



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
23.04.2008 Bulletin 2008/17

(51) Int Cl.:
F25B 31/00 (2006.01)

(21) Application number: **07118087.1**

(22) Date of filing: **09.10.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

(30) Priority: **11.10.2006 JP 2006277481**

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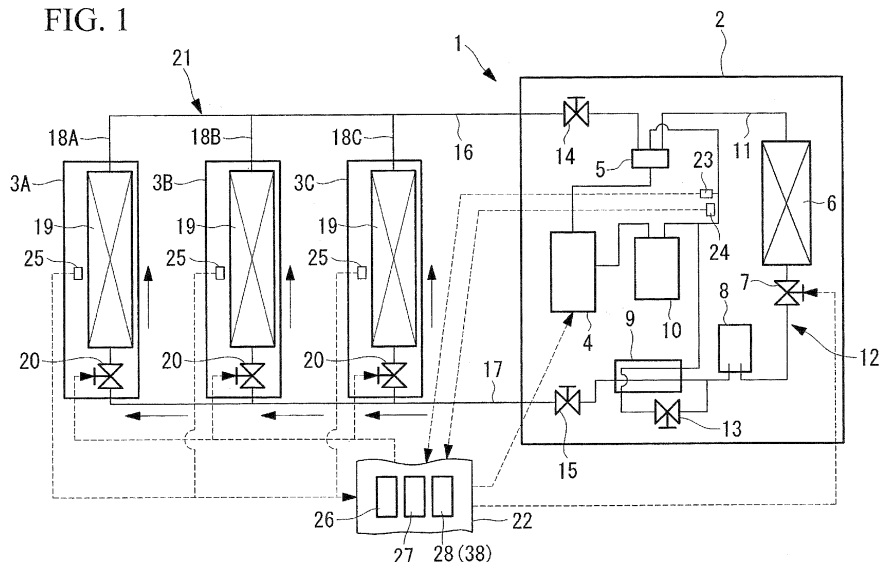
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(54) **Air-conditioning apparatus**

(57) An air-conditioning apparatus (1) capable of reliably recovering lubricant accumulated in indoor units (3A,3B,3C) and their refrigerant circuit, regardless of the refrigerant-pipe length differences of the indoor units connected to each other, has been desired, and includes an operating unit (22) configured to carry out liquid return at each indoor unit, to carry out an oil-recovery operation for recovering lubricant accumulated in the refrigerant

circuit, and to complete the oil-recovery operation when liquid return is detected at the outdoor unit (2). The operating unit includes a detecting unit configured to detect the refrigerant pipe length of each of the indoor units, a storing unit configured to store the refrigerant pipe lengths detected by the detecting unit, and a control unit configured to change the operation time during the oil-recovery operation on the basis of the refrigerant pipe length of each of the indoor units stored in the storing unit.

FIG. 1



Description

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

[0001] The present invention relates to a multi-unit air-conditioning apparatus having an oil-recovery function for recovering a lubricant that is circulated through a refrigerant circuit together with a refrigerant discharged from a compressor and that accumulates in the refrigerant circuit.

2. DESCRIPTION OF RELATED ART

[0002] With air-conditioning apparatuses using a refrigerant-compression refrigeration cycle, cooling and heating are carried out by compressing a refrigerant with a compressor and circulating the refrigerant inside a refrigerant circuit. The compressor contains a lubricant for lubricating a slidable section. Some of the lubricant is discharged from the compressor together with the compressed refrigerant. The lubricant circulates through the refrigerant circuit together with the refrigerant and then is returned to the compressor. However, some of the lubricant may accumulate in the refrigerant circuit. The amount of accumulated lubricant varies depending on the length of the refrigerant pipes in each indoor unit or the operation state of each indoor unit. However, in general, it is presumed that the amount of accumulated lubricant increases in proportion to the operating time of the air-conditioning apparatus.

[0003] As described above, as the amount of accumulated lubricant in the refrigerant circuit increases, the amount of lubricant retained in the compressor decreases. This affects the lubricating action of the compressor, and may cause, in some cases, failure or damage to the compressor due to lack of lubricant. Accordingly, at predetermined intervals of operating time (e.g., every eight hours) of the air-conditioning apparatus, an oil-recovery operation for forcefully recovering the lubricant accumulated inside the refrigerant circuit from the compressor is carried out for a predetermined amount of time (e.g., three minutes). A known oil-recovery operation is a method for recovering a lubricant accumulated together with a liquid refrigerant from a refrigerant circuit to a compressor by carrying out a liquid return operation in which the compressor is operated at a set rotational speed and indoor and outdoor expansion valves are set at predetermined degrees of opening.

[0004] With multi-unit air-conditioning apparatuses that include a plurality of indoor units connected in parallel, and, in particular, apparatuses that are installed for air-conditioning of a building, the length of refrigerant pipes is extremely large, and, in most cases, the lengths of the refrigerant pipes differ for each indoor unit. As described above, with a multi-unit air-conditioning apparatus, even when an oil-recovery operation is carried out

constantly for a predetermined amount of time, the expected amount of lubricant may not be returned to the compressor, causing defective lubrication.

[0005] To prevent such an incident, there is a proposed method for determining whether or not a lubricant has returned to a compressor during an oil-recovery operation, on the basis of suction superheating of a refrigerant sucked by the compressor, and changing the oil-recovery operation time when required (for example, refer to Japanese Unexamined Patent Application, Publication No. HEI-10-288410).

[0006] With the above-described multi-unit air-conditioning apparatus, after the air-conditioning apparatus is installed on site, an appropriate amount of refrigerant corresponding to the length of the refrigerant pipe of each indoor unit must be added. The amount of refrigerant to be added directly affects whether or not the rated air-conditioning performance can be achieved. Therefore, the length of the refrigerant pipe must be determined as accurately as possible, and an appropriate amount of refrigerant corresponding to the length of the refrigerant pipe must be added. A system and method for detecting the length of the refrigerant pipe has been proposed (for example, refer to Japanese Unexamined Patent Application, Publication No. 2006-183979).

[0007] However, according to Japanese Unexamined Patent Application, Publication No. HEI-10-288410, it is determined whether or not a lubricant has returned to a compressor on the basis of suction superheating of a refrigerant sucked by the compressor, and the oil-recovery operation is completed when the suction superheating is constantly equal to or less than a predetermined value for a predetermined amount of time or when a predetermined maximum amount of time elapses after the oil-recovery operation is started. Therefore, regardless of the difference in the lengths of the refrigerant pipes for a plurality of indoor units, suction superheating of the compressor decreases due to a liquid refrigerant that returns after circulating in an indoor unit having a relatively short refrigerant pipe. As a result, the oil recovery operation time is determined. Thus, with this configuration, there is a problem in that the lubricant accumulated in indoor units having relatively long refrigerant pipes and the refrigerant circuit cannot be sufficiently recovered.

[0008] Japanese Unexamined Patent Application, Publication No. 2006-183979 proposes a system and method for detecting the length of refrigerant pipes, but does not directly disclose nor suggest a technology for recovering a lubricant from a refrigerant circuit to a compressor.

BRIEF SUMMARY OF THE INVENTION

[0009] The present invention has been conceived in light of the problems described above. Accordingly, it is an object of the present invention to provide an air-conditioning apparatus capable of reliably recovering lubri-

cant accumulated in indoor units and their refrigerant circuit, regardless of the different lengths of refrigerant pipe of the indoor units which are connected to each other.

[0010] To achieve the above-described object, the air-conditioning apparatus according to the present invention provides the following solutions.

