

AIR CONDITIONING SYSTEM

This invention relates generally to air conditioning and in particular, although not exclusively, to a condensing unit for an air conditioning system having a plurality of individually operable cooling units.

In a typical application, the condensing unit will be mounted externally of the building to be cooled and the cooling units will be provided at the various locations to be cooled, such as the rooms of a house or apartment. A system of this general type provides several advantages, the principal ones being reduced materials and operational costs resulting from the sharing of one or more compressors and condensers by the plurality of cooling units. Additionally, the use of just one outdoor unit is aesthetically preferable, simplifies maintenance and may be otherwise required because of a lack of space or due to local government regulations. However, since all the indoor units will rarely, if ever, be in use at any one time, the system requires careful control of the flow of refrigerant between the outdoor and indoor units to ensure reliable and safe operation.

The aim of the invention is thus to provide a condensing unit and an air conditioning system including the same which meet these requirements.

In one aspect, the invention provides a condensing unit for an air conditioning system having a plurality of individually controllable cooling units, the condensing unit comprising:

- a compressor arranged for receiving gas refrigerant from said cooling units;

- a condenser for condensing the gas refrigerant compressed by the compressor into liquid refrigerant;

- a plurality of fluid lines for selectively supplying the liquid refrigerant to respective ones of said cooling units;

- each fluid line having a respective first valve means for controlling the supply of liquid refrigerant to its associated cooling unit; and

- electronic logic control means, responsive to input signals received from said cooling units, for controlling the operation of each first valve means;

- wherein each said first valve means is adapted to provide open fluid communication through its associated fluid line when the first valve means is in an unenergized state.

In another aspect, the invention provides an air conditioning system comprising such a condensing unit and a plurality of cooling units coupled to the condensing unit.

According to the invention, in the event that the power supply to the system is interrupted, the refrigerant path remains open, by virtue of the first valve means, to permit pressure equalization before the system is restarted. The power may have been interrupted by the user switching off the system at the mains, or as the result of a power cut. In a preferred embodiment, each first valve means is a normally-open solenoid valve. It is thus possible to use a relatively cheap and readily available component.

Conventional air-conditioning systems which use normally-closed solenoid valves in the liquid lines to the indoor units trap the refrigerant when the system is not operating. As a result, the compressor has to work against a high head pressure upon start-up. This tends to reduce the life of the compressor motor. The condensing unit of the invention overcomes this problem in a simple yet highly effective way, and without additional cost.

Furthermore, according to the invention, an electronic logic control means provides for efficient and central control of all the electrical items of the system, the valves, compressors and fans, from a single circuit board. This feature offers scope for cost savings and miniaturisation, as well as improved reliability when compared with a prior art control consisting of

electromechanical components. As a highly preferred feature, the circuit board supplies electrical power directly to the components being controlled, including the indoor unit fans, thereby minimizing the required wiring and achieving further cost reduction.

In a preferred embodiment, the or each compressor is fitted with a means for changing its effective capacity. If the number of cooling units in use at any time is too low for adequate loading of the compressor, liquid refrigerant may not be fully evaporated in the fan coil, resulting in liquid entering the compressor and causing damage. In extreme cases, freezing of the fan coil may occur. This problem is overcome by feeding a portion of the hot gas output by the compressor to the input thereof when the number of indoor units in operation is low, for example only one. This hot gas feedback device preferably includes a normally-closed solenoid valve, another relatively cheap and readily available component.

Other aspects, features and advantages of the invention will become apparent from the following detailed description of a preferred embodiment, given by way of example only, with reference to the accompanying drawings, in which :

Figure 1 is a refrigerant circuit diagram of an air conditioning system;

Figure 2 is an electrical circuit diagram for the air conditioning system;

Figure 3 is functional block diagram of the electronic control;

Figure 4 is a diagram showing the inputs and outputs of a control logic; and

Figure 5 is a logic table.

Referring to the drawings, Figure 1 shows the basic components of the refrigerant circuit of an air-conditioning system according to an embodiment of the invention. The system comprises a plurality of indoor cooling units, known in the art as fan coil units. In this embodiment, there are five fan coil units (FCU1 to FCU5). Each fan coil unit includes a cooling element in the form of a coiled pipe and a fan for directing air to be cooled to pass over the coil.

In operation, liquid refrigerant enters the coil, evaporates and emerges as a gas, the air blown or drawn by the fan providing the latent heat of evaporation and in the process being cooled. Since the basic construction and operation of the fan coil units are conventional and well-known, and do not form part of the invention, they will not be further described.

