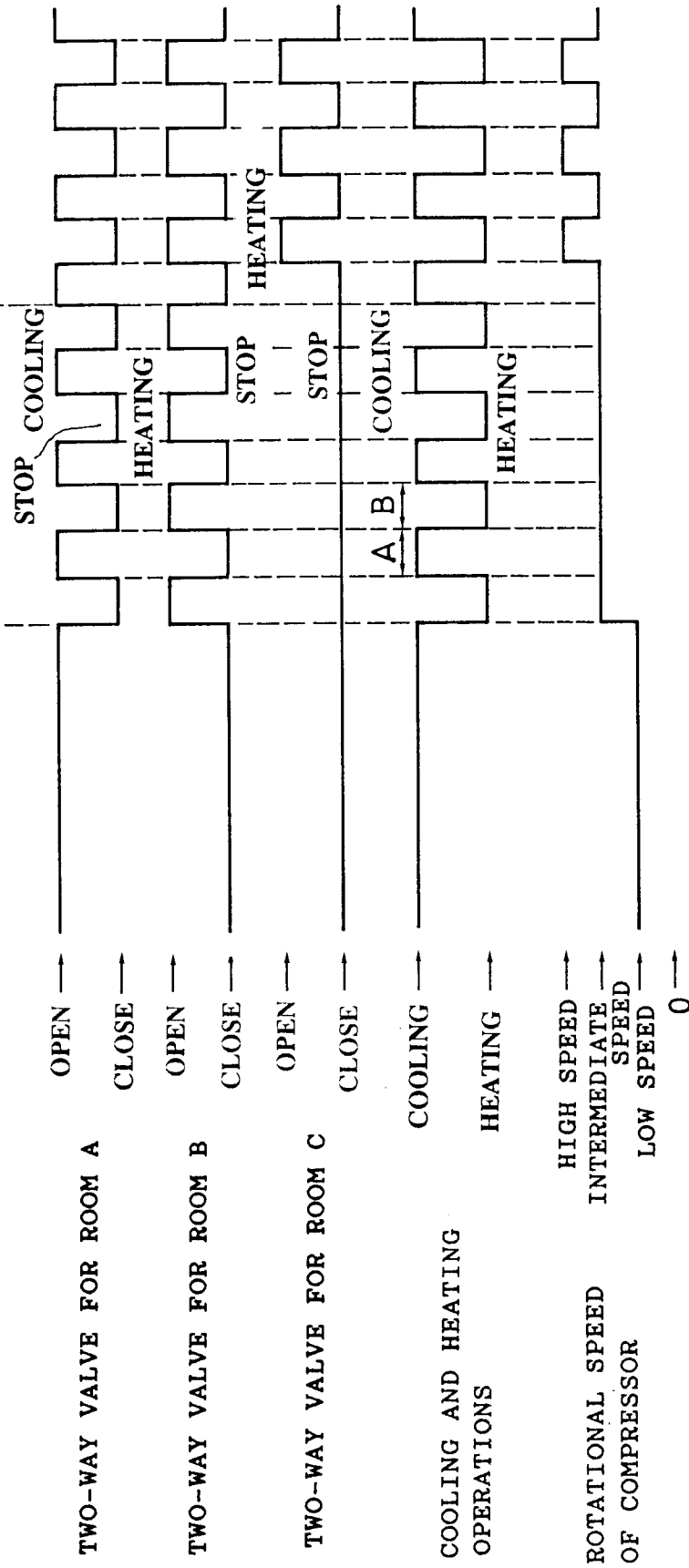


FIG.17
FIG.17A
FIG.17B

FIG. 17A

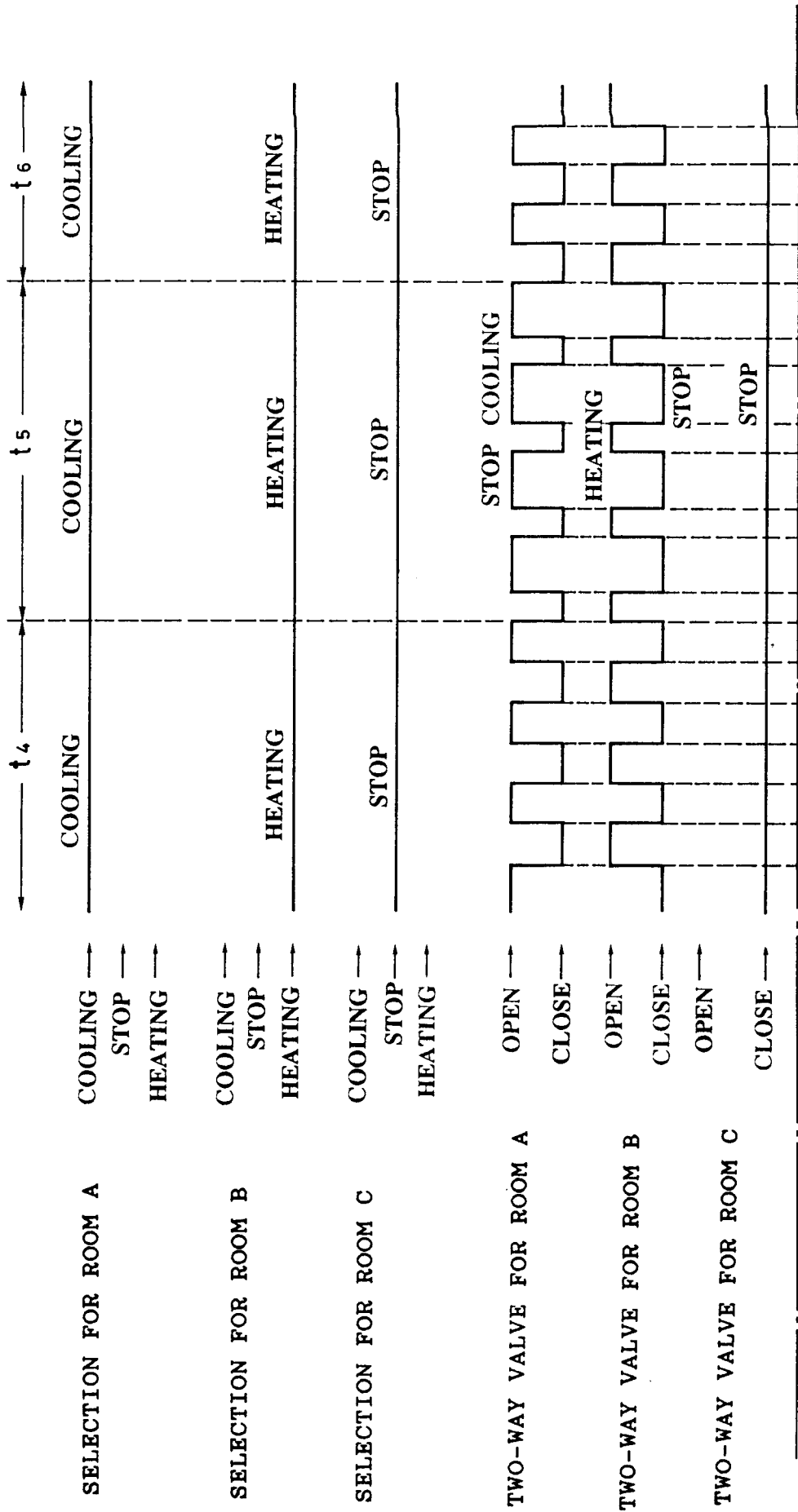


FIG. 17B

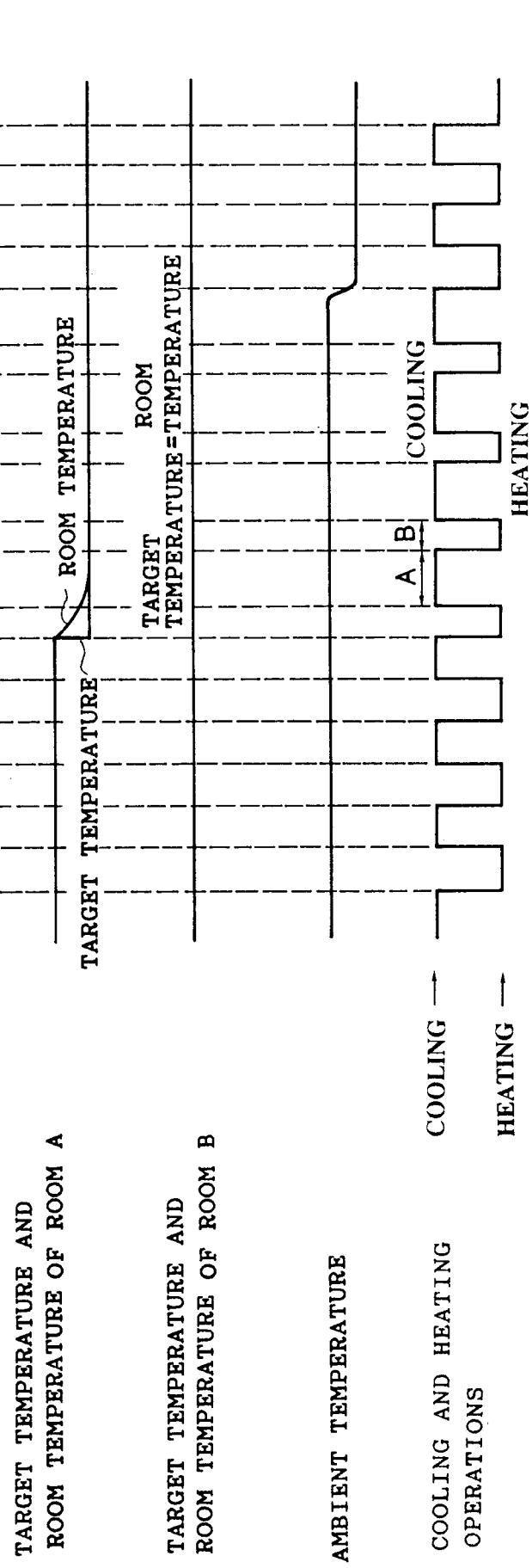


FIG. 18

AMBIENT TEMPERATURE COOLED ROOMS : HEATED ROOMS	BELOW 0°C	0~10°C	10~20°C	20~30°C	OVER 30°C
3:0 (INCLUDING 0:1 AND 0:2)	4:0 [*]	4:0	4:0	4:0	4:0
2:1	4:4	4:3	4:2	4:1	4:1
1:1 (ONE ROOM IS NOT AIR-CONDITIONED)	2:4	3:4	4:4	4:3	4:2
1:2	1:4	1:4	2:4	3:4	4:4
0:3 (INCLUDING 0:1 AND 0:2)	0:4	0:4	0:4	0:4	0:4