[0011] An air-conditioning apparatus according to a first aspect of the present invention includes an outdoor unit including a compressor and an outdoor heat-exchanger; a plurality of indoor units connected in parallel with each other, each of the indoor units including an indoor heat-exchanger and an indoor expansion valve; a refrigerant circuit formed by connecting, in order, the compressor, the outdoor heat-exchangers, the plurality of an indoor heat-exchangers, and the indoor expansion valves using refrigerant pipes; and an oil-recovery operating unit configured to carry out a liquid return operation at each indoor unit at a predetermined timing, to carry out a oil-recovery operation for recovering lubricant accumulated in the refrigerant circuit, and to terminate the oil-recovery operation when liquid return is detected at the outdoor unit. The oil-recovery operating unit includes a refrigerant-pipe-length detecting unit configured to detect the refrigerant pipe length of each of the indoor units; a refrigerant-pipe-length storing unit configured to store the refrigerant pipe lengths detected by the refrigerant-pipe-length detecting unit; and an oil-recovery control unit configured to change the operation time during the oil-recovery operation on the basis of the refrigerant pipe length of each of the indoor units stored in the refrigerant-pipe-length storing unit.

[0012] "Liquid return operation", as herein used, means an operation in which the degree of superheating of a refrigerant returning from an indoor unit to an outdoor unit via a gas pipe during a cooling cycle is lowered so as to return the refrigerant from the indoor unit to the outdoor unit in a state in which at least part of the refrigerant has been actively brought in a liquid state.

[0013] With the first aspect according to the present invention, since the oil-recovery operating unit includes a refrigerant-pipe-length detecting unit configured to detect the refrigerant pipe length of each indoor unit, a refrigerant-pipe-length storing unit configured to store the refrigerant pipe lengths detected by the refrigerant-pipe-length detecting unit, and an oil-recovery control unit configured to change the operation time during the oil-recovery operation on the basis of the refrigerant pipe length of each of the indoor units stored in the refrigerant-pipe-length storing unit, the lubricant accumulated in the indoor units and the refrigerant circuit can be recovered, even when the refrigerant pipe length of each indoor unit differs, by changing the operation time during the oil-recovery operation on the basis of the refrigerant pipe length of each indoor unit so as to set an appropriate oil-recovery operation time. Therefore, the lubricant accumulated in the indoor units having long refrigerant pipes and the refrigerant circuit can be reliably recovered to the compressor. Thus, a predetermined amount of lubri-

cant can be constantly retained in the compressor, reliably preventing defective lubrication caused by lack of lubricant in the compressor due to a large amount of lubricant being discharged to the refrigerant circuit.

[0014] With the air-conditioning apparatus according to the first aspect, the oil-recovery control unit may determine the refrigerant-pipe length differences among each of the indoor units and may change the operation completion time during the oil-recovery operation on the basis of the refrigerant-pipe length differences.

[0015] According to this configuration, since the refrigerant-pipe length differences among each of the indoor units are determined and the operation completion time is changed during the oil-recovery operation on the basis of the refrigerant-pipe length differences, when it is determined that the refrigerant pipe long, the completion time of the oil-recovery operation can be delayed by an amount of time corresponding to the refrigerant-pipe length differences, and the operation time can be extended. In this way, the lubricant accumulated in the indoor unit having a long refrigerant pipe and the refrigerant circuit can be reliably recovered. Thus, defective lubrication caused by lack of lubricant in the compressor can be reliably prevented.

[0016] With the air-conditioning apparatus according to the first aspect having the above-described structure, the oil-recovery control unit may determine a distribution of the refrigerant-pipe lengths of the indoor units and may change the operation completion time during the oil-recovery operation on the basis of the distribution of the refrigerant-pipe lengths.

[0017] According to this configuration, since a distribution of the refrigerant-pipe lengths of the indoor units is determined and the operation completion time is changed during the oil-recovery operation on the basis of the distribution of the refrigerant-pipe lengths, when it is determined that the number of indoor units having a refrigerant pipe length larger than the average refrigerant pipe length is provided, the completion time of the oil-recovery operation can be delayed by an amount of time corresponding to the refrigerant-pipe length difference, and the operation time can be extended. In this way, the lubricant accumulated in the indoor units having long refrigerant pipes and the refrigerant circuit can be reliably recovered. Thus, defective lubrication caused by lack of lubricant in the compressor can be reliably prevented.

[0018] With the air-conditioning apparatus according to the first aspect having the above-described structure, the oil-recovery control unit may add the refrigerant-pipe lengths of the indoor units and may change the operation completion time during the oil-recovery operation on the basis of the total refrigerant-pipe length.

[0019] According to this configuration, since the refrigerant-pipe lengths of the indoor units are added and the operation completion time is changed during the oil-recovery operation on the basis of the total refrigerant-pipe length, when it is determined that the refrigerant pipe is long, the completion time of the oil-recovery operation

can be delayed by an amount of time corresponding to the refrigerant-pipe length difference, and the operation time can be extended. In this way, the lubricant accumulated in the indoor units having long refrigerant pipes and the refrigerant circuit can be reliably recovered. Thus, defective lubrication caused by lack of lubricant in the compressor can be reliably prevented.

[0020] With the air-conditioning apparatus according to the first aspect having the above-described structure, the oil-recovery control unit may determine the refrigerant-pipe length differences among each of the indoor units and may change the operation start time during the oil-recovery operation on the basis of the refrigerant-pipe length differences.

[0021] According to this configuration, since the refrigerant-pipe length differences among each of the indoor units are determined and the operation start time is changed during the oil-recovery operation on the basis of the refrigerant-pipe length difference, the oil-recovery operation is started from the indoor unit having the longest refrigerant pipe so that the longer the refrigerant pipe of the indoor unit is, the greater the degree of opening is. In this way, the lubricant accumulated in the indoor units having long refrigerant pipes and the refrigerant circuit can be reliably recovered. Thus, defective lubrication caused by lack of lubricant in the compressor can be reliably prevented.

[0022] An air-conditioning apparatus according to a second aspect of the present invention includes an outdoor unit including a compressor and an outdoor heat-exchanger; a plurality of indoor units connected in parallel with each other, each of the indoor units including an indoor heat-exchanger and an indoor expansion valve; a refrigerant circuit formed by connecting, in order, the compressor, the outdoor heat-exchangers, the plurality of indoor heat-exchangers, and the indoor expansion valves using refrigerant pipes; and an oil-recovery operating unit configured to carry out a liquid return operation at each indoor unit at a predetermined timing, to carry out an oil-recovery operation for recovering lubricant accumulated in the refrigerant circuit, and to complete the oil-recovery operation when liquid return is detected at the outdoor unit. The oil-recovery operating unit includes a refrigerant-pipe-length detecting unit configured to detect the refrigerant pipe length of each of the indoor units; a refrigerant-pipe-length storing unit configured to store the refrigerant pipe lengths detected by the refrigerant-pipe-length detecting unit; and an oil-recovery control unit configured to change the degree of opening of each indoor expansion valve during the oil-recovery operation on the basis of the refrigerant pipe length of each of the indoor units stored in the refrigerant-pipe-length storing unit.

