

Liquid Temperature-Control Apparatus and Method

Technical Field

The present application relates to the field of refrigeration and, in particular, to a liquid temperature control apparatus and method.

Background

Existing photolithography tools usually do not perform well in terms of energy saving because they use heaters for liquid temperature control and rely on the heaters' duty ratios for control accuracy. In the field of refrigeration, there are known systems for condensing heat recovery, which typically recover heat by a dedicated condenser added between an outlet of the internal compressor and condenser of the refrigeration unit. The recovered heat is directly used to heat supply with the accuracy typically of ± 1 °C. In order to achieve the control with a high accuracy, the addition of more complicated components for refrigerant flow control in the refrigeration unit are required, leading to a higher structural complexity, greater capacity and lower reliability.

Summary

The present application provides a liquid temperature control apparatus and method to overcome the problem of high structural complexity that accompanies high control accuracy arising from the use of conventional refrigeration units.

To this end, the liquid temperature control apparatus provided in the present application comprises:

- a circulating refrigeration unit, configured to provide heat and cold to an object to be cooled;

- a circulating cold consuming unit coupled to the circulating refrigeration unit, configured to cool the object;

- a heat exchange unit, configured for heat exchange between the circulating

refrigeration unit and the circulating cold consuming unit; and

a temperature detection and control unit, configured to monitor temperatures of the circulating refrigeration unit and the circulating cold consuming unit.

Preferably, a heat output port of the circulating refrigeration unit may be configured to provide the circulating cold consuming unit with heat.

Preferably, the heat exchange unit may comprise a first heat exchange module and a second heat exchange module, wherein the circulating refrigeration unit and the first heat exchange module are configured to provide cold to the circulating cold consuming unit, and the circulating refrigeration unit and the second heat exchange module are configured to provide heat to the circulating cold consuming unit.

Preferably, the heat output port of the circulating refrigeration unit may be coupled to a three-way valve, the three-way valve having a water outlet coupled to the second heat exchange module and another water outlet serving as a bypass outlet.

Preferably, the temperature detection and control unit may be configured to regulate a heat supply of the circulating refrigeration unit through control of the three-way valve.

Preferably, the temperature detection and control unit may be arranged at the heat output port and/or a cold output port of the circulating refrigeration unit.

Preferably, the temperature detection and control unit may be arranged in the circulating cold consuming unit in order to detect and regulate the refrigeration of the object to be cooled.

Preferably, the circulating refrigeration unit may comprise a condenser, an expansion valve, a first heat exchange module and a compressor, which are sequentially connected in series, wherein: a second heat exchange module is disposed at an outlet of the condenser, and the expansion valve is coupled to the

temperature detection and control unit, the first heat exchange module being coupled to the circulating cold consuming unit.

Preferably, either or each of the outlet and the inlet of the condenser may be implemented as a bypass port.

Preferably, the temperature detection and control unit may be configured to regulate a cold supply of the circulating refrigeration unit through control of the expansion valve.

Preferably, the circulating cold consuming unit may comprise a water tank and a pump that is disposed between the water tank and the object to be cooled, the pump driving a coolant to circulate within the circulating cold consuming unit.

The present application also provides a liquid temperature control method, comprising:

providing a circulating refrigeration unit, a circulating cold consuming unit, a heat exchange unit and a temperature detection and control unit;

providing heat and cold to the circulating cold consuming unit through the heat exchange unit, by the circulating cold consuming unit; and

detecting temperature data and controlling a ratio of heat to cold supplied to the circulating cold consuming unit, by the temperature detection and control unit.

Preferably, the heat exchange unit may comprise a first heat exchange module and a second heat exchange module, the circulating refrigeration unit and the first heat exchange module are configured to provide cold to the circulating cold consuming unit, the circulating refrigeration unit and the second heat exchange module are configured to provide heat to the circulating cold consuming unit.

Preferably, the temperature detection and control unit may comprise the first

temperature detection and control module for detecting and controlling the temperature of a coolant flowing into an object to be cooled.

Preferably, the temperature detection and control unit may further comprise the second temperature detection and control module for detecting and controlling the temperature of a coolant in the circulating cold consuming unit that has been cooled.

