

[DESCRIPTION]

[Title of Invention]

AIR CONDITIONING SYSTEM

[Technical Field]

[0001] The present invention relates to an air conditioning system.

[Background Art]

[0002] Various air conditioning systems have been proposed in recent years (e.g., see PTL 1).

[Citation list]

[Patent Literature]

[0003]

[PTL 1] Japanese Patent No. 7068261

[Summary of Invention]

[Technical Problem]

[0004] Displacement ventilation is one way of reducing the energy required for air conditioning. Displacement ventilation air conditioning maintains thermal stratification while implementing air conditioning and reduces energy loss caused by the air conditioning of upper spaces where there is neither equipment nor humans. In such displacement ventilation, adding a swirl component, for example, to the air discharged from supply outlets located in the lower part of the air-conditioned space helps prevent occurrence of air turbulence in the air-conditioned space and more reliably maintains thermal stratification. Displacement ventilation air conditioning that

maintains thermal stratification is particularly effective relatively in high-ceilinged spaces such as factories.

[0005] In factories, machine tools and other equipment installed there generate heat, hence hot air from the heat-generating sources goes up toward the ceiling. Therefore, in an air conditioning system formed with a path that circulates air in which the air near the ceiling is cooled by an air conditioner and discharged from supply outlets in a lower part of the air-conditioned space, the heat-generating sources cause an additional load on the air conditioning system.

[0006] In view of the circumstances, one aspect of the present disclosure aims to provide an air conditioning system that reduces as much as possible the energy required for air conditioning a space that contains heat-generating sources.

[Solution to Problem]

[0007] To solve the above-described problem, according to the present invention, an outdoor air handling unit that supplies outside air to a room to be air conditioned, where heat-generating equipment is installed, includes a heating coil for a heat medium to pass therethrough after passing through a heat-absorbing coil, through which the air drawn in from the upper part of the room to be air conditioned passes.

[0008] More particularly, the present invention resides in an air conditioning system for displacement ventilation of a air-conditioned room where equipment that generates heat is installed, the system including an air conditioning outlet that

discharges air in a lower part of the air-conditioned room, an air conditioning intake that draws in air from an upper part of the air-conditioned room, a heat-absorbing coil through which the air drawn in from the air conditioning intake passes, and an outdoor air handling unit that supplies outside air to the air-conditioned room and includes a heating coil for heating the outside air by using a heat medium that has passed through the heat-absorbing coil.

[0009] According to this air conditioning system, the heat generated by the equipment installed and running in the air-conditioned room is transferred to the heat-absorbing coil via the air inside the air-conditioned room, and used to heat the heat medium that passes through the heat-absorbing coil. The heat medium, after a temperature thereof is raised by the heat of the equipment, flows from the heat-absorbing coil to the heating coil in the outdoor air handling unit to heat outside air. Thus, the air conditioning system uses heat generated by the equipment efficiently to heat the air in the outdoor air handling unit, thereby reducing the energy consumption of the entire air conditioning system.

[0010] In the air conditioning system, the heat medium, after passing through the heat-absorbing coil, flows through the heating coil in the outdoor air handling unit, where the outdoor air handling unit is used to heat the air. The circuit configuration is simpler compared to a two-step heat transfer system, for example, in which the circuit for passing the heat

medium through the heat-absorbing coil is separated from the circuit for passing the heat medium through the heating coil, with a heat pump being employed to perform heat exchange between these heat medium circuits. Thus, the energy for air conditioning required for heat transfer from the heat-absorbing coil to the heating coil is reduced as much as possible.

[0011] In the air conditioning system, the heat medium, after passing through the heat-absorbing coil, flows through the heating coil in the outdoor air handling unit, where the outdoor air handling unit is used to heat the air. This allows efficient use of the heat in the air in the upper part of the air-conditioned room to heat the air in the outdoor air handling unit compared to, for example, a system with a heat exchanger where heat is exchanged between the air in the upper part of the air-conditioned room and the outside air after dehumidified by a cooling coil in the outdoor air handling unit.

[0012] The air conditioning outlet may be provided with a fin that adds a swirl component to the outgoing air. This enables displacement ventilation by thermal stratification having a small temperature difference within the height range where air conditioning outlets are located. Compared to common displacement ventilation in which no swirl components are added to the air discharged from the air conditioning outlets, the temperature of the cool air supplied to the room to be air conditioned can be set higher. This allows reduction of the energy required for the production of cool air in the air

conditioning system.

[0013] A temperature condition may be set for a lower space of the room to be air conditioned, based on specifications of the heat-generating equipment, and the heat-absorbing coil may have a heat exchange ability to heat the heat medium to a higher temperature than the temperature condition by using the air drawn in from the air conditioning intake. This means that the heat-absorbing coil is able to exchange heat so as to raise the temperature of the heat medium flowing to the heating coil even higher. Thus, the heat generated by the equipment in the room to be air conditioned can be used as much as possible to heat the air in the outdoor air handling unit.

[0014] A heating means may be further provided in a heat medium route from the heat-absorbing coil to the heating coil to heat the heat medium in a case where the temperature of the heat medium after passing through the heat-absorbing coil is lower than a predetermined value. The predetermined temperature here refers to the temperature condition for the heat medium flowing to the heating coil, which is defined based on the temperature condition set for the room to be air conditioned, for example. This means that it is possible to supply air from the outdoor air handling unit to the room to be air conditioned at a suitable temperature even when the heat generated by the equipment in the room to be air conditioned is insufficient to heat the air in the outdoor air handling unit.