[0023] With the second aspect according to the present invention, since the oil-recovery operating unit includes a refrigerant-pipe-length detecting unit configured to detect the refrigerant pipe length of each indoor unit, a refrigerant-pipe-length storing unit configured to

store the refrigerant pipe lengths detected by the refrigerant-pipe-length detecting unit, and an oil-recovery control unit configured to change the degree of opening of each indoor expansion valve during the oil-recovery operation on the basis of the refrigerant pipe length of each of the indoor units stored in the refrigerant-pipe-length storing unit, the lubricant accumulated in the indoor units and the refrigerant circuit can be recovered, even when the refrigerant pipe length of each indoor unit differs, by changing the degree of opening of each indoor expansion valve during the oil-recovery operation on the basis of the refrigerant pipe length of each indoor unit so as to make an appropriate amount of refrigerant flow through each indoor unit. Therefore, the lubricant accumulated in the indoor units having long refrigerant pipes and the refrigerant circuit can be reliably recovered to the compressor. Thus, a predetermined amount of lubricant can be constantly retained in the compressor, reliably preventing defective lubrication caused by lack of lubricant in the compressor due to a large amount of lubricant being discharged to the refrigerant circuit.

[0024] With the air-conditioning apparatus according to the second aspect having the above-described structure, the oil-recovery control unit may determine the refrigerant-pipe length differences among each of the indoor units and may set the degree of opening of the indoor expansion valve so that the longer the refrigerant pipe of the indoor unit is, the greater the degree of opening is.

[0025] According to this configuration, since the refrigerant-pipe length differences among each of the indoor units are determined and the degrees of opening of the indoor expansion valves are set so that the longer the refrigerant pipe of the indoor unit is, the greater the degree of opening is, and the longer the refrigerant pipe of the indoor unit, the greater the amount of refrigerant to be discharged. Thus, liquid return can be actively carried out so as to recover the lubricant. In this way, the lubricant accumulated in the indoor units having long refrigerant pipes and the refrigerant circuit can be reliably recovered. Thus, defective lubrication caused by lack of lubricant in the compressor can be reliably prevented.

[0026] According to the present invention, since the operation time (completion time or start time) of the oil-recovery operation or the degree of opening of the indoor expansion valve is changed on the basis of the refrigerant pipe length of each indoor unit, even when the refrigerant pipe length differs for each indoor unit, the lubricant accumulated in the indoor units having long refrigerant pipes and the refrigerant circuit can be reliably recovered, reliably preventing defective lubrication caused by lack of lubricant in the compressor.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0027] Fig. 1 illustrates a refrigerant circuit of an air-conditioning apparatus according to a first embodiment of the present invention.

[0028] Fig. 2 is a control flowchart of an oil-recovery control unit of the air-conditioning apparatus according to the first embodiment of the present invention.

[0029] Figs. 3A and 3B are control flowcharts of an oil-recovery control unit of an air-conditioning apparatus according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0030] Embodiments of the present invention will be described with reference to the drawings.

First Embodiment

[0031] A first embodiment of the present invention will be described with reference to Figs. 1 and 2.

[0032] Fig. 1 illustrates a refrigerant circuit of a multi-unit air-conditioning apparatus 1 according to the first embodiment of the present invention. The air-conditioning apparatus 1 includes one outdoor unit 2 and a plurality of indoor units 3A, 3B, and 3C that are connected in parallel to the outdoor unit 2. In this embodiment, the three indoor units 3A, 3B, and 3C are connected. However, the number of indoor units 3A, 3B, and 3C to be connected is not limited thereto.

[0033] The outdoor unit 2 includes an inverter-driven compressor 4 configured to compress a refrigerant, a four-way diverter valve 5 configured to switch the circulation direction of the refrigerant, an outdoor heat-exchanger 6 configured to carry out heat exchange between the refrigerant and outdoor air, an outdoor electronic expansion valve 7 for heating, a receiver 8 configured to retain a liquid refrigerant, a supercooling heat-exchanger 9 configured to supercool the liquid refrigerant, and an accumulator 10 configured to supply the compressor 4 only with a gas refrigerant by separating the liquid component in the refrigerant gas. These components are connected by a known refrigerant pipe 11 to configure a refrigerant circuit 12 for the outdoor unit 2. The supercooling heat-exchanger 9 is a double-pipe heat-exchanger. The refrigerant from the refrigerant pipe 11 is guided in the inner pipe of the supercooling heat-exchanger 9 via an electronic expansion valve 13 so as to cool the liquid refrigerant circulating in the outer pipe of the supercooling heat-exchanger 9. The refrigerant guided in the inner pipe is guided to the inlet of the accumulator 10 as a gas refrigerant.

[0034] A gas-side control valve 14 and a liquid-side control valve 15 are provided in the outdoor unit 2. A gas pipe 16 and a liquid pipe 17 that extend to the indoor units 3A, 3B, and 3C are connected via the gas-side control valve 14 and the liquid-side control valve 15. The plurality of indoor units 3A, 3B, and 3C are connected in series to the gas pipe 16 and the liquid pipe 17 via a branching unit and indoor refrigerant pipes 18A, 18B, and 18C, which are not shown in the drawing.

[0035] The indoor units 3A, 3B, and 3C each include an indoor heat-exchanger 19 configured to carry out heat

exchange with indoor air and an indoor electronic expansion valve (EEV) 20 for cooling. The indoor units 3A, 3B, and 3C are provided for each air-conditioning zone or each room. The length of each indoor refrigerant pipe 18A, 18B, or 18C connected to the indoor units 3A, 3B, and 3C depends on the position of each indoor unit 3A, 3B, or 3C. Here, the relationship of the lengths of the indoor refrigerant pipes 18A, 18B, and 18C is $18A > 18B > 18C$. By connecting the indoor refrigerant pipes 18A, 18B, and 18C with the refrigerant circuit 12 on the side of the outdoor unit 2 via the gas pipe 16 and the liquid pipe 17, a completely closed single-system refrigerant circuit 21 is configured.

[0036] The air-conditioning apparatus 1 includes an oil-recovery operating unit 22 configured to carry out liquid return operation of the indoor units 3A, 3B, and 3C at a predetermined timing, for example, after the elapse of predetermined operation times so as to carry out an oil-recovery operation for recovering the lubricant accumulated in the gas side of the refrigerant circuit 21 and to complete the oil-recovery operation when a return of liquid refrigerant is detected at the outdoor unit 2. The timing for carrying out the oil-recovery operation is not limited thereto and may be carried out at other timings, such as when the cumulative flow amount of the lubricant, calculated on the basis of a predetermined formula, reaches a predetermined limit flow amount. In the liquid return operation, the indoor electronic expansion valves 20 of the indoor units 3A, 3B, and 3C can be set at predetermined degrees of opening for the oil-recovery operation. Whether or not liquid refrigerant is returning to the outdoor unit 2 during oil-recovery operation can be detected by determining the degree of superheating of the suction refrigerant from values detected by a low-pressure sensor 23 and an intake-refrigerant temperature sensor 24 that are provided on the refrigerant pipe 11 on the inlet side of the accumulator 10.

