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(54) **Method of regulating an air-conditioning plant and an air-conditioning plant according to the method.**

(57) The invention relates to a method and a device in the regulation of a room air-conditioning device (10). In the method, the condensation of water is prevented by means of a heat exchanger (12) in connection with the surface of heat transfer means by maintaining the temperature of the heat exchanger (12) above a momentary condensation point temperature (T_K). In the method, the condensation point temperature (T_K) of the room space is observed experimentally, and on the basis of said experimental information, the temperature of the heat exchanger (12) of the air-conditioning plant (10) is regulated above said observed condensation point temperature (T_K).

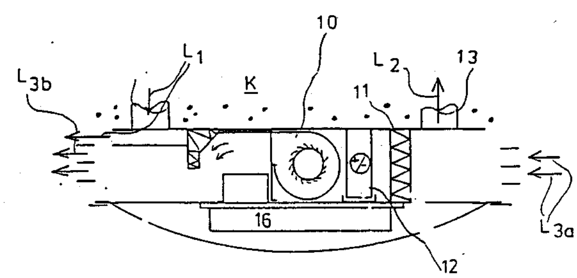

FIG. 1B

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The invention relates to a method in the regulation of an air-conditioning plant and an air-conditioning plant according to the method.

A problem related to room air-conditioning plants of prior art is the condensation of water into.heat transfer pipes. Said problem causes great disadvantages, since the removal of the condensation water has not succeeded in known device solutions in the best possible way. Removal solutions of the condensation water are known in prior art, in which the condensation water is collected into a separate intermediate storage, from which it may further be led away. Separate condensation-water evaporation systems are also known.

When the surface temperature of the water pipe of the heat transfer device is below the condensation point temperature, the condensation of water onto said surface begins. Said situation may occur unexpectedly, e.g. when a window is opened or if a steaming kettle is brought in the room space. If the number of persons in the room to be air conditioned changes, it may also cause changes in the air of the room space, which lead into a condensation problem of water. Condensation problems occur especially in air-conditioning plants, in which the plant comprises heat transfer means for cooling the air of the room space and which air-conditioning plant comprises circulation means for the air of the room space, whereby the circulation air of the room space is led into contact with the heat transfer means.

It has been realized in the invention to observe the condensation point temperature by means of an indicator device such that the room temperature is led in connection with the indicator-device element observing the heat and a counter-element adjacent to said element, its temperature, is regulated such that a condensation point occurs between the element T_{max} and T_{min}. The increase or the decrease in the temperature of said element occurs at the same effect, whereby, when the condensation point is reached, energy is consumed in said condensation point into a phase change and a change occurs in the temperature gradient in connection with the temperature increase/decrease per time unit. In said change point, the temperature decrease or the temperature increase decelerates. In the inventive arrangement, a microprocessor observes said change, and when it observes at the phase-change area a change in the temperature gradient, a control signal is produced for a heat exchanger of the air-conditioning plant, preferably for fluid circulation circuit, whereby the temperature of the fluid, preferably water, of the heat exchanger is maintained or regulated above the condensation point temperature.

The invention tends to find a solution to the condensation problem occurring in connection with a room-space air-conditioning plant. It has been realized in the invention to avoid said problem by totally preventing the forming of the condensation water. In one embodiment of the invention, the condensation phenomenon is observed at those points of the plant, in which the condensation first occurs. When the condensation is observed, a regulation information thereof is produced into the circulation of the heat transfer fluid. In one embodiment of the invention, the water circulation is interrupted completely for the period, until the condensation phenomenon stops. Thus, the inventive device solution and method does not tend to avoid secondary problems, i.e. problems related to the removal of the condensation water, but an attempt is made to prevent the entire problem by preventing the condensation of water in the plant.

The inventive method is mainly characterized in that in the method the condensation of water is prevented by means of a heat exchanger in connection with the surface of heat transfer means by maintaining the temperature of the heat exchanger above a momentary condensation point temperature, whereby in the method the condensation point temperature of the room space is observed experimentally, and on the basis of said experimental information, the temperature of the heat exchanger (12) of the air-conditioning plant is regulated above said observed condensation point temperature.

The inventive plant is many characterized in that observation devices for the condensation of water are provided, by means of which the condensation point of the air of the room space is observed, i.e. the temperature, in which the condensation of water on the surface of the heat transfer means of the air-conditioning plant occurs, and that in the method, on the basis of said condensation temperature, the temperature of the heat exchanger is regulated above the condensation point temperature.

The invention is next described with reference to certain preferred embodiments of the invention shown in the figures of the accompanying drawings, to which the invention is not intended solely to be limited.

Fig. 1A shows the air-conditioning plant placed in a room space.

Fig. 1B shows schematically the plant of Fig. 1A. The condensation prevention system is described on the basis of Fig. 1B.