[0015] The outdoor air handling unit may further include a

cooling coil for removing humidity from outside air. The air conditioning system may further include a chiller that supplies cooling energy to the cooling coil by using the heat medium, and a cooling tower that supplies cooling water to the chiller. The cooling tower may deliver cooling water to the chiller at a temperature that enhances the operation efficiency of the chiller. This means that the cooling water delivered to the chiller need not be at the temperature suitable for heating the air in the outdoor air handling unit, hence the operation efficiency of the chiller is improved and the energy consumption of the entire air conditioning system is reduced.

[Advantageous Effects of Invention]

[0016] The above-described air conditioning system enables as much as possible the reduction of the energy required for air conditioning a space that contains heat-generating sources.

[Brief Description of Drawings]

[0017]

[Fig. 1]

Fig. 1 is a schematic diagram of an air conditioning system according to an embodiment.

[Fig. 2]

Fig. 2 is an external perspective view of an indoor unit.

[Fig. 3]

Fig. 3 is an internal configuration diagram of the indoor unit.

[Fig. 4]

Fig. 4 is a diagram illustrating a temperature gradient in height

direction inside a room to be air conditioned.

[Fig. 5]

Fig. 5 is a circuit diagram of a heat source system.

[Fig. 6]

Fig. 6 is a diagram illustrating a first modification example of the air conditioning system.

[Fig. 7]

Fig. 7 is a diagram illustrating a second modification example of the air conditioning system.

[Fig. 8]

Fig. 8 is a circuit diagram of a heat source system according to a modification example.

[Description of Embodiments]

[0018] An embodiment of the present invention is described below. The following embodiment shows examples of some aspects of the present invention and is not intended to limit the technical scope of the present invention.

[0019] <Embodiment>

Fig. 1 is a schematic diagram of an air conditioning system according to the embodiment. The air conditioning system 1 is a system that conditions air in a room to be air conditioned 2 where equipment 3 is installed. This embodiment shows a clean room with high air cleanliness requirements in a semiconductor device manufacturing factory, as one example of the room to be air conditioned 2 to which the air conditioning system 1 is applied. Various semiconductor production machines that

generate heat are set in a clean room of a factory where semiconductor devices are manufactured. In this embodiment, equipment 3 is supposed to be one of these semiconductor production machines. Semiconductor production machines include an etching apparatus, a CVD (Chemical Vapor Deposition) apparatus, and so on. While Fig. 1 shows two pieces of equipment 3, there may be any number of equipment 3 in the room to be air conditioned 2. The application of the air conditioning system 1 of this embodiment is not limited to such a semiconductor manufacturing factory. For example, the system may be applied to factories manufacturing lithium-ion batteries, high-precision optical devices, or any of various other industrial products.

[0020] The room to be air conditioned 2 is required to meet temperature conditions specified for the equipment 3 by conditioning the air using the air conditioning system 1. When the equipment 3 is installed on the floor surface of the room to be air conditioned 2 as shown in Fig. 1, it is basically the ambient air around the equipment 3 that needs to meet temperature conditions. There is no need to condition the atmosphere of the space above the equipment 3 to meet the temperature conditions. Therefore, the air conditioning system 1 of this embodiment adopts a displacement ventilation method to reduce as much as possible the energy required for air conditioning the room to be air conditioned 2. Namely, the air conditioning system 1 includes an air supply unit 4 for supplying outside air to the

room to be air conditioned 2 after processing it in an outdoor air handling unit 6, and additionally, an indoor unit 5, which draws in air from an upper part of the room to be air conditioned 2, cools it, and discharges it in a lower part of the room to be air conditioned 2. Fig. 1 shows one each air supply unit 4 and indoor unit 5 near a wall of the room to be air conditioned 2. Alternatively, the air supply unit 4 and the indoor unit 5 may be positioned away from the wall, or, two or more of each of them may be provided.

[0021] The system configuration of the air conditioning system 1 is described in detail below.

[0022] The outdoor air handling unit 6 is a unit that purifies and supplies outdoor air to the air supply unit 4 via a duct 7 after adjusting the temperature and humidity. The unit includes a filter 6A, a heating coil 6B, a cooling coil 6C, a reheat coil 6D, and an electric fan 6E. The filter 6A catches foreign matter, such as dust and dirt, in the air. The heating coil 6B heats the air taken into the outdoor air handling unit 6. The cooling coil 6C removes humidity from the air by cooling it. The reheat coil 6D heats the air that has been cooled by the cooling coil 6C, ensuring that it reaches the appropriate temperature to be supplied to the room to be air conditioned 2. The electric fan 6E feeds the air by rotating a fan powered by an electric motor.

[0023] The air supply unit 4 is a unit that discharges the processed air from the outdoor air handling unit 6 into the room

to be air conditioned 2, and includes air conditioning outlets for the air to come out, and a filter 4C for purifying the outgoing air. Since the air conditioning system 1 adopts displacement ventilation, the air supply unit 4 is configured to discharge air horizontally (parallel to the floor surface), and installed on the floor surface of the room to be air conditioned 2.