[0037] A refrigerant-pipe-length detecting unit 26 that detects the pipe length of each indoor refrigerant pipe 18A, 18B, or 18C connected to each indoor unit 3A, 3B, or 3C, respectively, and a refrigerant-pipe-length storage unit 27 that stores the detected pipe length are provided in the oil-recovery operating unit 22. For detecting the refrigerant pipe length, the above-mentioned invention in Japanese Unexamined Patent Application, Publication No. 2006-183979, filed by the present assignee, may be employed. According to this refrigerant-pipe-length detection method, the pressure loss of a low-pressure gas pipe (i.e., indoor refrigerant pipe 18A, 18B, and 18C and the gas pipe 16) is calculated from the suction pressure of the compressor 4 (detected by the low-pressure sensor 23) and the saturation pressure of the indoor refrigerant pipe 18A, 18B, or 18C (calculated from the refrigerant temperature detected by heat-exchanger temperature sensors 25 provided on the indoor refrigerant pipes 18A, 18B, and 18C) during cooling operation. On the basis of the pressure loss, the length of the low-pressure gas pipe is determined by employing Darcy's formula, as

follows:

$$\Delta P = \lambda (\Delta x / D) \cdot (\rho u^2 / 2)$$

where λ represents Darcy's coefficient of pipe friction, Δx represents the length of the low-pressure gas pipe, D represents the inner diameter of the pipe, ρ represents the relative density of the refrigerant, and u represents the average flow speed. Darcy's coefficient of pipe friction λ , the inner diameter D of the pipe, relative density ρ of the refrigerant, and the average flow speed u are determined in advance. The average flow speed u can be determined by calculating the average flow volume of the refrigerant flowing inside the refrigerant circuit 21 on the basis of the discharge amount of the compressor 4 and dividing the derived value by the cross-sectional area of the refrigerant pipe ($\pi D^2/4$).

[0038] Detection of the refrigerant pipe length is not limited to the above-described method; other known methods may be employed. For example, the refrigerant pipe length may be calculated on the basis of the amount of time required for the temperature of the gas discharged from the compressor to reach a predetermined temperature after the degree of opening of the expansion valve is forcefully changed after the cooling operation is stabilized.

[0039] The detection of the refrigerant pipe length by the refrigerant-pipe-length detecting unit 26 is carried out so as to add an appropriate amount of refrigerant corresponding to the refrigerant pipe length after the air-conditioning apparatus 1 is installed. This detection result may be stored in the refrigerant-pipe-length storage unit 27 and may be used when the oil-recovery operation is carried out.

[0040] An oil-recovery control unit 28 that changes the amount of time for carrying out the oil-recovery operation on the basis of the length of each indoor refrigerant pipe 18A, 18B, or 18C (actually the length of the low-pressure gas pipe including the length of the gas pipe 16) of each indoor unit 3A, 3B, or 3C stored in the refrigerant-pipe-length storage unit 27 when the oil-recovery operation is carried out at the above-described timing is provided in the oil-recovery operating unit 22.

[0041] The oil-recovery control unit 28 controls the oil-recovery operation time in accordance with the control flow illustrated in Fig. 2.

[0042] At the oil-recovery control unit 28, first, it is determined, on the basis of the detection result of the refrigerant pipe length, whether the difference between the refrigerant pipe length ($L_{\max}$) of the indoor refrigerant pipe 18A connected to the furthest indoor unit 3A and the refrigerant pipe length ($L_{\min}$) of the indoor refrigerant pipe 18C connected to the closest indoor unit 3C is greater than a set pipe length difference $L_{\lim}$ (for example, 40 m) (S1). If the refrigerant-pipe length difference is smaller than the set pipe length difference $L_{\lim}$, the process pro-

ceeds to normal control, and the above-described oil-recovery operation is carried out. When liquid return is detected in the outdoor unit 2, the oil-recovery operation is completed after the elapse of an oil-recovery operation time T_k (for example, after 30 seconds) set on the basis of the refrigerant pipe length. When the refrigerant-pipe length difference is greater than the set pipe length difference $L_{\lim}$, the completion condition of the oil-recovery operation is changed (S2).

[0043] To change the completion condition of the oil-recovery operation, it is determined by how much time the oil-recovery operation completion time is to be delayed on the basis of the refrigerant-pipe length difference ($L_{\max} - L_{\min}$) (S3). If the refrigerant-pipe length difference ($L_{\max} - L_{\min}$) is within a set range (for example, $40 \text{ m} < L_{\max} - L_{\min} \leq 60 \text{ m}$), the operation completion time is delayed from the set completion time by, for example, 30 seconds, and the oil-recovery operation time is extended by 30 seconds (S4). When the refrigerant-pipe length difference ($L_{\max} - L_{\min}$) exceeds a set value (for example, 60 m), the operation completion time is delayed from the set completion time by, for example, 60 seconds, and the oil-recovery operation time is extended by 60 seconds (S5). The operation completion condition changed in the above-described manner is stored in the oil-recovery operating unit 22, which controls the outdoor unit 2 (S6). Then, the control is switched to normal control so as to carry out the above-described oil-recovery operation.

[0044] The following advantages are achieved according to this embodiment having the above-described structure.

[0045] While normal air-conditioning operation is being carried out, some of the lubricant discharged from the compressor 4 together with the refrigerant gas circulates in the refrigerant circuit 21 together with the refrigerant gas and returns to the compressor 4. However, some of the lubricant is accumulated in the indoor units 3A, 3B, and 3C and the indoor refrigerant pipes 18A, 18B, and 18C, i.e., mainly in the gas side refrigerant pipes. At a predetermined timing, for example, when a predetermined amount of operation time elapses, or when the flow amount of the lubricant reaches a limit flow amount, the oil-recovery operation is started.

[0046] During the oil-recovery operation, a liquid return operation is carried out in a cooling cycle while the indoor electronic expansion valves 20 of the indoor units 3A, 3B, and 3C are set at a predetermined degree of opening for the oil-recovery operation so as to return the liquid refrigerant to the outdoor unit 2. In this way, the lubricant accumulated in the indoor units 3A, 3B, and 3C and the indoor refrigerant pipes 18A, 18B, and 18C is flushed with the refrigerant flow and is recovered to the compressor 4.

[0047] When the liquid refrigerant returns to the outdoor unit 2, the liquid return is detected and the oil-recovery operation is completed. Whether or not the liquid refrigerant has returned to the outdoor unit 2 can be de-

terminated by calculating the degree of superheating of the suction refrigerant from values detected by the low-pressure sensor 23 and the intake-refrigerant temperature sensor 24 provided on the refrigerant pipe 11 on the inlet side of the accumulator 10. The oil-recovery operation is completed a predetermined amount of time (30 seconds according to this embodiment) after the liquid return to the outdoor unit 2 is detected.

[0048] In general, when the refrigerant pipe is long, pressure loss is large. Therefore, the pressure difference on both sides of an expansion valve is reduced, causing the flow amount of refrigerant to be reduced. Accordingly, the oil recovery is unsatisfactory. When the refrigerant pipe is long, heat loss from the pipe is large. Therefore, even during liquid return, the refrigerant becomes nearly overheated while it flows through the pipes. It is easier to recover the oil during liquid return; however, oil recovery is unsatisfactory when the oil is overheated.

[0049] According to this embodiment, the refrigerant-pipe length difference ($L_{\max} - L_{\min}$) of the indoor units 3A, 3B, and 3C detected in advance by the refrigerant-pipe-length detecting unit 26 and stored in the refrigerant-pipe-length storage unit 27 is compared with the set pipe length difference L_{lim} (for example, 40 m) (S1 in Fig. 2). If the refrigerant-pipe length difference ($L_{\max} - L_{\min}$) is less than 40 m, as described above, the oil-recovery operation is completed 30 seconds after liquid return is detected. If the refrigerant-pipe length difference ($L_{\max} - L_{\min}$) is equal to or greater than 40 m, the completion condition of the oil-recovery operation is changed.