Preferably, the temperature detection and control unit may be configured to perform a control process comprising detecting, by the first temperature detection and control module, a temperature at an inlet of the object to be cooled, and adjusting a ratio of heat to cold supplied to the circulating cold consuming unit by the circulating refrigeration unit until a required temperature at the inlet of the object to be cooled is reached.

Preferably, the temperature detection and control unit may be configured to perform a control process comprising detecting, by the first temperature detection and control module, a temperature at an inlet of the object to be cooled, and adjusting the heat supplied to the circulating cold consuming unit by the circulating refrigeration unit; and detecting, by the second temperature detection and control module, a temperature of a coolant after the circulating cold consuming unit has been cooled, and adjusting the cold supplied to the circulating cold consuming unit by the circulating refrigeration unit until a required temperature at the inlet of the object to be cooled is reached.

Preferably, a heat output port of the circulating refrigeration unit is coupled to a three-way valve, and the temperature detection and control unit is configured to adjust the heat supply of the circulating refrigeration unit by the circulating cold consuming unit through control of the three-way valve.

Compared with the prior art, the present application offers the following advantages:

1. A most commonly-used circulating refrigeration unit is allowed to be

employed and no additional components is required to be welded in the circulating refrigeration unit. As a result, the number of welded joints is able to be reduced, lowering the risk of refrigerant leakage and increasing the reliability.

2. Heat in the circulating refrigeration unit, if not reused, must be circulated to an external water chilling unit, resulting in a significant work load. According to the present application, since the heat in the condenser is recovered, the load on the water chilling unit is able to be reduced to a certain extent. Taking a small system recycling 1-2 kW per hour as an example, 8,760-17,520 kWh is able to be saved every year.

3. The present application feeds back the flow rate distribution in the liquid temperature control apparatus by the temperature detection and control unit, allowing an accuracy (better than $\pm 0.1^{\circ}\text{C}$) of temperature control higher than the accuracy ($\pm 1^{\circ}\text{C}$) of temperature control in the prior art.

4. The present application uses the exchange between heat at the outlet of the condenser and the cold at the outlet of the first heat exchange module in the circulating refrigeration unit to achieve condensation heat recovery, and replaces heat supplied by a conventional electrical heater with the condensation heat, thus resulting in energy savings.

5. The present application achieves a high-accuracy control through addition of the three-way valve at the outlet of the condenser and control of the heat flowing into the second heat exchange module.

Brief Description of the Drawings

Fig. 1 is a structural schematic of a liquid temperature control apparatus according to embodiment 1 of the present application.

Fig. 2 is a diagram showing a control mechanism of the liquid temperature control apparatus according to embodiment 1 of the present application.

Fig. 3 is a diagram showing a control mechanism of a liquid temperature

control apparatus according to embodiment 2 of the present application.

In these figures: 1- compressor; 2-condenser; 3- expansion valve; 4-first heat exchange module; 5- object to be cooled; 6-pump; 7- water tank; 8- three-way valve; 9- second heat exchange module; 10- bypass port; 11- control unit; 12- first temperature sensor; and 13- second temperature sensor.

Detailed Description

The above objects, features and advantages of the present application will become more apparent upon reading the following detailed description of a few specific embodiments in conjunction with the accompanying drawings. It is noted that, as used herein, the terms “refrigeration” refers to providing cold, while “heating” refers to providing heat, for the sake of convenient description. In addition, the drawings are provided in a very simplified form not necessarily drawn to scale, with the only intention is to facilitate convenience and clarity in explaining the embodiments.

Embodiment 1

As shown in Fig. 1, a liquid temperature control apparatus according to this embodiment includes a circulating refrigeration unit, a circulating cold consuming unit, a temperature detection and control unit and a heat exchange unit. The circulating refrigeration unit is configured to provide the circulating cold consuming unit with heat and cold, and the heat exchange unit is configured for heat exchange between the circulating refrigeration unit and the circulating cold consuming unit. The temperature detection and control unit is configured for high-accuracy cooling of an object to be cooled by detecting the temperature of a coolant and controlling a supply ratio of heat to cold based on the detected temperature.

Further, the circulating refrigeration unit is configured to refrigerate the circulating cold consuming unit and also take heat therefrom. Through detection

and control by the temperature detection and control unit, the said heat is reused to effectuate a thermal compensation for the coolant in the circulating cold consuming unit. In this way, accurate temperature control can be achieved over the coolant in the circulating cold consuming unit.