The system further comprises an outdoor condensing unit, which controls the flow of refrigerant through each of

the fan coil units and converts the hot gas emerging from the fan coils back into liquid refrigerant for resupply thereto. In this embodiment, the fan coil units are divided into two groups which are connected in independent fluid circuits. A first group consists of three fan coils units (FCU1, FCU3 and FCU5), and a second group consists of two fan coil units (FCU2 and FCU4). For each circuit, the components of the condensing unit comprise a compressor having an inlet (11 or 12) receiving hot gas from its associated group of fan coil units, and an outlet (13 or 14) coupled to the condensing coil (15 or 16) of a condenser. The two condensing coils (15,16) of the respective refrigerant circuits are conveniently located in the same metallic cooling structure and served by a common air fan (not shown). The outlet (17 or 18) of each condensing coil is coupled via primary (19) and secondary (20) expansion elements, consisting here of capillary tube, to respective fluid lines (21 to 23 or 24,25) for supplying the liquid refrigerant to the fan coil units of the group. Each of the liquid refrigerant lines (21 to 25) includes a normally-open solenoid valve (LSA to LSE) arranged to permit or arrest the flow of refrigerant to its associated fan coil unit according to whether or not cooling is required by that unit.

As an additional feature, each compressor includes the previously mentioned hot gas feedback device. This

device comprises a conduit including an expansion element (27 or 26), consisting here of capillary tube, connected between the output and the input of the compressor (COMP1 or COMP2), and a normally-closed solenoid valve (BS1 or BS2) for controlling the flow of hot gas through the conduit.

All of the electrically-powered components of the system, that is to say the liquid refrigerant control valves, the hot gas feedback device control valves, the compressors, the condenser fan and the indoor unit fans, are controlled from a single electronic control circuit board housed in the condensing unit. The control circuit generates outputs for controlling the operation of each of those components according to a logic function and based on input signals supplied from the fan coil units. Each input signal determines whether or not cooling is required of the fan coil unit in question.

Figure 2 shows the electrical circuit diagram of the system. A terminal block (32) on the control circuit board (31) of the condensing unit supplies power to the fan of each fan coil unit when a switch on the unit is operated by the user. The fan runs continuously until the unit is switched off. A demand for cooling at each unit is determined by the state of this switch and of the internal thermostat of the unit. When cooling is

required, the mains voltage supplied to the unit is returned to a signal terminal (S1 to S5) of the terminal block. The states of these five signal terminals control the operation of the logic circuitry (33) on the board (31). The logical processing of the input signals causes the generation of the required control signals for the liquid line valves (LSA to LSE), the compressors (COMP1, COMP2), the hot gas bypass valves (BS1, BS2) and the compressor fan. These control signals are converted to mains voltage by respective relays (not shown in Figure 2) which are conveniently also mounted on the circuit board (33). Thus, the circuit board has a plurality of output terminals (34 to 43) for supplying mains voltage, as required, to the fan motor (44) and the solenoid coils of the flow valves (LSA to LSE, BS1, BS2). In the case of the compressors, the output terminals (34,35) supply mains to the drive coils of respective power relays (PR1, PR2) in view of the much higher power rating of the compressor motors.

Figure 3 is a block diagram illustrating the components on the control circuit board (31). The mains voltage control signals (S1 to S5) are converted to low voltage digital signals in an opto-isolator (51). The digital signals are, in turn, input to the control circuitry (52), which is suitably constructed of transistor logic. The design of the logic circuit for performing the

functions described herein is within the competence of the person skilled in the art, and so need not be further elaborated. Finally, following the logical processing, the output, low voltage digital control signals are converted back to mains level in a bank of relays (53), for supplying the required mains voltage control signals at the output terminals (34 to 43) of the board (31).

Figure 4 is a diagram illustrating the logical relationship between the input and output control signals. This diagram is best read in conjunction with the logic table of Figure 5. In the logic table, "0" in relation to any of the input signals (S1-S5) from the fan coil units indicates that there is no demand for cooling, either because the unit is switched off or due to the temperature being already below that preset by the thermostat. On the other hand, "1" in relation to any of the input signals (S1-S5) indicates a demand for cooling due to the unit being switched on and the temperature being above the preset level. Turning now to the liquid line valve control signals (LSA-LSE) and the hot gas bypass valve control signals (BS1, BS2), for these "OFF" means the valve is in its unenergized state, that is open in the case of the liquid line valves and closed in the case of the bypass line valves. Similarly, "ON" means the valve is in its energized state, that is, closed in the

case of the liquid line valves and open in the case of the bypass line valves. For the compressor control signals (C1, C2) and the outdoor (condenser) fan motor control signal (OFM), "ON" and "OFF" have the logical meanings of the motor operating and switched off, respectively.

