

AN AIR CONDITIONING SYSTEM

The present invention relates to an air conditioning system and more particularly to a control apparatus thereof having motorized valves designed so that the system is able to serve a plurality of rooms simultaneously.

A type of control apparatus for an air conditioning system designed to control the circulation of refrigerant to indoor units by motorized valves installed in the refrigerant circuit of an outdoor unit is described in Japanese Laid-open Patent Publication No. 127055/1983. The control apparatus of said air conditioning system is designed so that the saturation temperature of suction gaseous refrigerant and the temperature of suction gaseous refrigerant are detected by temperature sensors to detect the quantity of superheat, and the detected signals are fed back to control the opening of motorized valves and adapt the cooling capacities of indoor units to variation of load and difference of pipe length.

However, such a conventional control apparatus is disadvantageous in that its production cost is relatively high because it requires a complicated control circuit to enable the feed back control with PID (proportional integral and differential) control action, for example, and a refrigerant circuit with a temperature sensor.

According to the present invention there is provided an air conditioning system comprising an outdoor unit which has a compressor, a condenser to receive refrigerant transferred from said compressor,

a liquid refrigerant pipe which is connected to said condenser at one end thereof and is divided into a plurality of branch pipes at the other end thereof, and a motorized valve being disposed in each of the
5 branch pipes, the motorized valves controlling a quantity of refrigerant flowing in said branch pipes;

a plurality of indoor units which have respective evaporators, and which are connected to individual branch pipes through connection pipes;

10 operation request signal output means for outputting an operation request signal indicating which of the indoor units is required to operate;

counting means for counting the number of the indoor units required to operate in accordance
15 with the request signal from said operation request signal output means;

valve-opening control means provided with a table which stores valve opening data for each of the motorized valves, the degree of opening of each
20 valve depending on the number of indoor units required to operate in such a manner that valve openings decrease in steps as the number of indoor units required to operate increases, and the valve openings increase in steps as the number of indoor
25 units required to operate decreases, the valve-opening^(control) means being responsive to the operation request signal and the count in the counting means, said valve-opening control means outputting a signal representative of the degree of valve opening; and
30 drive circuit means for driving said

motorized valves for the indoor units required to
operate in response to the valve opening signal and
for controlling the motorized valves corresponding to
5 the indicated indoor units to open to the degree
decided by the valve-opening control means.

By way of example, an embodiment of the
invention will now be described with reference to the
10 accompanying drawings, in which:

Fig. 1a is a schematic view of an air
conditioning system according to an embodiment of the
invention;

15 Fig. 1b is a schematic view of an indoor unit;

Fig. 2 is a block diagram of a control apparatus
of the system;

Fig. 3 is a graph to explain the opening of
motorized valves;

20 Figs 4a and 4b are flow charts of the control
apparatus;

Fig. 5 is a diagram explaining the operation of
motorized valves.

25 In the refrigerant circuit of outdoor unit F in
Fig. 1a, a discharge outlet of compressor 1 is
connected to a condenser 3. A filter 4, a stop valve
5 and a filter 6 are installed in a liquid
refrigerant piping 2 that extends from said condenser
3. The refrigerant piping 2 is divided into a
30 plurality of branch pipes 7a, 7b, 7c, 7d and 7e
corresponding to the indoor units A, B, C, D and E
connected respectively to connecting ports 9a, 9b,
9c, 9d and 9e. Each of these branch pipes 7a, 7b,
35 7c, 7d and 7e has a respective motorized valve 8a,
8b, 8c, 8d or 8e installed thereon. Each motorized

valve 8a, 8b, 8c, 8d or 8e is operated by, for example, a stepping motor. Accumulators 11 and 12 and a stop valve 13 are installed in a gaseous refrigerant pipe 10 connected to the suction inlet of the compressor 1. The gaseous refrigerant pipe 10 is divided into a plurality of branch pipes 14a, 14b, 14c, 14d and 14e in order to be connected respectively to connecting ports 15a, 15b, 15c, 15d and 15e. The inlet of condenser 3 of the liquid refrigerant pipe 2 and the inlet of accumulator 12 of gaseous refrigerant pipe 10 are connected by a bypass pipe 16 with a low pressure regulating valve 17 installed in the middle of said bypass pipe. The connecting ports 9a, 9b, 9c, 9d and 9e on the side of said liquid refrigerant pipe 2 and the connecting ports 15a, 15b, 15c, 15d and 15e on the side of said gaseous refrigerant pipe 10 are connected to each other through indoor units A, B, C, D and E. As shown in Fig. 1b, said indoor unit A is provided with an evaporator 41 and a fan 42. Said indoor units B, C, D

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and E have the same construction as that of the indoor unit A.