[0024] The indoor unit 5 is a device that draws in air from an upper part of the room to be air conditioned 2, cools it, and discharges it in a lower part of the room to be air conditioned 2. The unit includes an electric fan 5A and a heat-absorbing coil 5B. The indoor unit 5 also includes a filter 5C for purifying the outgoing air. Since the air conditioning system 1 adopts displacement ventilation, the indoor unit 5 is configured to discharge air horizontally and installed on the floor surface of the room to be air conditioned 2, similarly to the air supply unit 4.

[0025] Fig. 2 is an external perspective view of the indoor unit 5. Fig. 3 is an internal configuration diagram of the indoor unit 5. As shown in Fig. 2, the indoor unit 5 has an air conditioning intake 5D on its top surface. The indoor unit 5 has air conditioning outlets 5E on its front surface. The electric fan 5A produces suction that pulls air from the upper part of the room to be air conditioned 2 into the air conditioning intake 5D. The air is discharged by the electric fan 5A from the air conditioning outlets 5E.

[0026] As can be seen from Fig. 2, there are multiple circular air conditioning outlets 5E arrayed vertically and horizontally on the front surface of the indoor unit 5. The air conditioning outlets 5E are arranged along the height and width on the front of the indoor unit 5, with spacing from each other. Each air conditioning outlet 5E is provided with radial fins that are circumferentially equally spaced around the center axis thereof for creating a swirl flow around the center of the air conditioning outlet 5E. These fins provided around the center of the air conditioning outlet 5E are inclined relative to the center axis of the air conditioning outlet 5E. This imparts swirl components to the air discharged from the air conditioning outlet 5E to swirl around the center axis passing through the center of the air conditioning outlet 5E, allowing entrainment of the air around the air conditioning outlet 5E in the room to be air conditioned 2.

[0027] Among the plurality of the fins of the air conditioning outlets 5E, the fins of the air conditioning outlets 5E that are vertically adjacent each other are oriented oppositely so that their swirl components imparted to cool air are in opposite directions. For example, in the case where the air conditioning outlets 5E at the top line are to impart a counterclockwise swirl component to the air as indicated by the thin arrows in Fig. 2, the air conditioning outlets 5E in the second line from the top are to impart a clockwise swirl component to the air. Therefore, in the air conditioning outlets

5E, the air conditioning outlets 5E in the top line and the air conditioning outlets 5E in the second line from the top generate swirl components that are in the same direction (rightward in Fig. 2), with the respective swirl components enhancing each other. In this case, the air conditioning outlets 5E in the third line from the top are to impart a counterclockwise swirl component to the cool air. Therefore, with regard to the air conditioning outlets 5E in the second line from the top and the air conditioning outlets 5E in the third line from the top, the air conditioning outlets 5E in the second line from the top and the air conditioning outlets 5E in the third line from the top generate swirl components that are in the same direction (leftward in Fig. 2), with the respective swirl components enhancing each other.

[0028] Consequently, the amount of air entrainment (entrainment ratio) of the air around the air conditioning outlets 5E in the room to be air conditioned 2 entrained in the cool air coming out from the air conditioning outlets 5E is increased. Thus, the cool air can be diffused toward the front of the indoor unit 5 in the room to be air conditioned 2. This allows the air to be discharged with less draftiness, as compared to the case where no swirl components are added to the cool air. This also realizes displacement ventilation by thermal stratification with a small temperature difference between upper and lower sides, in the space between the heights of the lowest air conditioning outlets 5E and the highest air conditioning

outlets 5E in the room to be air conditioned 2.

[0029] Fig. 4 is a diagram illustrating a temperature gradient in height direction inside the room to be air conditioned 2. In Fig. 4, the solid line in the graph shows the temperature gradient with the use of the air conditioning system 1 of this embodiment, and the one-dot chain line shows a temperature gradient with a common displacement ventilation system in which no swirl components are added to cool air. The air conditioning system 1 of this embodiment uses the indoor unit 5 with air conditioning outlets 5E that impart swirl components to the air. Therefore, as shown by the solid line in the graph in Fig. 4, the system can realize displacement ventilation by thermal stratification with a small temperature difference in the space between the heights of the lowest air conditioning outlets 5E and the highest air conditioning outlets 5E in the room to be air conditioned 2. On the other hand, common displacement ventilation where no swirl components are added to cool air inevitably creates thermal layers with a large temperature difference. This is because the temperature of the cool air discharged into the lower zone of the room to be air conditioned 2 would have to be lower than the cool air discharged from the air conditioning outlets 5E of the air conditioning system 1 as indicated by the one-dot chain line in the graph in Fig. 4, in order to meet the preset temperature condition for the upper zone. Therefore, with common displacement ventilation, it is difficult to regulate the air to temperatures

equal to or lower than the upper limit and equal to or higher than the lower limit within the zone for which a temperature condition is preset with a relatively small difference between the upper and lower limits. The air conditioning system 1 of this embodiment that uses cool air imparted with swirl components allows displacement ventilation with a small temperature difference between the upper and lower layers. Therefore, even when the temperature condition is set within a relatively small range for a zone, the system can regulate the air to temperatures equal to or lower than the upper limit and equal to or higher than the lower limit within that zone. Displacement ventilation using air flows without swirl components requires a large amount of blown air to meet a temperature condition. The air conditioning system 1 of this embodiment, which uses air flows with swirl components can meet a temperature condition with a reduced amount of blown air. Thus, the energy associated with blowing air throughout the entire air conditioning system 1 can be reduced. Since the cool air imparted with swirl components allows displacement ventilation with a small temperature difference between the upper and lower layers, a temperature condition can be met even if the temperature of the outgoing air is set higher than in common displacement ventilation without swirl components. Raising the temperature of outgoing air equals raising the temperature of the heat medium passed through the heat-absorbing coil 5B, which enables an increase in heat source efficiency.

