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TITLE OF THE INVENTION

TEMPERATURE CONTROL APPARATUS

BACKGROUND OF THE INVENTION

5 The present invention relates to a temperature control apparatus, and particularly to a temperature control apparatus for controlling the temperature of an electronic device at the time of test.

10 Prior to shipment, performance test of an electronic device, for example, a semiconductor chip needs to be carried out at a room temperature or a higher temperature or a lower temperature. When the performance test of a semiconductor chip is carried out at a room temperature under a rated current, heat is generated inside the semiconductor chip by this current  
15 so that the temperature of the chip is raised more than the room temperature. Thus, the semiconductor chip needs to be cooled appropriately to maintain the temperature at the room temperature. When the semiconductor chip is heated with a heater or the like  
20 in case of high temperature test, it needs to be cooled appropriately in order to keep the temperature from being raised more than a setting temperature. These cases of cooling are carried out with a temperature setting head loaded with a semiconductor chip connected  
25 to a predetermined cooling system.

As a conventional temperature control apparatus, a temperature control apparatus disclosed in, for



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example, USP No. 6,668,570 has been well known. This conventional apparatus, as shown in FIG. 1 of this prior art document, executes temperature control of an electronic device 10 by keeping a thermal head 14 which combines a passage 36 in which refrigerant flows with an electric heater 30 in contact with the electronic device 10. In a cooling system using the thermal head 14 having such a structure, heat is generated from the electronic device 10 and the heater 30 and this heat is absorbed by the cooling system. Therefore, when the amount of heat generated from the heater increases at the time of high temperature test, for example, the quantity of heat absorbed by refrigerant in the thermal head 14 increases so that the temperature of refrigerant supplied to a compressor 32 rises. As a result, the temperature in the compressor 32 is raised by heat generated when refrigerant is compressed and if this temperature exceeds a setting maximum temperature of the compressor 32, a large thermal stress is applied to components inside the compressor 32, so that the compressor 32 may be possibly damaged. Therefore, the quantity of heat generated from the heater 14 needs to be controlled strictly in order to prevent this serious phenomenon. This leads to increase in cost of the entire temperature control apparatus and a temperature controllable range between the lower limit and upper limit of the temperature control narrows, thereby

limiting an electronic device which can be tested to particular ones.

#### BRIEF SUMMARY OF THE INVENTION

5 An object of the present invention is to provide a temperature control apparatus which is cheap in cost, has a wide temperature controllable range and a compressor provided therein may not be applied with a large heat stress.

10 According to one aspect of the present invention, there is provided a temperature control apparatus comprising: a temperature control head kept in contact with an electronic device as a testing object thermally; an electric heater attached to the temperature control head; a refrigerant passage formed  
15 within the temperature control head so as to run through inside thereof; a compressor which compresses refrigerant coming out of the temperature control head; a temperature sensor which detects a temperature of refrigerant on an outlet side of the compressor; a  
20 condenser which condenses refrigerant coming out of the compressor; a returning portion which returns refrigerant condensed by the condenser to the temperature control head; and a control portion which bypasses the condensed refrigerant to an intake side of  
25 the compressor by a predetermined quantity corresponding to an output of the temperature sensor.

According to another aspect of the present

invention, there is provided a temperature control apparatus comprising: a temperature control head kept in contact with an electronic device as a testing object thermally; an electric heater attached to the temperature control head; a refrigerant passage formed within the temperature control head so as to run through inside thereof; a first temperature sensor which detects a temperature of the electronic device; a compressor which compresses refrigerant coming out of the temperature control head; a second temperature sensor which detects a temperature of refrigerant on the outlet side of the compressor; a condenser which condenses refrigerant coming out of the compressor; a returning portion which returns refrigerant condensed by the condenser to the temperature control head; and a control portion which controls the temperature of the electronic device by controlling the quantity of electricity supplied to the electric heater and the quantity of refrigerant flowing through the refrigerant passage corresponding to an output of the first temperature sensor and controls the quantity of the condensed refrigerant bypassed to the intake side of the compressor corresponding to an output of the second temperature sensor.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a diagram schematically showing a structure of a cooling circuit of a temperature control

apparatus of an electronic device including a compressor protection section according to an embodiment of the present invention;

FIG. 2 is a structure diagram showing a concrete structure of the embodiment shown in FIG. 1;

FIG. 3 is a flow chart for explaining the temperature control operation of this embodiment; and

FIG. 4 is a flow chart for explaining the protective operation of the cooling circuit according to this embodiment.

#### DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, an embodiment of the present invention will be described in detail with reference to the accompanying drawings.

Referring to FIG. 1, an evaporator 13 is provided within a temperature control head 12 with which an electronic device 11 as a testing object such as a semiconductor chip is kept in contact thermally. An electric heater described later is attached to this head 12 and a refrigerant passage 14 in which refrigerant flows through is formed within the evaporator 13. The evaporator 13 is connected to a cooling circuit including a pipe 15 serving as a passage of refrigerant. An expansion valve 16 is connected to a refrigerant intake side of the evaporator 13 and an outlet side thereof is connected to a compressor 18 through an accumulator 17. The

pressure of refrigerant on the intake side of the expansion valve 16 is high while the pressure of refrigerant in the downstream of the evaporator 13 on the outlet is low.

5           After passing the temperature control head 12, low pressure refrigerant is collected in the accumulator 17 and then fed to and compressed in the compressor 18. High pressure refrigerant compressed by this compressor 18 is condensed by a condenser 19 on a next step using  
10           a fan 20 and condensed refrigerant is returned to the expansion valve 16 through the pipe 15 and further returned to the accumulator 17 through an electromagnetic valve 21 and a capillary tube 22.

          The cooling system having such a structure  
15           includes a first temperature sensor T1 for detecting the temperature in the temperature control head 12 and a second temperature sensor T2 for detecting the temperature of refrigerant on the outlet side of the compressor 18. It further includes a system controller  
20           (not shown in FIG. 1) which executes for example PID control as a control portion for controlling the temperature of the electronic device by controlling the quantity of current in the electric heater and the quantity of refrigerant flowing through the refrigerant  
25           passage corresponding to an output of the first temperature sensor T1 and controlling the quantity of bypassing of the condensed refrigerant on the intake

side of the compressor 18 corresponding to an output of the second temperature sensor T2.

The cooling system shown in FIG. 1 may be provided with a drier DR, a high-pressure gauge G1, a high-  
5 pressure pressure switch P1, an electromagnetic valve S, a service port SP, a ball valve V, a low pressure gauge G2, a low-pressure pressure switch P2 and the like corresponding to each purpose.

Hereinafter, the concrete structure of the cooling  
10 system shown in FIG. 1 will be described with reference to FIG. 2.

The same reference numerals are attached to components corresponding to those of FIG. 1. The temperature control head 12 is constructed by combining  
15 the evaporator 13 having plural refrigerant passages 14a and an electric heater 14b. A semiconductor chip 11 is bonded to the bottom face of the temperature control head 12 through heat conductive films 12a, 12b. A plurality of solder ball terminals 11a are formed on  
20 the bottom face of the semiconductor chip 11 and the semiconductor chip is connected to a connecting terminal provided on a socket 10s through this solder ball terminal 11a and further connected to an outside test unit (not shown) so as to perform a predetermined  
25 test. A probe T1P of the temperature sensor T1 is kept in contact with the semiconductor chip 11 and a detection output of the temperature sensor T1 is

supplied to a system controller 31 for PID control.

The electric heater 14b provided on the temperature control head 12 is driven by a heater driver 14bD under a control of the system controller 31.

5           The plurality of refrigerant passages 14a formed within the evaporator 13 are connected to the refrigerant pipe 15 on the intake side and the refrigerant pipe 15 on the outlet side. The refrigerant pipe 15 connected to the outlet side of the  
10           temperature control head 12 is connected to the compressor 18 through the accumulator 17. A probe T2P of another temperature sensor T2 is installed on the refrigerant pipe 15 on the outlet side of this compressor 18 so as to detect the temperature of  
15           refrigerant on the outlet side of the compressor 18. A detection output of this temperature sensor T2 is supplied to the system controller 31.