The construction of a control apparatus to control the opening of said motorized valves 8a, 8b, 8c, 8d and 8e will be explained with reference to Fig. 2. The opening for each of said motorized valves 8a, 8b, 8c, 8d and 8e is controlled respectively by a drive circuit 21 that is operated by a valve signal V to determine the motorized valve to be actuated and an opening signal S to determine the opening of each of the motorized valves which are outputted from a microcomputer 20. Said microcomputer 20 is designed to receive not only the input of operation request signals a, b, c, d and e which are to determine the units to be operated out of indoor units A, B, C, D and E and outputted from indoor thermostats 22a, 22b, 22c, 22d and 22e as operation request signal output means but also the setting signals set by selection switches SWa, SWb, SWc, SWd and SWe which are provided corresponding to indoor units A, B, C, D and E. The selection switches SWa, SWb, SWc, SWd and SWe are scanned by the microcomputer 20. In this embodiment, the operating conditions of air conditioning system are determined by said thermostats i.e. sensors 22a, 22b, 22c, 22d and 22e and selection switches SWa, SWb, SWc, SWd and SWe. Said selection switches SWa, SWb, SWc, SWd and SWe include capacity setting means and pipe-length setting means and are designed so

that they can be used for selecting and setting of the combinations of the capacities of the indoor units A, B, C, D and E and the lengths of pipes reaching to said indoor units A, B, C, D and E by selecting desired contact points out of their contact points after the air conditioning system is installed. For example, where the air conditioning system is capable of operating at any of three different capacities such as 2200 kcal/h, 3500 kcal/h and 4500 kcal/h and the pipes of more than 15 m and less than 15 m are available, each of said selection switches is designed to select the combination of the operating capacity and pipe length. Such combination can be selected at the time of the installation of indoor units A, B, C, D and E. In this case, there are six selectable combinations. In the case shown in Fig. 2, however, there are eight selectable combinations, since there are three input terminals.

The microcomputer 20 stores the data A (j, k) concerning the opening of motorized valves corresponding to combinations of number of indoor units in operation, capacities of indoor units and pipe lengths as shown in the following table. That is, said microcomputer stores the data listed in the following table and includes an opening control means for setting the openings of the motorized valves according to the data of the table. Said microcomputer also includes a counting means for counting the number of indoor units which are required to be operated

according to the outputs from the sensors 22a, 22b, 22c, 22d and 22e.

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Table 1

Capacity of indoor unit	Piping length	Number of indoor units required operation (j)				
		1	2	3	4	5
Small	Short	A(1.0)	A(2.0)	A(3.0)	A(4.0)	A(5.0)
	Long	A(1.1)	A(2.1)	A(3.1)	A(4.1)	A(5.1)
Medium	Short	A(1.2)	A(2.2)	A(3.2)	A(4.2)	A(5.2)
	Long	A(1.3)	A(2.3)	A(3.3)	A(4.3)	A(5.3)
Large	Short	A(1.4)	A(2.4)	A(3.4)	A(4.4)	A(5.4)
	Long	A(1.5)	A(2.5)	A(3.5)	A(4.5)	A(5.5)

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The opening control means for motorized valves is designed so that the opening of motorized valves 8a, 8b, 8c, 8d and 8e can respectively be controlled to the predetermined opening A (j, k) by steps, according to the number of indoor units in operation detected by the inputs a, b, c, d, e from said sensors 22a, 22b, 22c, 22d and 22e, the capacities of indoor units A, B, C, D and E and the lengths of pipes reaching said indoor units respectively which are detected by the input signals from said selection switches SWa, SWb, SWc, SWd and SWe.

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The opening data A (j, k) generally shows the tendencies as shown in Fig. 3. That is, as the number of

indoor units in operation increases, the circulation quantity of refrigerant per an indoor unit decreases; as the capacity of an indoor unit becomes large, the circulation quantity of refrigerant required
5 increases; and the greater the length of pipe, the larger the required opening of motorized valve because of the fluid friction. Therefore, the opening KD (i) needs to be set to a relatively large value where the number of indoor units in operation
10 is small, the capacity of indoor units in operation is relatively large, and the length of pipe is relatively great, whereas the opening KD (i) is set to a relatively small value in the reverse case.