With continued reference to Fig. 1, the heat exchange unit includes a first heat exchange module 4 and a second heat exchange module 9. In the first heat exchange module 4, the circulating refrigeration unit provides cold to, and thus refrigerates, the coolant in the circulating cold consuming unit, while in the second heat exchange module 9, the circulating refrigeration unit provides heat to, and thus effectuates thermal compensation for, the coolant in the circulating cold consuming unit.

Further, the first heat exchange module 4 may be an evaporator, and the second heat exchange module 9 may be a heat exchanger.

With continued reference to Fig. 1, the apparatus may include a three-way valve 8. The three-way valve 8 is connecting to each of the heat output port of the circulating refrigeration unit and the second heat exchange module 9. The third port of the three-way valve 8 can serve as a bypass port for discharging cooling water carrying excess heat.

The temperature detection and control unit may include a first temperature sensor 12, a second temperature sensor 13 and a control unit 11. The first temperature sensor 12 may be act as a parameter taken into account in temperature detection feedback control or only used as temperature detection of the coolant in the circulating cold consuming unit. The temperature detection and control unit is configured to regulate the heat exchange unit based on the detected temperature, thus achieving accurate temperature control over an object to be cooled. The control of the heat exchange unit by the temperature detection and control unit may be accomplished by virtue of control of the three-way valve 8 and the circulating refrigeration unit. The expansion valve 3 is provided in the

circulating refrigeration unit. In the circulating refrigeration unit, the amount of refrigerating medium flowing into the first heat exchange module 4 is determined by the duty ratio of the expansion valve 3. The control of the circulating refrigeration unit by the temperature detection and control unit may be accomplished by control of the expansion valve 3. In particular, the first temperature sensor 12 may be disposed at the outlet of the first heat exchange module 4 and the circulating cold consuming unit and configured to detect a temperature at the outlet of the first heat exchange module 4 and transfer the temperature data to the control unit 11. The second temperature sensor 13 may be disposed at an inlet of the object to be cooled 5 to detect the temperature at the inlet of the object to be cooled 5 as well as discover and adjust temperature of the coolant in real time so as to ensure a stable temperature of the coolant flowing into the object to be cooled 5.

Further, the liquid temperature control apparatus according to this embodiment may include the circulating refrigeration unit, the circulating cold consuming unit, the three-way valve 8, the heat exchanger and the temperature detection and control unit. In this case, the circulating refrigeration unit is configured to provide the circulating cold consuming unit with heat and cold. The three-way valve 8 is disposed at the heat output port of the circulating refrigeration unit. The circulating cold consuming unit is coupled to the circulating refrigeration unit for circulating cold supply to the object to be cooled 5. The heat exchange is configured to mix heat and cold from the circulating refrigeration unit and then provide the resulting heat or cold to the circulating cold consuming unit. The temperature detection and control unit is configured to monitor temperatures of the circulating refrigeration unit and the circulating cold consuming unit. The control unit 11 is connected to each of the circulating refrigeration unit, the three-way valve 8 and the temperature detection and control unit so as to be able to accurately control a cold supply temperature for the object

to be cooled 5.

With continued reference to Fig. 1, the circulating refrigeration unit may include a compressor 1, a condenser 2, the expansion valve 3 and the first heat exchange module 4. The output port of the condenser 2 is coupled to the three-way valve 8 to provide heat to the circulating cold consuming unit. The first heat exchange module 4 may be configured to provide cold to the circulating cold consuming unit, and the outlet temperature of the first heat exchange module 4 is controlled by the temperature detection and control unit through controlling the duty ratio of the expansion valve 3.

The circulating cold consuming unit may include a water tank 7 and a pump 6 disposed between the water tank 7 and the object to be cooled 5. The pump 6 drives the coolant to circulate within the circulating cold consuming unit. Specifically, the coolant is driven by the pump 6 to flow from the water tank 7 into the object to be cooled 5, and thus take out the heat from the object. Then, the coolant flows into the heat exchanger (i.e., the second heat exchange module 9) after flowing into the first heat exchange module 4 for refrigeration. Since the another inlet of the second heat exchange module 9 is connected to the three-way valve 8, the circulating coolant that has been cooled by the first heat exchange module 4 is compensated with heat from the outflow from the condenser 2. Finally, the coolant is provided to the water tank 7 to accomplish the cycle.