          The refrigerant pipe 15 connected to the outlet side of the compressor 18 is coupled with the intake  
20           side of the condenser 19. This condenser 19 is a radiator and heat of refrigerant is radiated by blowing air to the radiator 19 with the fan 20 to condense gaseous refrigerant to liquid refrigerant. The refrigerant pipe 15 connected to the outlet side of the  
25           condenser 19 is branched to a first branch pipe 15A and a second branch pipe 15B in succession. These first and second branch pipes 15A, 15B communicate with the

refrigerant pipe 15 connected to the intake side of the accumulator 17 through electromagnetic valves 15AV, 15BV. These electromagnetic valves 15AV, 15BV are opened/closed by the system controller 31 under each  
5 predetermined condition, which will be described later.

The refrigerant pipe 15 connected to the outlet side of the condenser 19 is connected to the intake side of the electronic expansion valve 16 provided on the intake side of evaporator 13.

10 Next, the operation of the cooling system having such a structure will be described with reference to FIGS. 3, 4. If the performance test of the electronic device 11 is carried out at a predetermined temperature higher than the room temperature, a user sets up a  
15 lower limit value STL of a setting temperature range in the system controller 31. In this case, a temperature DT of the electronic device 11 is equal to the room temperature and a temperature detected by the temperature sensor T1 through the probe T1P is low when  
20 the temperature control is started. Thus, a result of determination turns to YES in initial step S1 of FIG. 3 (DT < STL?) and the control proceeds to step S2. As a consequence, an instruction of "CLOSE" is sent from the system controller 31 to the electromagnetic expansion  
25 valve 16 so that no refrigerant flows to the evaporator 13 and the valve 15BV turns to "OPEN" to allow refrigerant to pass through the bypass passage 15B. At

the same time, the heater driver 14bB is driven to supply electricity to the electric heater 14b, so that the electronic device 11 is heated without being cooled.

5           When the temperature DT of the electronic device 11 exceeds the lower setting temperature STL, a result of determination in step S1 is NO and then, the control proceeds to step S3. Here, whether or not the temperature DT of the device 11 detected by the  
10           temperature sensor T1 exceeds the upper limit value STH of the test temperature range ( $DT > STH?$ ) is determined. If the result is NO, the control proceeds to step S4, in which an instruction of "CLOSE" continues to be given to the electromagnetic expansion  
15           valve 16 from the system controller 31 and a condition in which refrigerator is blocked from flowing to the evaporator 13 is maintained and the valve 15BV turns to "OPEN" so that refrigerant continues to pass through  
20           the bypass passage 15B. At the same time, the drive condition of the heater driver 14bD is released so that the electric heater 14b turns to non-conductive state, thereby stopping heating of the electronic device 11.

          On the other hand, if the temperature of the electronic device 11 rises too much ( $DT > STH?$ ) in the  
25           condition of step S3 (YES in step S3), the control proceeds to step S5, in which an instruction of "OPEN" is supplied from the system controller 31 to the

electromagnetic expansion valve 16 and refrigerant flows into the evaporator 13. At the same time, the valve 15BV turns to "CLOSE" so that refrigerant is blocked from passing the bypass passage 15B. At this  
5 time, the drive condition of the heat driver 14bD is released so that the electric heater 14b turns to non-conductive state and the heating of the electronic device 11 is continuously halted. As a result, the electronic device 11 is cooled by absorption of heat  
10 when refrigerant flowing through the evaporator 13 is evaporated and the temperature DT falls to the lower setting temperature STL. When  $DT < STL$ , the control is YES in step S1 so that the same temperature control action is maintained between the lower and upper  
15 temperature setting ranges STL and STH.

As for the control of the electric heater 14b and the expansion valve 16, software control by a computer can be executed instead of hardware control by the system controller 31 by PID.