The reduced amount of blown air results in a higher temperature of the heat medium after it has passed through the heat-absorbing coil 5B, which absorbs the heat in the upper space of the room to be air conditioned 2. This facilitates more efficient heating of outside air with the heat of the heat medium after it has passed through the heat-absorbing coil 5B as will be described later.

[0030] Next, the heat source system of the air conditioning system 1 is described. Fig. 5 is a circuit diagram of the heat source system. The air conditioning system 1 includes a heat source system 8 such as the one shown in Fig. 5. The heat source system 8 includes, for example, a heat medium circuit 8A, a cooling water circuit 8B, and a hot water circuit 8C.

[0031] The heat medium circuit 8A is a circuit that circulates a heat medium to deliver cooling or heating energy to the equipment that handles the conditioning air, such as the indoor unit 5 and the outdoor air handling unit 6. The heat medium circuit 8A includes a chiller 8A1 for producing cooling energy, a heat medium circulation pump 8A2 for circulating the heat medium, a heat medium supply header 8A3 for feeding the heat medium to various air-conditioning units, and a heat medium return header 8A4 to which the heat medium returns after being distributed to various units of the system. In the heat medium circuit 8A, the heat medium that has passed through the evaporator in the chiller 8A1 is delivered to the heat medium supply header 8A3 by the heat medium circulation pump 8A2, which

is provided midway in heat medium piping 8A10 connecting the chiller 8A1 and the heat medium supply header 8A3. The heat medium delivered to the heat medium supply header 8A3 flows into heat medium piping 8A12 that leads to the heat-absorbing coil 5B of the indoor unit 5, or heat medium piping 8A13 that leads to the cooling coil 6C of the outdoor air handling unit 6. The heat medium that flowed to the heat-absorbing coil 5B of the indoor unit 5 returns to the heat medium return header 8A4 through heat medium piping 8A15. The heat medium that flowed to the cooling coil 6C of the outdoor air handling unit 6 returns to the heat medium return header 8A4 through heat medium piping 8A16. The heat medium that returned to the heat medium return header 8A4 again passes through the evaporator of the chiller 8A1 via heat medium piping 8A11. While the heat medium circuit 8A shown in Fig. 5 has only one each of the indoor unit 5, outdoor air handling unit 6, and chiller 8A1, there may be any number of units, valves, piping, or pumps in the heat medium circuit 8A.

[0032] The cooling water circuit 8B is a circuit that circulates cooling water for cooling the condenser of the chiller 8A1 in the heat medium circuit 8A. The cooling water circuit 8B includes a cooling water circulation pump 8B1 for circulating the cooling water, and a cooling tower 8B2 for cooling the cooling water. In the cooling water circuit 8B, the heat medium that has passed through the condenser in the chiller 8A1 is delivered to the cooling tower 8B2 by the cooling water

circulation pump 8B1 that is provided midway in cooling water piping 8B4 connecting the chiller 8A1 and the cooling tower 8B2. The cooling water delivered to the cooling tower 8B2 drops down from the top in the cooling tower 8B2 and accumulates at the bottom of the cooling tower 8B2. The cooling water accumulated at the bottom of the cooling tower 8B2 flows back to the condenser of the chiller 8A1 via cooling water piping 8B3. An electric fan is provided in the cooling tower 8B2 to create an upward current inside. The electric fan is operated and stopped according to the temperature of the cooling water flowing through the cooling water piping 8B3, thereby cooling it by the principle of evaporation. The electric fan is controlled to start and stop to adjust the temperature of the cooling water flowing through the cooling water piping 8B3, preferably to maximize the operation efficiency of the chiller 8A1. The cooling tower 8B2 is equipped with a water supply means that uses a ball tap valve or similar device to replenish the cooling water and maintain a constant level of the cooling water accumulated at the bottom of the cooling tower 8B2. While the cooling water circuit 8B shown in Fig. 5 has only one each of the chiller 8A1, cooling tower 8B2, and cooling water circulation pump 8B1, there may be any number of units, valves, piping, or pumps in the cooling water circuit 8B.

[0033] The hot water circuit 8C is a circuit that delivers hot water to various parts of the building where the air conditioning system 1 is installed. The hot water circuit 8C

employs a suitable heating energy source. The hot water circuit 8C may utilize various heating energy sources, including heat generators such as heat pumps and boilers, or waste heat generated in utility equipment such as compressors.

[0034] Air conditioning equipment generally uses heating energy such as the heat produced in the hot water circuit 8C to heat the air. In the air conditioning system 1 of this embodiment, the heat medium that has passed through the heat-absorbing coil 5B is sent to the heating coil 6B and reheat coil 6D of the outdoor air handling unit 6 that processes outside air, to reduce the energy required to heat the air. Namely, as shown in the circuit diagram of Fig. 5, heat medium piping 8A14 is connected midway in the heat medium piping 8A15 that connects the heat-absorbing coil 5B and the heat medium return header 8A4, forming a branching route for the heat medium to flow to the heating coil 6B and the reheat coil 6D. The heat medium split into the heat medium piping 8A14 flows further through heat medium piping 8A18 to the heating coil 6B and the reheat coil 6D. The heat medium that passed through the heating coil 6B and the reheat coil 6D flows back to the heat medium piping 8A15 via heating medium piping 8A19 to return to the heat medium return header 8A4.