[0050] When it is determined whether or not the refrigerant-pipe length difference of the indoor unit 3A and the indoor unit 3C is within the range of $40 \text{ m} < L_{\max} - L_{\min} \leq 60 \text{ m}$ (S3 in Fig. 2), the completion condition of the oil-recovery operation is set such that, when the refrigerant-pipe length difference is between 40 and 60 m, the oil-recovery operation time is extended by 30 seconds (S4 in Fig. 2), and the oil-recovery operation is completed 60 seconds after liquid return is detected at the outdoor unit 2. When the refrigerant-pipe length difference exceeds 60 m, the oil-recovery operation time is extended by 60 seconds (S5 in Fig. 2), and the oil-recovery operation is completed 90 seconds after liquid return is detected at the outdoor unit 2. In this way, even when the refrigerant pipe length differs for each indoor unit 3A, 3B, or 3C, the oil-recovery operation time can be changed on the basis of the refrigerant pipe length of each indoor unit 3A, 3B, or 3C so as to set an appropriate oil-recovery operation time corresponding to the indoor unit 3A that has the largest refrigerant pipe length. Therefore, the lubricant accumulated in the indoor units 3A, 3B, and 3C and their refrigerant circuits can be reliably collected.

[0051] In particular, according to this embodiment, the refrigerant-pipe length difference of the indoor units 3A, 3B, and 3C is determined, and the completion time of the oil-recovery operation can be changed on the basis of the determined refrigerant-pipe length difference. Therefore, when it is determined that the refrigerant-pipe length

difference is large, the completion time of the oil-recovery operation can be delayed by an amount of time corresponding to the refrigerant-pipe length difference, and the oil-recovery operation time can be extended. In this way, the lubricant accumulated in the indoor unit 3A having the largest refrigerant pipe length and the indoor refrigerant pipe 18A can be reliably recovered to the compressor 4. Accordingly, a predetermined amount of lubricant can be constantly retained in the compressor 4, reliably preventing defective lubrication caused by lack of lubricant in the compressor 4 due to a large amount of lubricant being discharged to the refrigerant circuit 21.

[0052] According to this embodiment, when the refrigerant-pipe length difference is equal to or greater than the set pipe difference, the oil-recovery operation time is changed in two steps. However, it may be changed in three steps or may be changed continuously.

[0053] The oil-recovery operation time is changed on the basis of the refrigerant-pipe length difference of the indoor units 3A, 3B, and 3C. However, the process of changing the oil-recovery operation time is not limited thereto, and various modifications, as described below, may be employed.

[0054] First, the distribution of the refrigerant pipe length is determined on the basis of the detection result of the refrigerant pipe lengths of the indoor units 3A, 3B, and 3C. When many of the indoor units have refrigerant pipes longer than the average refrigerant pipe length, the completion time of the oil-recovery operation is delayed by an amount of time corresponding to the indoor units having long refrigerant pipes so as to extend the oil-recovery operation time. In this way, similar to the above-described embodiment, the lubricant accumulated in the indoor units having long refrigerant pipes and their refrigerant pipes can be reliably recovered to the compressor 4. Thus, a sufficient amount of lubricant can be constantly retained in the compressor 4, and defective lubrication caused by lack of lubricant can be reliably prevented.

[0055] Second, the total length of the refrigerant pipes of the indoor units 3A, 3B, and 3C is calculated on the basis of the detection result of the length of the indoor units 3A, 3B, and 3C. When it is determined that the total refrigerant pipe length is larger than a reference pipe length on the basis of the total refrigerant pipe length, the completion time of the oil-recovery operation is delayed by an amount of time corresponding to the length, and the oil-recovery operation time is extended. In this way, also, the same advantages according to the above-described embodiment may be achieved.

[0056] Third, according to the above-described embodiment and modifications, the completion time of the oil-recovery operation is delayed in accordance with the indoor unit having the longest refrigerant pipe on the basis of the refrigerant pipe lengths of the indoor units 3A, 3B, and 3C so as to extend the oil-recovery operation time. Instead, however, a reference oil-recovery operation time may be set in accordance with the indoor unit 3A having the longest refrigerant pipe, and the start time

of the oil-recovery operation may be changed for the indoor unit 3C having the shortest refrigerant pipe. In other words, the oil-recovery operation is started in order from the indoor unit 3A having the longest refrigerant pipe, and the oil-recovery operation time of the indoor unit 3A having the longest refrigerant pipe is extended and the oil-recovery operation time of the indoor unit having a small refrigerant pipe length is shortened by delaying the start time of the oil-recovery operation of the indoor unit 3C having a small refrigerant pipe length. In this way, also, the same advantages according to the above-described embodiment may be achieved.

[0057] According to this embodiment, the operation time changed during the oil-recovery operation is not limited to that described above, and may be set appropriately. However, since the oil-recovery operation is a liquid return operation, it is desirable to limit the maximum operation time by taking into consideration the volume of the accumulator 10.

Second Embodiment

[0058] Next, a second embodiment of the present invention will be described with reference to Figs. 1, 3A and 3B.

[0059] The structure of an oil-recovery control unit 38 according to this embodiment differs from that according to the above-described first embodiment. Since other structures according to this embodiment are the same as those according to the first embodiment, descriptions thereof are not repeated here.

[0060] The oil-recovery control unit 38 according to this embodiment changes the degrees of opening of the indoor electronic expansion valves 20 on the basis of the refrigerant pipe lengths of the indoor units 3A, 3B, and 3C, instead of changing the oil-recovery operation time.

[0061] The oil-recovery control unit 38 controls the degrees of opening of the indoor electronic expansion valves 20 during the oil recovery operation in accordance with the flowchart shown in Figs. 3A and 3B.

[0062] As shown in Figs. 3A and 3B, on the basis of the refrigerant pipe lengths detected by the refrigerant-pipe-length detecting unit 26 and stored in the refrigerant-pipe-length storage unit 27, the oil-recovery control unit 38 determines whether or not the difference between the refrigerant pipe length (L_{max}) of the farthest indoor unit 3A having the longest indoor refrigerant pipe 18A and the refrigerant pipe length (L_{min}) of the closest indoor unit 3C having the shortest indoor refrigerant pipe 18C is greater than a set pipe-length difference L_{lim} (for example, 40 m) (S11). If the refrigerant pipe-length difference is smaller than the set pipe-length difference L_{lim} , the process proceeds to normal control, and the above-described oil recovery operation is carried out. The oil recovery operation is completed 30 seconds after liquid return is detected at the outdoor unit 2. When the refrigerant pipe-length difference is greater than the set pipe-length difference L_{lim} , the oil-recovery operation condi-

tions, i.e., the degree of opening of the indoor electronic expansion valve 20 of each indoor unit 3A, 3B, and 3C, is changed as described below.

[0063] First, the average length L_{ave} of each indoor refrigerant pipe 18A, 18B, and 18C of each indoor unit 3A, 3B, and 3C, respectively, is calculated by the formula $L_{ave} = (L_{max} - L_{min})/2$ (actually the average length of the low-pressure gas pipe includes the length of the gas pipe 16) (S12). Next, the total refrigerant pipe length L_i (where i equals the number of unit(s) connected) and the average length L_{ave} are compared (S13), and it is determined whether $L_i > L_{ave}$ (S14). As a result, when L_i is greater ("Yes"), it is determined whether $L_i > L_{ave} + 20$ (S15). When L_i is smaller ("No"), it is determined whether $L_i > L_{ave} - 20$ (S16).

[0064] Here, "+20" and "-20" correspond to "X = +20 pulses" and "X = -20 pulses", respectively, when the pulse number corresponding to the newly set degree of opening is defined as "X pulses" with respect to the originally set degree of opening of the indoor electronic expansion valve 20 during the oil-recovery operation.