20 Next, the operation of preventing the compressor 18 from being destroyed by overheat will be described with reference to FIG. 4. When the temperature control of the electronic device 11 is carried out with reference to FIG. 3, the refrigerant temperature RT in  
25 the pipe 15 on the outlet side of the compressor 18 is detected by the probe T2P of the temperature sensor T2 and sent to the system controller 31. A refrigerant

upper limit temperature PT is set up on the system controller 31 in order to protect the compressor 18 and whether or not this refrigerant temperature RT is over the set refrigerant upper limit temperature PT is  
5 determined in step S11.

When the refrigerant temperature RT is lower than the refrigerant upper limit temperature PT, the result is NO and the control proceeds to step S12, in which the electromagnetic valve 15AV on the refrigerant  
10 bypass passage 15A is kept in "CLOSE". At this time, the electromagnetic valve 15BV on the other refrigerant bypass passage 15B can be opened or closed corresponding to the temperature DT of the electronic device 11 as described in FIG. 3.

15 When the refrigerant temperature RT on the outlet side of the compressor 18 is higher than the upper limit temperature PT, a determination result in step S11 is YES and the control proceeds to step S13. The electromagnetic valve 15AV is opened by a control of  
20 the system controller 31 and refrigerant condensed and cooled by the condenser 19 flows into the accumulator 17 through the bypass passage 15A. As a consequence, the temperature RT of refrigerant supplied from the accumulator 17 to the compressor 18 drops thereby  
25 preventing the compressor 18 from being overheated.

Drop of the refrigerant temperature RT on the outlet side of the compressor 18 by opening of the

electromagnetic valve 15AV is continued while the result is NO in step S14 ( $RT < PT?$ ).

If the result is YES in step S14 ( $RT < PT?$ ), the control proceeds to step S12, in which the  
5 electromagnetic valve 15AV is closed under a control of the system controller 31 so that bypass refrigerant flowing into the accumulator 17 is vanished. As a consequence, the refrigerant temperature RT on the outlet side of the compressor 18 begins to rise again.  
10 Control of the refrigerant temperature on the outlet side of the compressor 18 by opening/closing of the electromagnetic valve 15AV can be carried out without affecting the temperature control operation of the electronic device 11 so much.

15 According to this embodiment, as described above, this temperature does not exceed the setting maximum temperature of the compressor 18 even if the quantity of heat generated from the heater 14b increases in a high temperature test so that the temperature of  
20 refrigerant supplied to the compressor 18 rises. Thus, components in the compressor 18 are protected from a large thermal stress, thereby protecting the compressor 18 from a damage. Therefore, the quantity of heat generated from the heater 14b does not need to be  
25 carried out strictly, cost of the entire temperature control apparatus can be suppressed to a low level, a temperature controllable range between the lower limit

and upper limit of the temperature control can be secured and an electronic device which can be tested is not restricted to any particular type.

Additional advantages and modifications will  
5 readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various  
modifications may be made without departing from the  
10 spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

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## WHAT IS CLAIMED IS:

1. A temperature control apparatus comprising:  
a temperature control head kept in contact with an  
electronic device as a testing object thermally;

5 an electric heater attached to the temperature  
control head;

a refrigerant passage formed within the  
temperature control head so as to run through  
refrigerant inside thereof;

10 a compressor which compresses the refrigerant  
coming out of the temperature control head;

a temperature sensor which detects a temperature  
of refrigerant on an outlet side of the compressor;

15 a condenser which condenses refrigerant coming out  
of the compressor;

a returning portion which returns refrigerant  
condensed by the condenser to the temperature control  
head;

20 at least one bypass passage connected in parallel  
to the returning portion for returning the refrigerant  
condensed by the condenser to the compressor by  
bypassing the temperature control head; and

25 a control portion which bypasses the condensed  
refrigerant to an intake side of the compressor via the  
bypass passage by a predetermined quantity  
corresponding to an output of the temperature sensor.

2. The temperature control apparatus according to

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claim 1, wherein the control portion includes means for  
bypassing the refrigerant via the bypass passage when  
an output temperature value of the temperature sensor  
exceeds the upper limit value of the temperature of  
5 refrigerant on the outlet side of the compressor set  
preliminarily as a result of comparison of the output  
temperature value of the temperature sensor with the  
upper limit value of the refrigerant temperature.