[0035] As described above, the heat medium circuit 8A of the heat source system 8 includes a route that delivers the heat medium that has passed through the heat-absorbing coil 5B to the heating coil 6B and the reheat coil 6D. Therefore, the heat

generated by each equipment 3 installed and running in the room to be air conditioned 2 is transmitted to the heat-absorbing coil 5B via the air inside the room to be air conditioned 2, and used to heat the heat medium passing through the heat-absorbing coil 5B. Since the heat medium circuit 8A includes a route that delivers the heat medium that has passed through the heat-absorbing coil 5B to the heating coil 6B and the reheat coil 6D, the heat medium flows from the heat-absorbing coil 5B to the heating coil 6B and the reheat coil 6D after its temperature has been raised by the heat from the equipment 3. The heat medium in the heating coil 6B then heats the outside air, while the heat medium in the reheat coil 6D heats the outside air that has been dehumidified and cooled by the cooling coil 6C. In the air conditioning system 1, the heat generated by the equipment 3 is efficiently used in this way to heat the outside air taken into the outdoor air handling unit 6, and to heat the air after dehumidified by the cooling coil 6C, so that the energy consumption of the entire air conditioning system 1 is reduced. In such a mechanism for efficient use of heat, the heat-absorbing coil 5B should, from the perspective of heat usage, preferably have a heat exchange ability to heat the heat medium to a temperature higher than the preset temperature condition for the lower space of the room to be air conditioned 2.

[0036] In the heat medium circuit 8A of this embodiment, the heat medium, after passing through the heat-absorbing coil 5B, flows through the heating coil 6B and the reheat coil 6D of the

outdoor air handling unit 6, thereby being used to heat the air in the outdoor air handling unit 6. The circuit configuration is simpler compared to a two-step heat transfer system, for example, in which the circuit for passing the heat medium through the heat-absorbing coil 5B is separated from the circuit for passing the heat medium through the heating coil 6B and reheat coil 6D, with a heat pump performing heat exchange between these heat medium circuits. Thus, the energy required for heat transfer from the heat-absorbing coil 5B to the reheat coil 6D is reduced as much as possible.

[0037] In the heat medium circuit 8A of this embodiment, the heat medium, after passing through the heat-absorbing coil 5B, flows through the heating coil 6B and the reheat coil 6D of the outdoor air handling unit 6, thereby being used to heat the air in the outdoor air handling unit 6. This allows efficient use of the heat in the air in the upper part of the room to be air conditioned 2 to heat the air in the outdoor air handling unit 6 compared to, for example, a system with a heat exchanger where heat is exchanged between the air in the upper part of the room to be air conditioned 2 and the outside air taken into the outdoor air handling unit 6 or the outside air after dehumidified by the cooling coil 6C in the outdoor air handling unit 6.

[0038] The heat medium circuit 8A is equipped with control valves 8A8 and 8A9 to adjust the flow amount of the heat medium passing through the reheat coil 6D, in order to prevent excessive cooling of the air passing through the reheat coil 6D. The

degree of opening of the control valves 8A8 and 8A9 is adjusted based on the temperature of the heat medium that has passed through the reheat coil 6D measured by a temperature sensor 8A7. For example, if the measurement value of the temperature sensor 8A7 is higher than the preset value, the degree of opening of the control valve 8A8 is decreased, while the degree of opening of the control valve 8A9 is increased. Alternatively, for example, if the measurement value of the temperature sensor 8A7 is lower than the preset value, the degree of opening of the control valve 8A8 is increased, while the degree of opening of the control valve 8A9 is decreased. In this way, the air that has passed through the reheat coil 6D is adjusted to an appropriate temperature.

[0039] For reasons such as the equipment 3 being stopped or having just started, the heat from the equipment 3 may sometimes be insufficient to heat the heat medium passing through the heat-absorbing coil 5B. For such a situation, the heat source system 8 further includes a means of heating the heat medium flowing from the heat-absorbing coil 5B to the heating coil 6B and the reheat coil 6D using the heat of hot water in the hot water circuit 8C. Namely, the heat source system 8 includes a heat exchanger 8C2 between the heat medium piping 8A14 and heat medium piping 8A18 of the heat medium circuit 8A for heat exchange with the hot water in the heat source system 8, and a control valve 8A17 in a bypass route for increasing or decreasing the flow amount of the heat medium passing through the heat