It is noted that, both the outlet and inlet of the condenser 2 may be implemented as bypass ports 10 so as to ensure constant flow rate at the outlet and inlet of the condenser 2, and hence ensure no impact occurred on the heat dissipation performance.

Furthermore, referring to Fig. 2 and Fig. 1, according to the present embodiment, there is also provided a liquid temperature control method, comprising:

Providing, with a water tank 7 and a pump 6, a circulating cold consuming

unit for circulating cold supply to an object to be cooled 5;

providing, with a condenser 2, an expansion valve 3, a first heat exchange module 4 and a compressor 1, a circulating refrigeration unit for providing the circulating cold consuming unit with heat and cold;

arranging a three-way valve 8 at an outlet of the condenser 2 in the circulating refrigeration unit;

arranging a heat exchange unit for mixing heat and cold from the circulating refrigeration unit and providing the resulting heat or cold to the circulating cold consuming unit; and

arranging a temperature detection and control unit for monitoring and controlling temperature of the circulating cold consuming unit. Specifically, the temperature detection and control unit may include a first temperature sensor 12 disposed at an output port of the first heat exchange module 4 and the circulating cold consuming unit, a second temperature sensor 13 arranged at an inlet of the object to be cooled 5 and a control unit 11.

In particular, as shown in Fig. 2, the liquid temperature-control method comprising:

detecting, by the second temperature sensor 13, the temperature at the inlet of the object to be cooled 5 and determining, by the control unit 11, if the temperature at the inlet of the object to be cooled 5 satisfies the requirement. If it is not satisfied, detecting, by the first temperature sensor 12, the temperature at a cold output port of the circulating refrigeration unit, i.e., the temperature at the outlet of the first heat exchange module 4, and then regulating the duty ratio of the expansion valve 3 according to the temperature so as to regulate the temperature at the outlet of the first heat exchange module 4 and thus regulate the cold from the circulating refrigeration unit. Subsequently, heat from the circulating refrigeration unit (i.e., heat supply from the outlet of the condenser 2 to the second heat exchange module 9) is regulated via the three-way valve 8.

Finally, detecting, by the second temperature sensor 13, the temperature at the inlet of the object to be cooled 5 again. In this way, the temperature at the inlet of the object to be cooled 5 can satisfy the requirement.

Embodiment 2

This embodiment differs from Embodiment 1 in that the control unit 11 implements a different control method.

As shown in Fig. 3, according to this embodiment, data detected by the first temperature sensor 12 is not used for feedback control but simply uses as a temperature monitoring. In other words, according to this embodiment, the control unit 11 simply uses the second temperature sensor 13 to simultaneously feed back the opening of the expansion valve 3 and the three-way valve 8 and achieves the accurate temperature control through the control unit 11. Specifically, the control unit 11 is configured to detect, via the second temperature sensor 13, if a temperature at the inlet of the object to be cooled 5 satisfies the requirement. If the temperature is not satisfied, simultaneously regulating the three-way valve 8 and the expansion valve 3 so as to make the temperature at the inlet of the object to be cooled 5 satisfy the requirement.

Apparently, those skilled in the art can make various modifications and variations to the present application without departing from the spirit and scope thereof. Accordingly, the invention is intended to embrace all such modifications and variations if they fall within the scope of the appended claims and equivalents thereof.

CLAIMS

1. A liquid temperature control apparatus, comprising:
 - a circulating refrigeration unit, configured to provide heat and cold to an object to be cooled;
 - a circulating cold consuming unit coupled to the circulating refrigeration unit, configured to cool the object;
 - a heat exchange unit, configured for heat exchange between the circulating refrigeration unit and the circulating cold consuming unit; and
 - a temperature detection and control unit, configured to monitor temperatures of the circulating refrigeration unit and the circulating cold consuming unit.
2. The liquid temperature control apparatus of claim 1, wherein a heat output port of the circulating refrigeration unit is configured to provide the circulating cold consuming unit with heat.
3. The liquid temperature control apparatus of claim 1, wherein the heat exchange unit comprises a first heat exchange module and a second heat exchange module, the circulating refrigeration unit and the first heat exchange module being configured to provide cold to the circulating cold consuming unit, the circulating refrigeration unit and the second heat exchange module being configured to provide heat to the circulating cold consuming unit.
4. The liquid temperature control apparatus of claim 3, wherein a heat output port of the circulating refrigeration unit is coupled to a three-way valve, the three-way valve having a water outlet coupled to the second heat exchanger module and another water outlet serving as a bypass outlet.
5. The liquid temperature control apparatus of claim 4, wherein the temperature detection and control unit is configured to regulate a heat supply of the circulating refrigeration unit through control of the three-way valve.