3. The temperature control apparatus according to  
10 claim 2, wherein the bypass passage is configured to  
communicate the outlet side of the condenser to the  
intake side of the compressor and the control portion  
includes means for turning ON/OFF refrigerant flowing  
through the bypass passage.

15 4. The temperature control apparatus according to  
claim 1, wherein the control portion includes a system  
controller for PID control.

5. A temperature control apparatus comprising:  
a temperature control head kept in contact with an  
20 electronic device as a testing object thermally;  
an electric heater attached to the temperature  
control head;

a refrigerant passage formed within the  
temperature control head so as to run through  
25 refrigerant inside thereof;

a first temperature sensor which detects a  
temperature of the electronic device;

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a compressor which compresses refrigerant coming out of the temperature control head;

a second temperature sensor which detects a temperature of refrigerant on the outlet side of the compressor;

a condenser which condenses refrigerant coming out of the compressor;

a returning portion which returns refrigerant condensed by the condenser to the temperature control head;

at least one bypass passage connected in parallel to the returning portion for returning the refrigerant condensed by the condenser to the compressor by bypassing the temperature control head; and

a control portion which controls the temperature of the electronic device by controlling the quantity of electricity supplied to the electric heater and the quantity of refrigerant flowing through the refrigerant passage corresponding to an output of the first temperature sensor and controls the quantity of the condensed refrigerant bypassed via the bypass passage to the intake side of the compressor corresponding to an output of the second temperature sensor.

6. The temperature control apparatus according to claim 5, wherein the control portion includes means for bypassing the refrigerant via the bypass passage when an output temperature value of the second temperature

sensor exceeds the upper limit value of the temperature of refrigerant on the outlet side of the compressor set preliminarily as a result of comparison of the output temperature value of the second temperature sensor with the upper limit value of the refrigerant temperature.

7. The temperature control apparatus according to claim 6, wherein the bypass passage is configured to communicate the outlet side of the condenser to the intake side of the compressor and includes means for turning ON/OFF refrigerant flowing through the bypass passage.

8. The temperature control apparatus according to claim 5, wherein the control portion includes a system controller for PID control.

9. A temperature control apparatus comprising:  
a temperature control head kept in contact with an electronic device as a testing object thermally;  
an electric heater attached to the temperature control head;  
a refrigerant passage formed within the temperature control head so as to run through refrigerant inside thereof;  
a first temperature sensor which detects a temperature of the electronic device;

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a compressor which compresses refrigerant coming out of the temperature control head;

a second temperature sensor which detects a temperature of refrigerant on the outlet side of the  
5 compressor;

a condenser which condenses refrigerant coming out of the compressor;

a returning portion which returns refrigerant condensed by the condenser to the temperature control  
10 head;

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a bypass portion including first and second bypass passages connected in parallel to each other for returning the refrigerant condensed by the condenser to the compressor by bypassing the temperature control head;

a first control portion which controls the temperature of the electronic device by controlling the quantity of electricity of the electric heater, the quantity of refrigerant flowing through the first bypass passage and the quantity of refrigerant flowing through the refrigerant passage in the temperature control head corresponding to an output of the first temperature sensor; and

a second control portion which controls a total flow rate of the refrigerant on the intake side of the compressor by controlling the quantity of refrigerant flowing through the second bypass passage corresponding to the output of the second temperature sensor.

10. The temperature control apparatus according to claim 9, wherein the second control portion includes means for bypassing the refrigerant to the second bypass passage when an output temperature value of the second temperature sensor exceeds the upper limit value of the temperature of refrigerant on the outlet side of the compressor set preliminarily as a result of comparison of the output temperature value of the temperature sensor with the upper limit value of the

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refrigerant temperature.

11. The temperature control apparatus according to claim 9, wherein the means for bypassing includes an electromagnetic valve provided on the second bypass  
5 passage and means for turning ON/OFF the refrigerant flowing through the second bypass passage by means of the electromagnetic valve.

12. The temperature control apparatus according to claim 9, wherein at least one of the first and  
10 second control portions includes a controller for PID control.