exchanger 8C2. The hot water circuit 8C further includes a control valve 8C1 for adjusting the flow amount of hot water in the heat exchanger 8C2 based on the temperature of the heat medium flowing from the heat exchanger 8C2 to the heat medium piping 8A18 measured by a temperature sensor 8A6 so as to regulate the heat medium that has passed through the heat exchanger 8C2 to a predetermined temperature. The heat medium piping 8A14 is equipped with a heat medium booster pump 8A5 to compensate for a shortage in the flow amount caused by the pressure loss when the heat medium passes through the heat exchanger 8C2. The degree of opening of the control valve 8A17 is increased or decreased to adjust the pressure difference between the heat medium piping 8A14 and the heat medium piping 8A18 to control the flow amount of the heat medium passing through the heating coil 6B and the reheat coil 6D. For example, when the heat generated by the equipment 3 is insufficient to heat the heat medium passing through the heat-absorbing coil 5B, the heat medium that has passed through the heat-absorbing coil 5B may be below the predetermined temperature. In this case, the degree of opening of the control valve 8C1 is increased until the heat medium that has passed through the heat exchanger 8C2 reaches the predetermined temperature. This allows the heat medium flowing from the heat-absorbing coil 5B to the heating coil 6B and the reheat coil 6D to be heated with the heat of the hot water in the hot water circuit 8C. For example, when the heat generated by the equipment 3 sufficiently heats the heat

medium passing through the heat-absorbing coil 5B, the heat medium that has passed through the heat-absorbing coil 5B may be equal to or higher than the predetermined temperature. In this case, the degree of opening of the control valve 8C1 is decreased so that the heat medium that has passed through the heat exchanger 8C2 will be below the predetermined temperature. The control valve 8C1 is eventually closed, stopping the hot water in the hot water circuit 8C from heating the heat medium flowing from the heat-absorbing coil 5B to the heating coil 6B and the reheat coil 6D. With the heat source system 8 configured as described above, the air conditioning system 1 is able to reduce the air conditioning energy consumption of the entire air conditioning system during the operation of the equipment 3, and to supply air of a suitable temperature from the outdoor air handling unit 6 to the room to be air conditioned 2 when the equipment 3 is stopped or has just started.

[0040] One example of a system design will be described in which the temperature setting for the heat medium in the heat medium supply header 8A3 is 14°C as shown in Fig. 5. When the target temperature of the heat medium set in the controller of the chiller 8A1 is 14°C, the heat medium in the heat medium supply header 8A3 is at 14°C. As described above, the heat medium at 14°C in the heat medium supply header 8A3 is delivered to the heat-absorbing coil 5B of the indoor unit 5, or to the cooling coil 6C of the outdoor air handling unit 6. The heat medium at 14°C sent to the cooling coil 6C of the outdoor air

handling unit 6 cools the outside air as it is drawn into the outdoor air handling unit 6 by the electric fan 6E.

[0041] Meanwhile, the heat medium at 14°C sent to the heat-absorbing coil 5B of the indoor unit 5 cools the air in the room to be air conditioned 2 drawn into the indoor unit 5 by the electric fan 5A, thereby being heated to about 26°C, for example. The heat medium heated to about 26°C by the heat-absorbing coil 5B is delivered from the heat-absorbing coil 5B to the heating coil 6B and the reheat coil 6D as described above. Therefore, in the outdoor air handling unit 6 the outside air flowing into the outdoor air handling unit 6 is heated by the heat medium at 26°C in the heating coil 6B. In the outdoor air handling unit 6, the outside air that has been cooled with the heat medium at 14°C in the cooling coil 6C is heated by the heat medium at 26°C in the reheat coil 6D.

[0042] In the air conditioning system 1 of this embodiment, as described above, the heat medium that is split at the heat medium supply header 8A3 to the indoor unit 5 and the outdoor air handling unit 6 is not just returned to the heat medium return header 8A4, but part of the heat medium that has passed through the indoor unit 5 is used in the heating process in the outdoor air handling unit 6. This way, the energy required for heat transfer is reduced as much as possible, and the heat contained in the air in the room to be air conditioned 2 is efficiently used, with a simple circuit configuration.

[0043] With common displacement ventilation, it was

difficult to regulate the air to temperatures equal to or lower than the upper limit and equal to or higher than the lower limit within a zone for which temperature conditions are preset with a relatively small difference between the upper and lower limits. Therefore, a common displacement ventilation system could hardly be applied to a place with strict temperature requirements such as a clean room in a semiconductor manufacturing factory (where the temperature must be regulated to, e.g., $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$). The air conditioning system 1 of this embodiment allows displacement ventilation with a small temperature difference between upper and lower layers by using cool air imparted with swirl components. Therefore, the system is able to maintain the air to temperatures equal to or lower than the upper limit and equal to or higher than the lower limit within a zone for which the temperature condition is set with a relatively small difference between the upper and lower limits. Thus, the system can be applied to places with strict temperature conditions.

[0044] According to the air conditioning system 1 of the embodiment, the cool air imparted with swirl components allows displacement ventilation with a small temperature difference between the upper and lower layers. Therefore, the temperature condition can be met even if the temperature of the outgoing air is set higher than in common displacement ventilation without swirl components. With common displacement ventilation in which no swirl components are added, when the temperature of the air

supplied from the indoor unit is set to 19°C to 20°C, it was not possible to bring the temperature to not higher than the upper limit in the zone for which the preset temperature condition is 23°C ± 3°C, for example. In contrast, the air conditioning system 1 of this embodiment that uses cool air imparted with swirl components allows displacement ventilation with a small temperature difference between the upper and lower layers. Therefore, even when the air supplied from the indoor unit 5 is at a temperature of 19°C to 20°C, the system can maintain the air temperature at not higher than the upper limit in the zone for which the preset temperature condition is 23°C ± 3°C. Thus, even though the temperature of the heat medium supplied from the heat medium supply header 8A3 to the indoor unit 5 is relatively high at 14°C, it is possible to adjust the temperature of a zone to not higher than the upper limit of its preset temperature condition.