6. The liquid temperature control apparatus of claim 1, wherein the temperature detection and control unit is arranged at the heat output port and/or a cold output port of the circulating refrigeration unit.
7. The liquid temperature control apparatus of claim 1, wherein the temperature detection and control unit is arranged in the circulating cold consuming unit in order to detect and regulate a refrigeration of the object to be cooled.
8. The liquid temperature control apparatus of claim 1, wherein the circulating refrigeration unit comprises a condenser, an expansion valve, a first heat exchanger module and a compressor, which are sequentially connected in series, wherein a second heat exchange module is disposed at an outlet of the condenser, the expansion valve being coupled to the temperature detecting and controlling unit, the first heat exchanger module being connected to the circulating cold consuming unit.
9. The liquid temperature control apparatus of claim 8, wherein either or each of the outlet and an inlet of the condenser is implemented as a bypass port.
10. The liquid temperature control apparatus of claim 8, wherein the temperature detection and control unit is configured to regulate a cold supply of the circulating refrigeration unit through control of the expansion valve.
11. The liquid temperature control apparatus of claim 1, wherein the circulating cold consuming unit comprises a water tank and a pump that is disposed between the water tank and the object to be cooled, the pump driving a coolant to circulate within the circulating cold consuming unit.
12. A liquid temperature control method, comprising:
 - providing a circulating refrigeration unit, a circulating cold consuming unit, a heat exchange unit and a temperature detection and control unit;
 - providing heat and cold to the circulating cold consuming unit through the heat exchange unit, by the circulating cold consuming unit; and

detecting temperature data and controlling a ratio of heat to cold supplied to the circulating cold consuming unit, by the temperature detecting and controlling unit.

13. The liquid temperature control method of claim 12, wherein the heat exchange unit comprises a first heat exchange module and a second heat exchange module, the circulating refrigeration unit and the first heat exchange module are configured to provide cold to the circulating cold consuming unit, the circulating refrigeration unit and the second heat exchange module are configured to provide heat to the circulating cold consuming unit.

14. The liquid temperature control method of claim 12, wherein the temperature detection and control unit comprises a first temperature detection and control module for detecting and controlling a temperature of a coolant flowing into an object to be cooled.

15. The liquid temperature control method of claim 14, wherein the temperature detection and control unit further comprises a second temperature detection and control module for detecting and controlling a temperature of the coolant in the circulating cold consuming unit that has been cooled.

16. The liquid temperature control method of claim 15, wherein the temperature detection and control unit is configured to perform a control process comprising detecting, by the first temperature detection and control module, a temperature at an inlet of the object to be cooled, and adjusting a ratio of heat to cold supplied to the circulating cold consuming unit by the circulating refrigeration unit until a required temperature at the inlet of the object to be cooled is reached.

17. The liquid temperature control method of claim 15 or 16, wherein the temperature detection and control unit is configured to perform a control process comprising detecting, by the first temperature detection and control module, a temperature at an inlet of the object to be cooled, and adjusting the heat supplied

to the circulating cold consuming unit by the circulating refrigeration unit; and detecting, by the second temperature detection and control module, a temperature of a coolant after the circulating cold consuming unit has been cooled, and adjusting the cold supplied to the circulating cold consuming unit by the circulating refrigeration unit until a required temperature at the inlet of the object to be cooled is reached.

18. The liquid temperature control method of claim 12, wherein a heat output port of the circulating refrigeration unit is coupled to a three-way valve, and wherein the temperature detection and control unit is configured to adjust the heat supply of the circulating refrigeration unit by the circulating cold consuming unit through control of the three-way valve.