15 Next, the operation of the control apparatus will be explained with reference to Fig. 4a and 4b. When all the indoor units A, B, C, D and E stop, and the operation request signal is absent, the compressor 1 is in an off-state and motorized valves
20 8a, 8b, 8c, 8d and 8e are fully opened. In this condition, when the operation request signal is outputted from any one of the indoor units, scan output will be generated from the microcomputer 20 at step S₁ so that the data concerning the capacity of
25 each indoor unit and pipe length will be read through switches SWa, SWb, SWc, SWd and SWe. Next, at step S₂, the data concerning the number of indoor units to be operated will be read through sensors 22a, 22b, 22c, 22d and 22e. Then, in order to discriminate if
30 any one of the indoor units is in operation, it will be determined whether the number N_p of indoor units required for operation was 0 or not. This operation is judged at step S₃, and, when it is judged that the number N_p has been 0, the program proceeds to
35 step S₄ and the previously set opening KD (i) = A₀ in order to fully close the motorized valves 8a, 8b,

8c, 8d and 8e once or to zero the settings of all the motorized valves 8a, 8b, 8c, 8d and 8e. On the other hand, when the judgement at step S₃ is NO because anyone of the indoor units is in operation, whether the number N_c of indoor units in operation is equal to that N_p of the indoor units for which the operation has been requested previously or not is judged at step S₅. When the result of this judgement is NO because some of the indoor units are in operation, and the number N_c of the indoor units in operation is not equal to that N_p at the time of the previous operation, the program proceeds to step S₆ in order to judge if the operations of all the indoor units are to be stopped or not at this stage, whether the number N_c of indoor units which are in operation at this stage is zero or not is judged. When the result of this judgement is YES because all the indoor units are stopped, the program proceeds to step S₇ and the openings KD (i) of the motorized valves 8a, 8b, 8c, 8d and 8e for all the rooms are set as KD (i) = A₁ or the fully opened position. Following said judgement and processing, at step S₈, the data KD (i) =

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A (j, k) concerning the opening of the motorized valves 8a, 8b, 8c, 8d and 8e as are set in said Table 1, according to the data of the capacities, pipe lengths and the number of driven indoor units are read for indoor units A, B, C, D and E respectively. Then, at step S_9 , $D(i) = KD(i) - KD'(i)$, the difference between the opening data $KD(i)$ and previously set opening data $KD'(i)$ is calculated. Then, the program proceeds to step S_{10} as shown in Fig. 4b and the pulse signals corresponding to the opening to be varied for various indoor units according to this data $D(i)$ are outputted sequentially to motorized valves 8a, 8b, 8c, 8d and 8e from a drive circuit 21 and the opening of these valves is adjusted to the necessary degree. Then, the program proceeds to step S_{11} in order to judge if the number of indoor units for which the operation requests have been made is zero or not, and, when said number is zero, the program returns to step S_2 to read the data concerning the number of indoor units required for operation, and this processing will be repeated thereafter.

On the other hand, when the number of indoor units required for operation is found not to be zero at step S_{11} , the program proceeds to step S_{12} to judge if the settings of the opening for the indoor units required for operation are completed or not. When said settings are found not to have been completed at step S_{12} , the program returns to step S_2 . When the settings for the openings for the indoor units

required for operation are found to have been completed at Step S_{12} , the program proceeds to step S_{13} . At step S_{13} , the microcomputer 20 outputs the signal for driving the compressor 1 to a relay 31 and also outputs the signal for driving an outdoor fan of outdoor unit F not shown in the drawing. Then, the program returns to step S_2 .

The aforementioned processes will be explained in detail with reference to Fig. 5. When only indoor unit A is turned on while all other indoor units are stopped, all motorized valves 8a, 8b, 8c, 8d and 8e which have been in a fully opened state will be fully closed. After all the motorized valves 8a, 8b, 8c, 8d and 8e are fully closed, only the motorized valve 8a corresponding to the indoor unit A will be opened to the set opening in the case where "Number of indoor units required operation = 1" while the other motorized valves 8b, 8c, 8d and 8e are kept fully closed. In this case, in order to prevent the erroneous operation of the valve owing to the noise from the compressor 1, said compressor 1 is driven on after the opening of motorized valve 8a corresponding to the indoor unit A is completed. When the number of indoor units required for operation has become two, for example, as indoor unit C is turned on while the indoor unit A is on, the opening of motorized valve 8a is altered to the set opening in the case where "Number of indoor units required operation = 2", and then the opening of motorized valve 8c

corresponding to the indoor unit C will also be set to that applicable to the case where the number of indoor units required operation = 2. Furthermore, when the indoor unit E is turned on, the opening of the motorized valves 8a and 8c corresponding to indoor units A and C will sequentially be set to those applicable to the case where the number of indoor units in operation = 3, and then the opening of motorized valve 8e corresponding to the indoor unit E will also be set to that applicable to the case where the number of indoor units in operation = 3. When indoor units A and C are turned off later, the motorized valves 8a and 8c corresponding to these indoor units A and C will be fully closed sequentially, and then the opening of motorized valve 8e corresponding to the indoor unit E will also be altered to that applicable to the case where the number of indoor unit in operation = 1. When the operations of all indoor units are stopped, the compressor 1 is turned off, and all the motorized valves 8a, 8b, 8c, 8d and 8e will be fully opened sequentially.