[0045] The heat medium circuit 8A allowing a relatively high temperature range to be set, i.e., at 14°C for the heat medium supplied from the chiller 8A1, means that the chiller 8A1 can operate with a lower load, hence the power for operation of the chiller 8A1 can be reduced. Consequently, the entire heat medium circuit 8A can be operated with high efficiency.

[0046] As an alternative heat source, for example, the heat that was carried by the cooling water coming out of the chiller 8A1 in the cooling water circuit 8B could be used in the heating coil 6B and the reheat coil 6D. However, in this case, the

cooling water would have to be kept in a relatively high temperature range (e.g., 32°C) in the cooling water circuit 8B in order to properly heat the outside air in the outdoor air handling unit 6. Maintaining the cooling water in such a high temperature range in the cooling water circuit 8B would lower the condensation ability of the condenser in the chiller 8A1 and compromise the operation efficiency of the chiller 8A1. In this regard, the air conditioning system 1 of this embodiment, which uses the heat of the heat medium that has passed through the heat-absorbing coil 5B as the source of the heat used in the heating coil 6B and the reheat coil 6D enables the use of the cooling water, which is in the cooling water circuit 8B, in a temperature range suitable for the operation efficiency of the chiller 8A1. Namely, the air conditioning system 1 of this embodiment allows the use of the cooling water in the cooling water circuit 8B within a low temperature range suitable for the condenser of the chiller 8A1 to fully exhibit its condensation performance. Thus, the chiller 8A1 can be operated with high efficiency.

[0047] The air conditioning system 1 of this embodiment is supposed to be applied to a room to be air conditioned 2 in which the air temperature in the upper part ranges approximately from 30°C to 35°C, which will depend on the heat emission from the equipment 3 in the room to be air conditioned 2 or the insulation performance of the building. As the waste heat discharged from various types of equipment, this is relatively

low. In general, it is difficult to collect heating energy from the waste heat in this temperature range using a heat medium such as hot water. The air conditioning system 1 of the embodiment is built on the finding that the waste heat of even this temperature range can be collected using a heat medium flowing through the heat-absorbing coil 5B in the indoor unit 5, focusing on an observation that a temperature condition can be met using air of a higher temperature than in common displacement ventilation by using air currents imparted with swirl components. The use of waste heat of such a temperature range for the heating of outside air in the outdoor air handling unit 6 is made possible only through the configuration that allows a temperature condition to be met using higher temperature air by making use of currents with swirl components in displacement ventilation. Such efficient use of heat is not feasible with common displacement ventilation.

[0048] The above embodiment was described on the premise that humidity is removed from the outside air by the cooling coil 6C in the outdoor air handling unit 6. This dehumidification process may be performed only during the summer months, for example, when humidity is high, and may be omitted during the winter months when humidity is low. If the air conditioning system 1 is to omit the dehumidification process during the winter months, for example, the heat medium may be stopped from flowing through the cooling coil 6C by closing the valve, and the outside air may be heated using only the heating coil 6B and

reheat coil 6D.

[0049] In the embodiment described above, the outdoor air handling unit 6 includes both the heating coil 6B and the reheat coil 6D. Instead, for example, the heating coil 6B may be omitted from the outdoor air handling unit 6 in the air conditioning system 1. In this case, the reheat coil 6D will be the example of the "heating coil" as described herein, as reheating is considered as a way of heating.

[0050] <Modification Examples>

Fig. 6 is a diagram illustrating a first modification example of the air conditioning system 1. The air conditioning system 1 of the embodiment described above may be modified as shown in Fig. 6, for example, in which the air in the room to be air conditioned 2 is drawn in from air conditioning intakes in the ceiling, processed in an air conditioner inside or outside the room to be air conditioned 2, and discharged from air conditioning outlets of the air supply unit 4. With this modification example, it is also possible to use the heat from the equipment 3 in the air drawn in from the air conditioning intakes in the ceiling of the room to be air conditioned 2 for the air heating process in the outdoor air handling unit 6. Therefore, the heat generated by the equipment 3 will be efficiently used to heat the outside air taken into the outdoor air handling unit 6, and to heat the air that has been dehumidified by the cooling coil 6C, so that the energy consumption of the entire air conditioning system 1 can be

reduced. In the first modification example, too, the heat medium may be used only for the heating of the outside air in the heating coil 6B and reheat coil 6D during the winter months when dehumidification is not necessary, by closing the valve to stop the flow of the heat medium to the cooling coil 6C, similarly to the embodiment described above.

[0051] Fig. 7 is a diagram illustrating a second modification example of the air conditioning system 1. The air conditioning system 1 of the embodiment described above may be modified, for example, such as to deliver the cool air from the outdoor air handling unit 6 to the indoor unit 5 instead of the air supply unit 4. With this modification example, it is also possible to use the heat from the equipment 3, which is contained in the air drawn into the indoor unit 5, to heat the air in the outdoor air handling unit 6. Therefore, the heat generated by the equipment 3 will be efficiently used to heat the outside air taken into the outdoor air handling unit 6, and to heat the air that has been dehumidified by the cooling coil 6C, so that the energy consumption of the entire air conditioning system 1 can be reduced. In the second modification example, too, the heat medium may be used only for the heating of the outside air in the heating coil 6B and reheat coil 6D during the winter months when dehumidification is not necessary, by closing the valve to stop the flow of the heat medium to the cooling coil 6C, similarly to the embodiment described above.