[0065] Next, based on the comparison result of $L_i > L_{ave} + 20$, when L_i is greater ("Yes"), the corresponding indoor electronic expansion valve 20 of the indoor unit is determined to be, for example, +40 pulses with respect to the set degree of opening, i.e., is determined to have a degree of opening 40 pulses greater than the set degree of opening (S17). When L_i is small ("No"), the indoor electronic expansion valve 20 of the corresponding indoor unit is determined to be, for example, +20 pulses with respect to the set degree of opening, i.e., is determined to have a degree of opening 20 pulses greater than the set degree of opening (S18). Based on the comparison result of $L_i > L_{ave} - 20$, when L_i is greater ("Yes"), the corresponding indoor electronic expansion valve 20 of the indoor unit is determined to be, for example, -20 pulses with respect to the set degree of opening, i.e., is determined to have a degree of opening 20 pulses smaller than the set degree of opening (S19). When L_i is small ("No"), the indoor electronic expansion valve 20 of the corresponding indoor unit is determined to be, for example, -40 pulses with respect to the set degree of opening, i.e., is determined to have a degree of opening 40 pulses smaller than the set degree of opening (S20).

[0066] As described above, the degree of opening of each indoor electronic expansion valve 20 is determined, and a degree-of-opening changing instruction is sent to each indoor electronic expansion valve 20 (S21). Each indoor electronic expansion valve 20 is set to the determined degree of opening, and the oil-recovery operation is carried out. When liquid return is detected at the outdoor unit 2, as described above, while the oil-recovery operation is being carried out, the oil-recovery operation is completed 30 seconds thereafter. As a method of changing the degree-of-opening changing instruction of each indoor electronic expansion valve 20, either of the following two methods may be employed (S22).

1) The new degree of opening of each indoor electronic expansion valve 20 is sent to each of the indoor units 3A, 3B, and 3C; the indoor units 3A, 3B, and 3C store the information; and during the oil-recovery operation, the degree of opening of each indoor electronic expansion valve 20 is corrected on the basis of the information. 5

2) During oil-recovery, the degree of opening of each indoor electronic expansion valve 20 forcefully corrected by the outdoor unit 2 is reported to each of the indoor units 3A, 3B, and 3C. 10

[0067] As described above, even when the refrigerant pipe length differs for each of the indoor units 3A, 3B, and 3C, by changing the degree of opening of each indoor electronic expansion valve 20 during the oil-recovery operation on the basis of the refrigerant pipe length of each of the indoor units 3A, 3B, and 3C, the liquid return operation can be carried out by discharging an appropriate amount of refrigerant corresponding to the refrigerant pipe length of each of the indoor units 3A, 3B, and 3C, and the lubricant accumulated in the indoor units 3A, 3B, and 3C and the indoor refrigerant pipes 18A, 18B, and 18C can be recovered. Therefore, the lubricant retained in the indoor unit 3A having a great refrigerant pipe length and its indoor refrigerant pipe 18A can be reliably recovered to the compressor 4. 20 25

[0068] Since the refrigerant-pipe length difference of each of the indoor units 3A, 3B, and 3C is determined and the degree of opening of the indoor electronic expansion valve 20 of the indoor unit 3A having the longest refrigerant pipe is set to the largest value, the lubricant accumulated in the indoor unit 3A having the longest refrigerant pipe can be actively recovered by discharging a large amount of refrigerant. 30 35

[0069] Accordingly, also with this embodiment, similar to the above-described first embodiment, a predetermined amount of lubricant can be constantly retained in the compressor 4. Therefore, defective lubrication caused by lack of lubricant in the compressor 4 is reliably prevented. 40

[0070] According to the above-described embodiments, as the various sensors, including the low-pressure sensor 23, the intake-refrigerant temperature sensor 24, and the heat-exchanger temperature sensor 25, known sensors already installed in the air-conditioning apparatus 1 may be employed, and, thus, new sensors do not have to be installed. Furthermore, a refrigerant-pipe length detection system installed for adding refrigerant may also be used as the refrigerant-pipe-length detecting unit 26. 45 50

Claims

1. An air-conditioning apparatus comprising:

an outdoor unit including a compressor and an

outdoor heat-exchanger;
a plurality of indoor units connected in parallel with each other, each of the indoor units including an indoor heat-exchanger and an indoor expansion valve;
a refrigerant circuit formed by connecting, in order, the compressor, the outdoor heat-exchangers, the plurality of indoor heat-exchangers, and the indoor expansion valves using refrigerant pipes; and
an oil-recovery operating unit configured to carry out a liquid return operation at each indoor unit at a predetermined timing, to carry out an oil-recovery operation for recovering lubricant accumulated in the refrigerant circuit, and to complete the oil-recovery operation when liquid return is detected at the outdoor unit,

wherein the oil-recovery operating unit includes a refrigerant-pipe-length detecting unit configured to detect the refrigerant pipe length of each of the indoor units,
a refrigerant-pipe-length storing unit configured to store the refrigerant pipe lengths detected by the refrigerant-pipe-length detecting unit, and
an oil-recovery control unit configured to change the operation time during oil-recovery operation on the basis of the refrigerant pipe length of each of the indoor units stored in the refrigerant-pipe-length storing unit.

2. The air-conditioning apparatus according to Claim 1, wherein the oil-recovery control unit determines refrigerant-pipe length differences among each of the indoor units and changes the operation completion time during the oil-recovery operation on the basis of the refrigerant-pipe length differences. 35
3. The air-conditioning apparatus according to Claim 1, wherein the oil-recovery control unit determines a distribution of the refrigerant-pipe lengths of the indoor units and changes the operation completion time during the oil-recovery operation on the basis of the distribution of the refrigerant-pipe lengths. 40
4. The air-conditioning apparatus according to Claim 1, wherein the oil-recovery control unit adds the refrigerant-pipe lengths of the indoor units and changes the operation completion time during the oil-recovery operation on the basis of the total refrigerant-pipe length. 45
5. The air-conditioning apparatus according to Claim 1, wherein the oil-recovery control unit determines the refrigerant-pipe length differences among each of the indoor units and changes the operation start time during the oil-recovery operation on the basis of the refrigerant-pipe length differences. 50 55

6. An air-conditioning apparatus comprising:

an outdoor unit including a compressor and an outdoor heat-exchanger;
a plurality of indoor units connected in parallel with each other, each of the indoor units including an indoor heat-exchanger and an indoor expansion valve;
a refrigerant circuit formed by connecting, in order, the compressor, the outdoor heat-exchangers, the plurality of indoor heat-exchangers, and the indoor expansion valves using refrigerant pipes; and
an oil-recovery operating unit configured to carry out a liquid return operation at each indoor unit at a predetermined timing, to carry out an oil-recovery operation for recovering lubricant accumulated in the refrigerant circuit, and to complete the oil-recovery operation when liquid return is detected at the outdoor unit,

wherein the oil-recovery operating unit includes
a refrigerant-pipe-length detecting unit configured to detect the refrigerant pipe length of each of the indoor units,
a refrigerant-pipe-length storing unit configured to store the refrigerant pipe lengths detected by the refrigerant-pipe-length detecting unit, and
an oil-recovery control unit configured to change the degree of opening of each indoor expansion valve during the oil-recovery operation on the basis of the refrigerant pipe length of each of the indoor units stored in the refrigerant-pipe-length storing unit.

7. The air-conditioning apparatus according to Claim 6, wherein the oil-recovery control unit determines the refrigerant-pipe length differences among each of the indoor units and sets the degree of opening of the indoor expansion valve so that the longer the refrigerant pipe of the indoor unit is, the greater the degree of opening is.