* TIME RATIO OF COOLING OPERATION TO
HEATING OPERATION

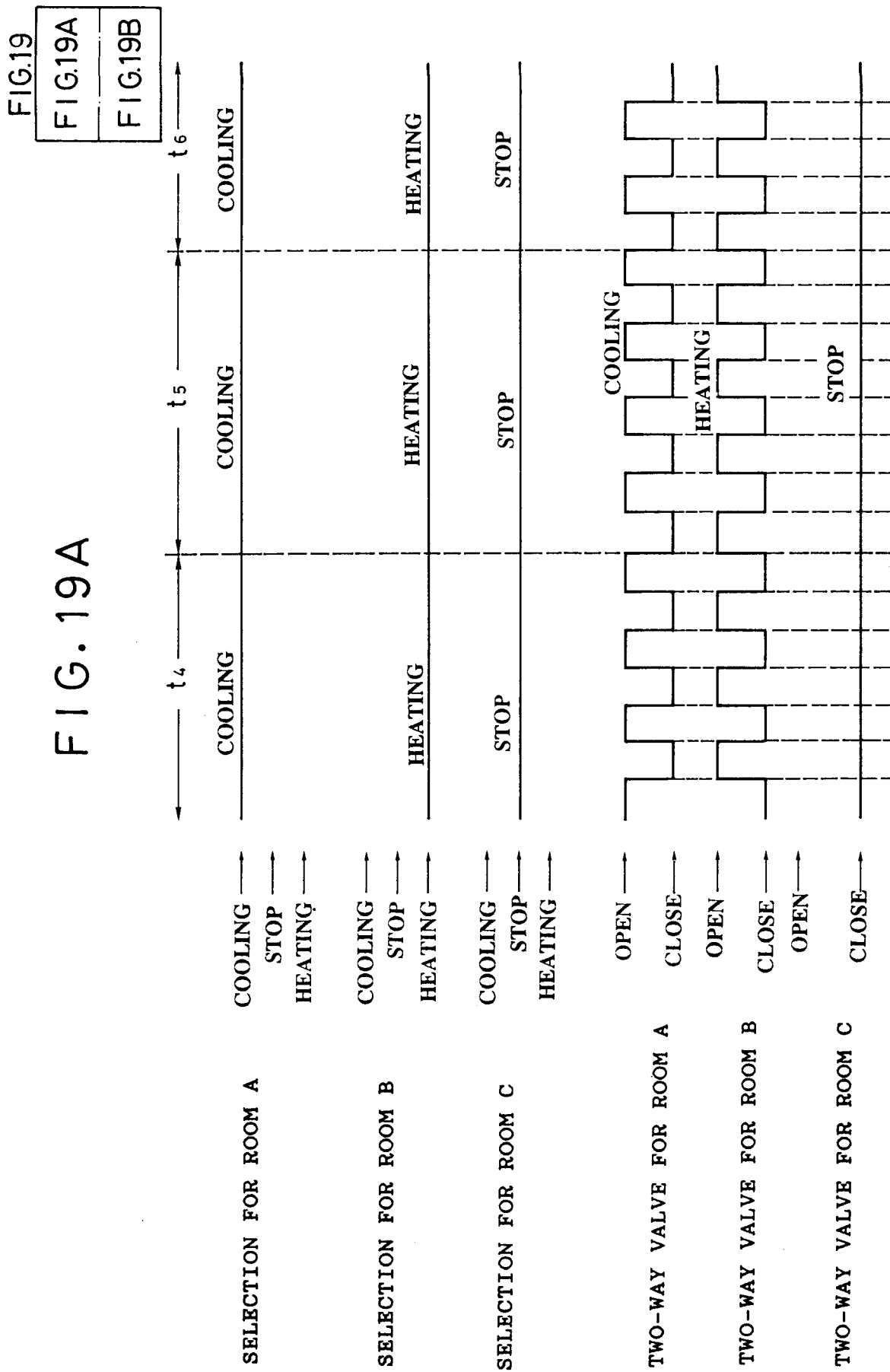
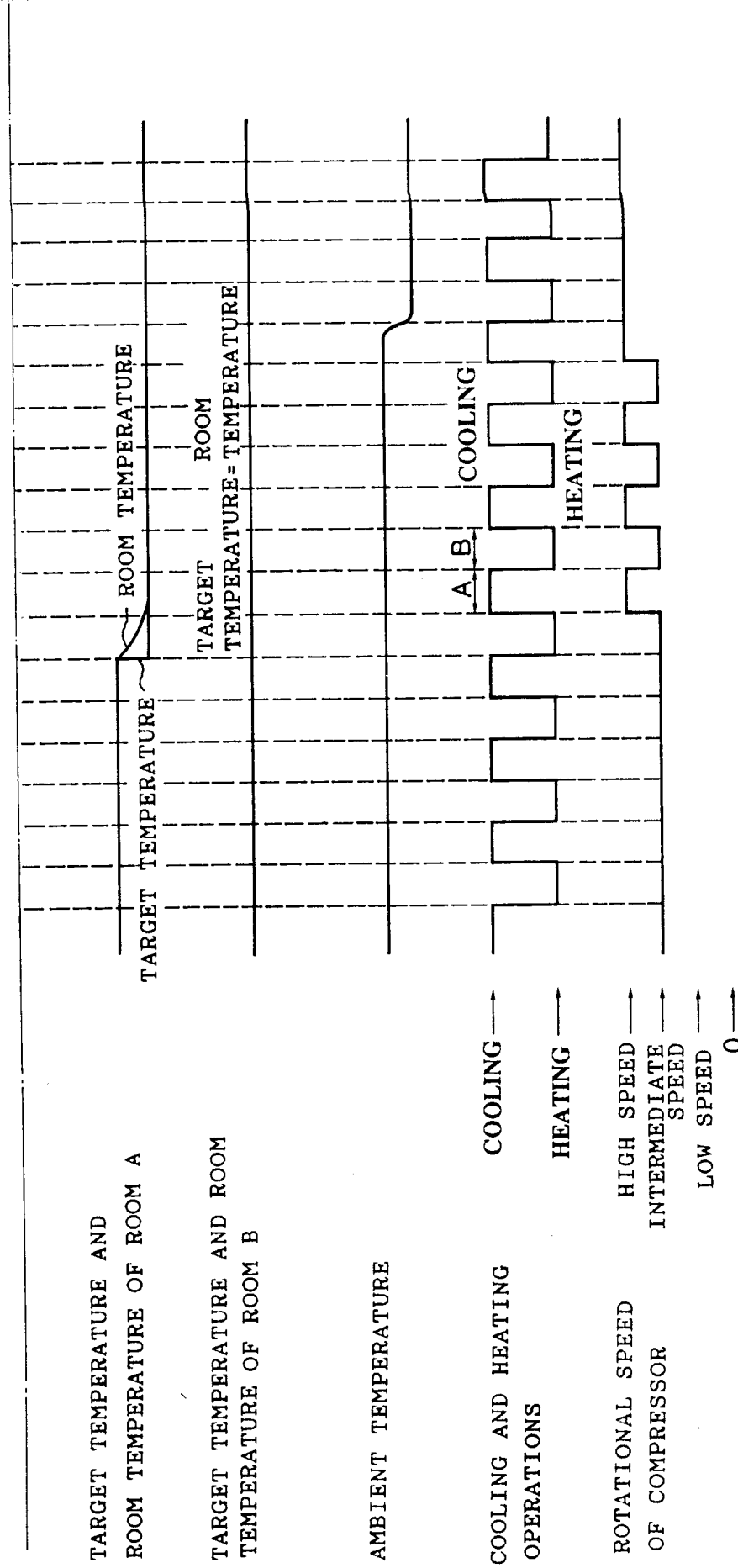


FIG. 19B





European
Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 11 8140

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	PATENT ABSTRACTS OF JAPAN vol. 4, no. 99 (M-21)(581) 16 July 1980 & JP-A-55 056 549 (MATSUSHITA DENKI SANGYO) 25 April 1980 * abstract ** -- --	1,2,7-10	F 24 F 1/02
X	EP-A-0 188 630 (DAIKIN INDUSTRIES LIMITED) * the whole document ** -- --	1-3,9,10	
X	GB-A-2 217 826 (MATSUSHITA ELECTRIC INDUSTRIAL CO LTD) * claim 1 ** -- -- -- --	1,2,9,10	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F 24 F
Place of search		Date of completion of search	Examiner
Berlin		12 February 92	PIEPER C
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone		E : earlier patent document, but published on, or after the filing date	
Y : particularly relevant if combined with another document of the same category		D : document cited in the application	
A : technological background		L : document cited for other reasons	
O : non-written disclosure		-----	
P : intermediate document		& : member of the same patent family, corresponding document	
T : theory or principle underlying the invention			