[0052] Fig. 8 is a circuit diagram of a heat source system

according to a modification example. The heat source system 8 of the air conditioning system 1 may be modified as shown in Fig. 8, for example. Namely, the heat source system 8 may include, in addition to the indoor unit 51 that corresponds to the indoor unit 5 described above, another indoor unit 52, in which the heat medium that has passed through the heat-absorbing coil 5B returns directly to the heat medium return header 8A4 without passing through the outdoor air handling unit 6. In applications where the room to be air conditioned 2 processed by the air conditioning system 1 is a vast space where multiple indoor units 5 are installed, the temperature of the air drawn into the indoor units 5 may vary largely depending on the layout of the equipment 3 and indoor units 5. For example, the indoor unit 52 may be arranged in a place where the temperature of the incoming air is relatively low in the room to be air conditioned 2, while the indoor unit 51 may be arranged in a place where the temperature of the incoming air is relatively high in the room to be air conditioned 2. This will allow efficient use of the heat generated by the equipment 3, and reduce the energy consumption of the entire air conditioning system 1.

[0053] The heat source system 8 of the air conditioning system 1 may further include, in addition to the heat medium circuit 8A, a chilled water circuit for cooling the air flowing into the outdoor air handling unit 6 to a lower temperature than the cooling coil 6C. The outdoor air handling unit 6 may include a cooling coil for passing the cool water of this chilled water

circuit. With such a chilled water circuit and a cooling coil, the air conditioning system 1 can introduce low-humidity air into the room to be air conditioned 2 even when the outside air has high humidity due to weather conditions, for example, while the outside air to be introduced into the room to be air conditioned 2 need to meet low humidity requirements.

[0054] The air conditioning system 1 may be modified in other ways. For example, in the air conditioning system 1 of the embodiment described above, the heat source system 8 includes a means of heating the heat medium flowing from the heat-absorbing coil 5B to the heating coil 6B and the reheat coil 6D using the heat of the hot water in the hot water circuit 8C, in case the heat generated by the equipment 3 is insufficient to heat the heat medium passing through the heat-absorbing coil 5B. Such a heating means may be omitted. Alternatively, the system may be designed such that the hot water circuit 8C directly heats the air, by passing the hot water of the hot water circuit 8C through a coil inside the outdoor air handling unit 6.

[Reference Signs List]

[0055]

- 1 Air conditioning system
- 2 Room to be air conditioned
- 3 Equipment
- 4 Air supply unit
- 4C Filter
- 5 Indoor unit

5A Electric fan

5B Heat-absorbing coil

5C Filter

5D Air conditioning intake

5E Air conditioning outlet

6 Outdoor air handling unit

6A Filter

6B Heating coil

6C Cooling coil

6D Reheat coil

6E Electric fan

7 Duct

8 Heat source system

8A Heat medium circuit

8B Cooling water circuit

8C Hot water circuit

8A1 Chiller

8A2 Heat medium circulation pump

8A3 Heat medium supply header

8A4 Heat medium return header

8A5 Heat medium booster pump

8A6, 8A7 Temperature sensor

8A8, 8A9, 8A17 Control valve

8A10 to 8A16, 8A18, 8A19 Heat medium piping

8B1 Cooling water circulation pump

8B2 Cooling tower

8B3, 8B4 Cooling water piping

8C1 Control valve

8C2 Heat exchanger

8C3, 8C4 Hot water piping

[CLAIMS]

[Claim 1]

An air conditioning system for displacement ventilation of a room to be air conditioned where equipment that generates heat is installed, the system comprising:

an air conditioning outlet that discharges air in a lower part of the room to be air conditioned,

an air conditioning intake that draws in air in an upper part of the room to be air conditioned,

a heat-absorbing coil through which air drawn in from the air conditioning intake passes, and

an outdoor air handling unit that supplies outside air to the room to be air conditioned and includes a heating coil to heat outside air by using a heat medium that has passed through the heat-absorbing coil.

[Claim 2]

The air conditioning system according to claim 1, wherein the air conditioning outlet is provided with a fin that adds a swirl component to the outgoing air.

[Claim 3]

The air conditioning system according to claim 2, wherein a temperature condition is set for a lower space of the room to be air conditioned, based on a specification of the heat-generating equipment, and

the heat-absorbing coil has a heat exchange ability to heat the heat medium to a higher temperature than the temperature condition by using air drawn in from the air conditioning intake.

[Claim 4]

The air conditioning system according to claim 3, wherein a heating means is provided in a heat medium route from the heat-absorbing coil to the heating coil so as to heat the heat medium in a case where the heat medium after passing through the heat-absorbing coil is at a temperature below a predetermined value.

[Claim 5]

The air conditioning system according to claim 3, wherein the outdoor air handling unit may further include a cooling coil for removing humidity from outside air, and

the air conditioning system further include

a chiller that supplies cooling energy to the cooling coil by using the heat medium, and

a cooling tower that supplies cooling water to the chiller, wherein

the cooling tower is configured to deliver the cooling water to the chiller at a temperature that enhances operation efficiency of the chiller.