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FIG. 1

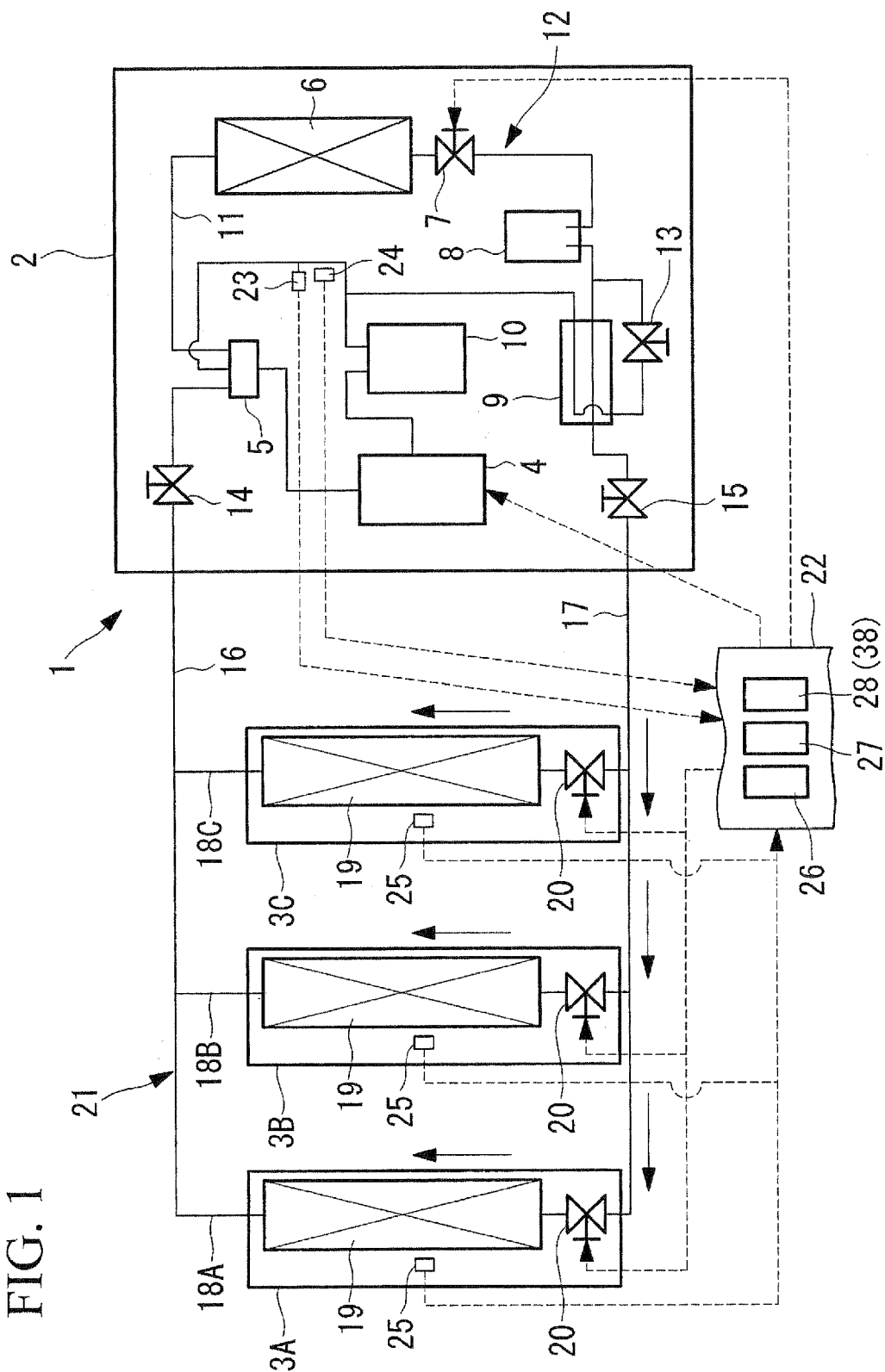


FIG. 2

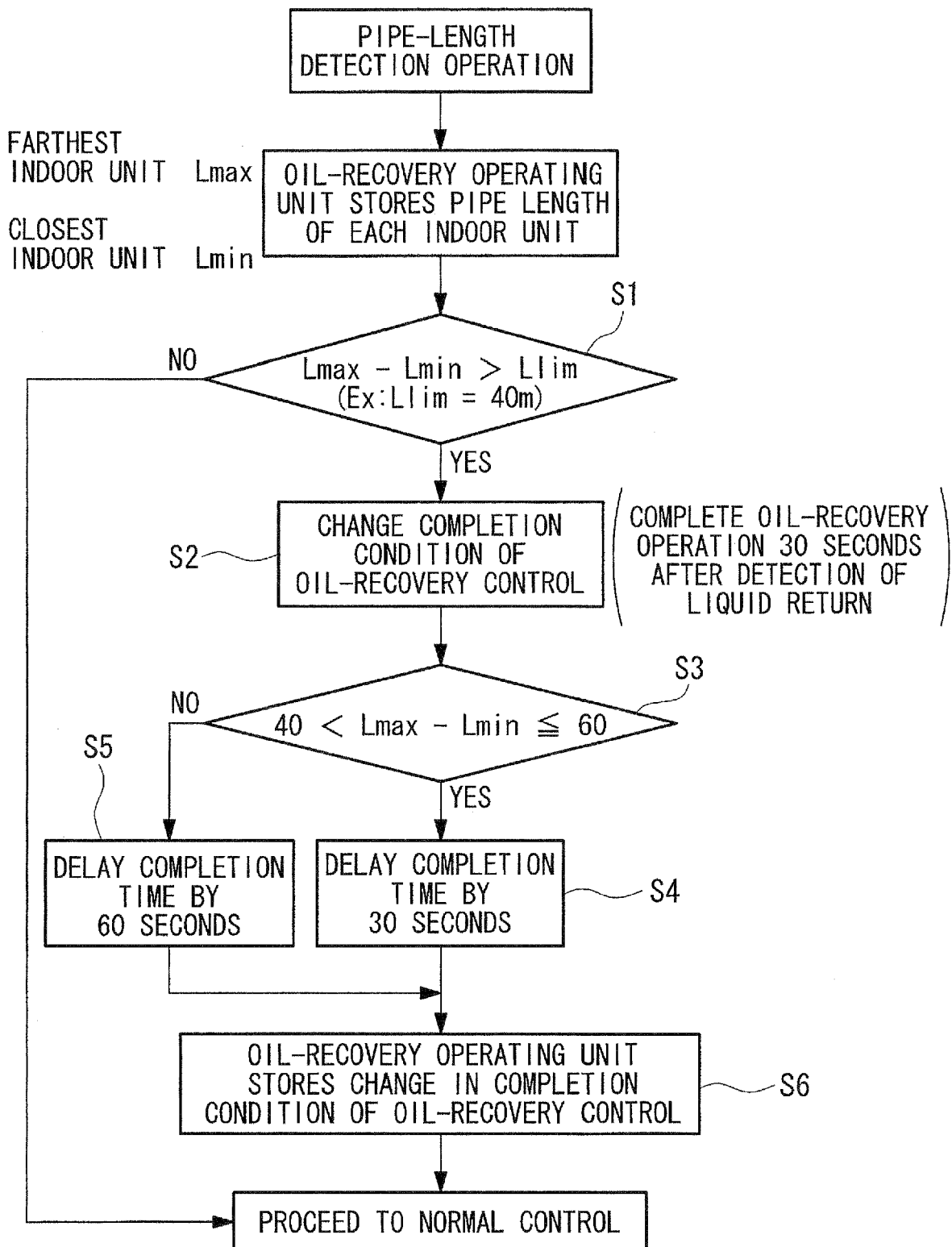


FIG. 3A