In operation, the compressor is switched on in response to one or more of the indoor units of its group providing cooling. The condenser fan motor, which in this embodiment is shared by the two condensing coils, is switched on whenever cooling is being provided by any one or more of the indoor units. The liquid line solenoid valves are operated so as to be off (open) when cooling is required by the associated indoor unit or the system is unpowered, but otherwise on (closed).

The state of each hot gas bypass valve depends on the number of indoor units in its group which are providing cooling at any one time. When only one indoor unit of the group is operating, the compressor will be overcapacity, so the bypass valve is switched on (open) thereby feeding back a portion of the hot gas to the compressor input to effectively increase its load. In this embodiment, the operation of two only of the three indoor units of the first group satisfactorily loads the compressor (COMP1),

so the bypass valve (BS1) is then turned off (closed) for normal compressor operation. Needless to say, the bypass valve is also closed when the compressor is fully loaded by the operation of all three, or both, indoor units of the first, and second, groups respectively.

An embodiment of the invention has been described in detail for the purposes of illustration only, and the skilled person will realise that many modifications are possible without departing from the scope of the invention. In particular, the actual number of indoor fan coil units is not critical to the principles of the invention. Equally it is not essential to divide the system into two or more parallel refrigerant circuits. However, the use of two such circuits is preferable in the case of, say, a four, five or six unit system, where the use of two compressors will normally result in lower running costs than having one compressor of a capacity suitable for handling simultaneous operation of all the indoor units. The liquid lines valves may be located at any convenient point on the fluid lines, including within the fan coil units.

A modification of the described embodiment provides a condensing unit for serving six fan coil units. In this modification, there are two refrigerant circuits and associated control which are each the same as those of the first group of three fan coil units in the described embodiment.



Claims

1. A condensing unit for an air conditioning system having a plurality of individually controllable cooling units, the condensing unit comprising:

a compressor arranged for receiving gas refrigerant from said cooling units;

a condenser for condensing the gas refrigerant compressed by the compressor into liquid refrigerant;

a plurality of fluid lines for selectively supplying the liquid refrigerant to respective ones of said cooling units;

each fluid line having a respective first valve means for controlling the supply of liquid refrigerant to its associated cooling unit; and

electronic logic control means, responsive to input signals received from said cooling units, for controlling the operation of each first valve means;

wherein each said first valve means is adapted to provide open fluid communication through its associated fluid line when the first valve means is in an unenergized state.

2. A condensing unit according to claim 1, further comprising means for feeding back a portion of the gas output by the compressor to the input of the compressor when the number of associated cooling units providing cooling is less than a predetermined number.



3. A condensing unit according to claim 2, wherein the feeding back means comprises a conduit which connects the output of the compressor to the input thereof, the conduit having a second valve means for controlling the gas flow through the conduit in response to a signal from the electronic logic control means.

4. A condensing unit according to claim 3, wherein the second valve means is adapted to prevent gas flow through the conduit when the second valve means is in an unenergized state.

5. A condensing unit according to claim 4, wherein the second valve means is a normally-closed solenoid valve.

6. A condensing unit according to any one of claims 2 to 5, wherein said number of cooling units associated with the compressor is two and said predetermined number is two.

7. A condensing unit according to any one of claims 2 to 5, wherein said number of cooling units associated with the compressor is three and said predetermined number is two.

8. A condensing unit according to any one of the preceding claims, wherein the first valve means is a normally-open solenoid valve.



9. A condensing unit according to any one of the preceding claims, wherein said plurality of fluid lines is divided into groups for coupling to respective groups of cooling units, and a respective said compressor is provided for each group of cooling units.

10. A condensing unit according to claim 9, wherein the number of said groups is two.

11. A condensing unit according to claim 10, wherein the number of cooling units is five, divided into a first group having three cooling units and a second group having two cooling units.

12. A condensing unit according to claim 10, wherein the number of cooling units is six, divided into two groups each having three cooling units.

13. A condensing unit according to any one of claims 9 to 12, wherein a respective said condenser is provided for each group of cooling units.

14. A condensing unit according to claim 13, wherein the condensers share a common air fan.

15. A condensing unit according to any one of the preceding claims, wherein said electronic logic control means comprises transistor logic circuitry.



16. A condensing unit according to any one of the preceding claims, further comprising means for supplying electrical power to the cooling units.

17. An air conditioning system comprising a condensing unit according to any one of the preceding claims and a plurality of cooling units coupled to the condensing unit, each cooling unit including a cooling element through which refrigerant may pass and means for generating a said input signal for the electronic logic control means.

18. An air conditioning system comprising a plurality of liquid refrigerant supply lines, a normally-open valve associated with each supply line, and an electronic control means for controlling the state of each valve.