Therefore, in this embodiment, the opening of motorized valves 8a, 8b, 8c, 8d and 8e are controlled by steps according to the number of indoor units A, B, C, D and E of the air conditioning system in operation, the capacities of indoor units A, B, C, D and E and the lengths of the pipes so that a complicated control system such as a feedback control with PID control action is not required. Thus, the control system

can be simplified, and the optimum distribution of refrigerant to the indoor units is set quickly and this helps the operations in a plurality of indoor units to be stabilized quickly. The control system being simple, the control circuit is also quite simple. Moreover the control system does not require the refrigerant circuit with temperature sensors. Thus, the control apparatus according to this embodiment can be compactly designed and produced at low cost.

Furthermore, in said embodiment, the operating condition of the air conditioning system is judged according to the number of indoor units required for operation, the capacities of the indoor units and the pipe lengths, but it is also possible to judge the operating condition of the air conditioning system according to any one of them.

As explained in the foregoing, according to the present invention, the opening of motorized valves corresponding to indoor units can be controlled respectively to the predetermined degree according to the number of indoor units to be operated, so that the present control apparatus can dispense with the complicated control system such as a feedback control with PID control action. Therefore, the control apparatus cannot only be extremely simplified because of the simple control but also the refrigerant circuit with temperature sensor is not required. As a result, the system according

to the present invention features a compactness and low production cost.

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CLAIMS:

1. An air conditioning system comprising an
5 outdoor unit which has a compressor, a condenser to
receive refrigerant transferred from said compressor,
a liquid refrigerant pipe which is connected to said
condenser at one end thereof and is divided into a
10 plurality of branch pipes at the other end thereof,
and a motorized valve being disposed in each of the
branch pipes, the motorized valves controlling a
quantity of refrigerant flowing in said branch pipes;
a plurality of indoor units which have
respective evaporators, and which are connected to
15 individual branch pipes through connection pipes;
operation request signal output means for
outputting an operation request signal indicating
which of the indoor units is required to operate;
counting means for counting the number of
20 the indoor units required to operate in accordance
with the request signal from said operation request
signal output means;
valve-opening control means provided with
a table which stores valve opening data for each of
25 the motorized valves, the degrees of opening of each
valve depending on the number of indoor units
required to operate in such a manner that valve
openings decrease in steps as the number of indoor
units required to operate increases and the valve
30 openings increase in steps as the number of indoor
units required to operate decreases, the valve-
opening^{control} means



being responsive to the operation request signal and the count in the counting means, said valve-opening control means outputting a signal representative of the degree of valve opening;

drive circuit means for driving said motorized valves for the indoor units required to operate in response to the valve opening signal and for controlling the motorized valves corresponding to the indicated indoor units to open to the degree decided by the valve-opening control means.

2. An air conditioning system as claimed in Claim 1, and further comprising capacity indicating means for selecting one value out of predetermined, discrete numerical values to set a capacity for each of said indoor units and for outputting a signal indicating the capacity, wherein the table represents degrees of valve opening for each of the motorized valves, the degrees being predetermined relative to the number of said indoor units required to operate and the capacity thereof in a manner that when the capacity is constant, the valve opening decreases in steps as the number of indoor units required to operate increases, and when the valve opening increases in steps as the number of indoor units required to operate decreases and when a number of indoor units required to operate is constant, the opening of said motorized valves increases in steps as the capacity increases, and when the valve opening decreases in steps as the capacity increases;

said valve-opening control means looks up within the table the degree of valve opening corresponding to a combination of the number of indoor



units required to operate and capacity decided based on the signal output from the counting means and the signal output from the capacity indicating means with respect to each of the indoor units required to
5 operate, and outputs a signal indicative of the degree of valve opening.

3. An air conditioning system as claimed in claim 1 or claim 2 and further comprising pipe length
10 indicating means for selecting one value out of predetermined, discrete numerical values to set a pipe length of each of the connection pipes and for outputting a signal indicating the pipe length, wherein the table represents degrees of valve opening
15 for each of the motorized valves, which degrees are predetermined relative to the number of said indoor units required to operate and the pipe length of the connection pipes in a manner that when the pipe length of the connection pipe is constant, the valve
20 opening decreases in steps as the number of indoor units required to operate increases, and when the valve opening increases in steps as the number of indoor units required to operate decreases, and when the number of indoor units required to operate is
25 constant, the valve opening increases in steps as the length of the connection pipes increases in steps, and when the valve opening decreases in steps as the length of connection pipe decreases;

said valve-opening control means looks up
30 within the table the degree of valve opening for a combination of the number of indoor units required to operate and pipe length of the connection pipes decided based on the signals from the counting means and length indicating means with respect to each of
35 the indoor units required to operate, and outputs a signal indicative of the degree of valve opening.



4. An air conditioning system substantially as herein described with reference to and as shown in the accompanying drawings.

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