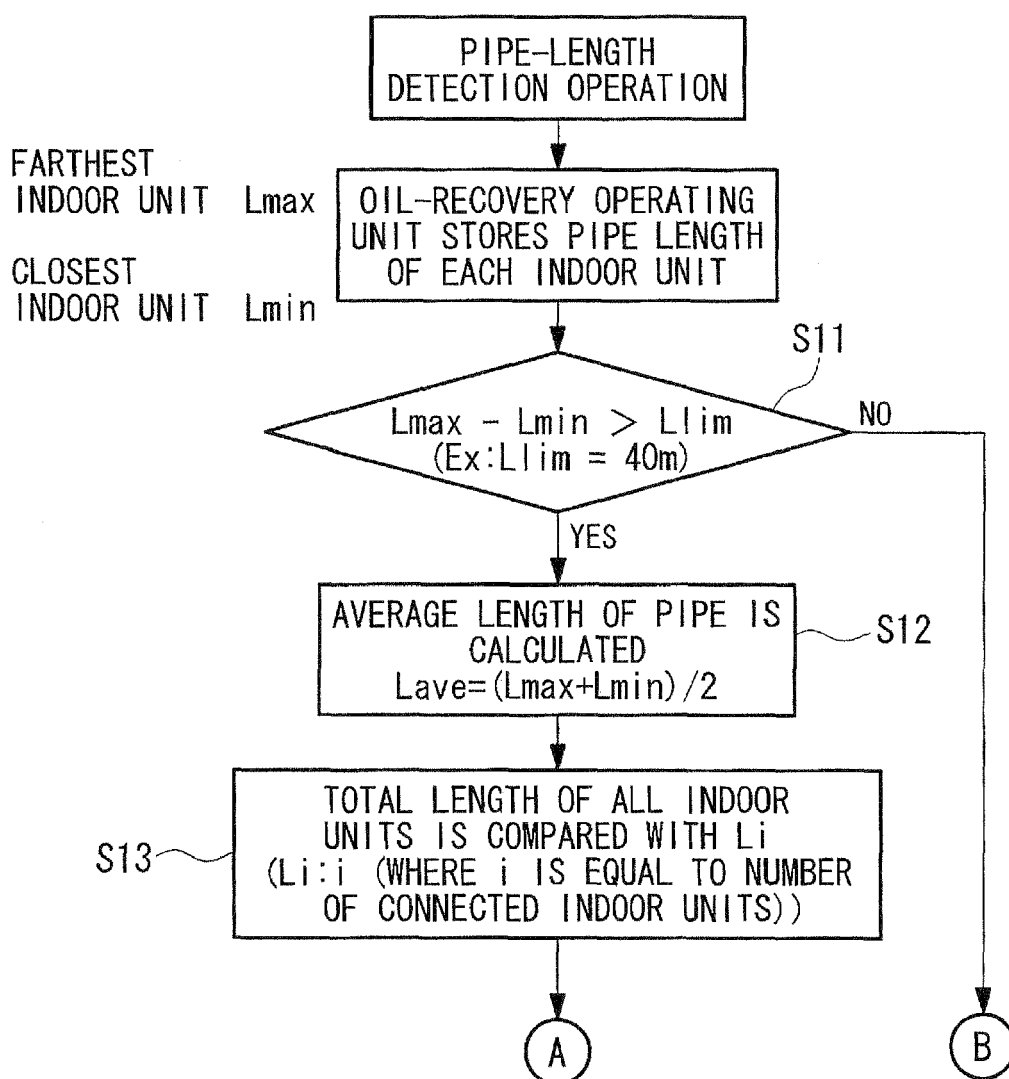
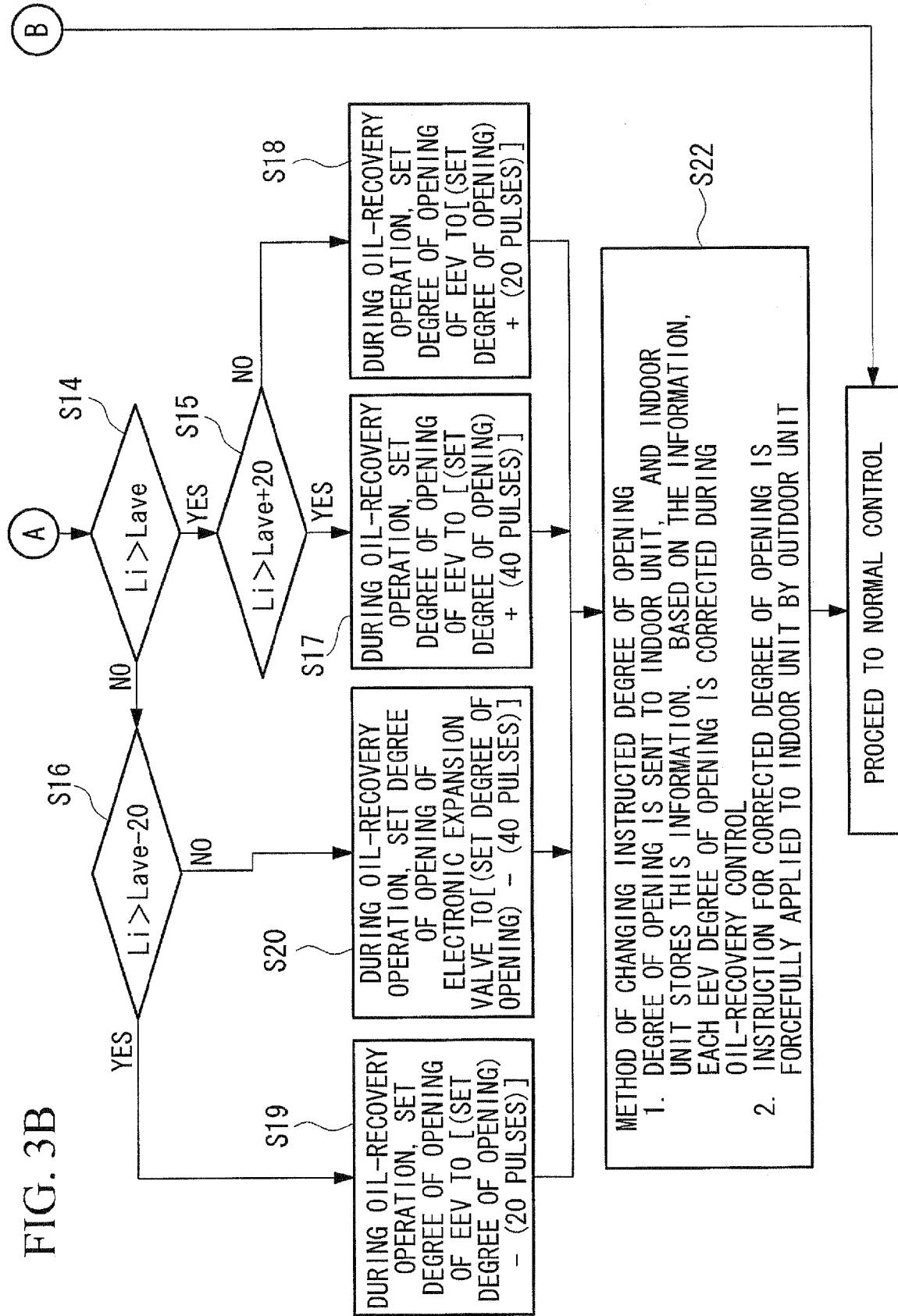


FIG. 3B



REFERENCES CITED IN THE DESCRIPTION

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