Fig. 2A shows schematically the water circulation system of the room air-conditioning plant of Fig. 1A. The figure shows schematically the inventive condensation prevention system based on the water circulation regulation.

Fig. 2B shows the condensation-point observation equipment used in the regulation of the system of Fig. 2A.

Fig. 2C shows graphically the operation of the equipment of Fig. 2B as a time/temperature coordinate system.

Fig. 2D illustrates graphically a condensation-point calculation performed repeatedly.

Fig. 2E shows as a block diagram representation the inventive condensation-point observation-device arrangement.

Fig. 3 shows a fluid circulation diagram of the room air-conditioning plant. The reflation of the water temperature of the fluid circulation occurs by adjusting a valve K of the water circulation.

Fig. 4 shows a second preferred embodiment of the inventive regulation.

Fig. 5 shows a third preferred embodiment of the inventive regulation

Fig. 6 shows a fourth preferred embodiment of the inventive regulation.

Fig. 1A shows the inventive air-conditioning plant placed in a room space.

Fig. 1B shows the plant of Fig 1A as a principal schematic representation. Via the inventive plant, room air is circulated by means of circulation created by a blower device 10. The entry of the circulation air into the plant is indicated by arrows L_{3A} and the removal of the circulation air from the plant is indicated by arrows $_{3A}$. The blower device 10 creates the room-air circulation via a filter 11 and a heat exchanger 12. Air is removed from the room space via a channel 13 (arrow L_2) and fresh air is brought into the room space via a channel 14 (arrow L_1). In this invention, the heat exchanger 12 may be of any type. However, a fluid and most preferably water is preferably used as a heat transfer medium.

Fig. 2A illustrates the regulation of the water circulation of the heat exchanger 12 of the room air-conditioning plant. According to the figure, several room air-conditioning plants 10 are coupled to the same water circulation system. The heating/cooling arrangement of the plant is realized by means of water circulation. The figure shows three room air-conditioning plants 10. They are located in different room spaces, i.e. in room spaces H_1, H_2, H_3. Via the heat exchanger 12 of the room air-conditioning unit 10, the heat transfer fluid, preferably water, is circulated by bringing it into the heat exchanger 12, as shown by an arrow V_1, and by removing it from the heat exchanger 12, as shown by an arrow V_2. The fluid flow may be, according to each plant, regulated by means of a valve K. The inlet water flow V_1 is brought from a heating unit C_1 or from a cooling unit C_2 of a central device F depending on the fact, whether heat is removed from the room H_1, H_2, H_3 or whether heat is brought via the heat exchanger into the room space. Thus, by controlling valves E_1, E_2 and M_1, M_2, the heat transfer medium preferably water, of frame channels R_1, R_2 is circulated either to the heating unit C_1 or via the cooling unit C_2. The heating and cooling units C_1 and C_2 are located in the central device F.

Fig. 2A illustrates the condensation temperature by a condensation-temperature observation device 15. The embodiment of the figure illustrates the condensation temperature in a room space such that the observation device 15 comprises a surface, with which the room air is in contact, and a temperature element in contact with said surface, the temperature of which element is increased and/or decreased at the same heat effect. The equipment further comprises a central unit, preferably a microprocessor, which observes the temperature change per time unit occurring in the temperature elements, and when an abrupt change occurs in the temperature gradient, i.e. in the temperature increase or decrease per time unit, a control information is produced thereof further to the control of the heat exchanger 12 for maintaining the temperature above a condensation point temperature T_k. If the heat exchanger 12 uses a fluid circulation system, a control information is produced for the valve K, or generally into the heat-transfer-fluid circulation system, whereby the temperature of the heat transfer fluid, preferably water, is adjusted above the above-mentioned observed condensation point temperature T_k.

Fig. 2B shows the inventive observation and indicator device 15 observing the condensation point temperature. The observation device 15 comprises a temperature element C and a heat-transfer and test surface D, between which prevails a thermal contact. The temperature of the temperature element is increased or decreased by bringing a constant heating or cooling effect into the temperature element C, whereby the increase or decrease in temperature per time unit of the temperature element C is observed, and when a change occurs in said temperature gradient when reaching the condensation point temperature T_k, a control information thereof is produced to a central unit 100, preferably a microprocessor. The microprocessor 100 further adjusts the temperature of the heat exchanger 12 of the air-conditioning plant 10, preferably the temperature of the heating fluid when using fluid circulation, such that it is above the observed condensation point temperature T_k. Thus, the method utilizes such an observation device, which, on the basis of a phase change occurring in the condensation point, adjusts the temperature of the heat exchanger 12 of the air-conditioning plant 10 above the condensation point temperature point T_k observed. The above-mentioned adjustment may occur, when the heat exchanger 12 is provided with fluid circulation, by adjusting the temperature of the fluid circulation above the condensation point temperature. Said adjustment may occur e.g. by closing for a certain period of time the valve K of the fluid circulation, whereby the temperature of the heat transfer fluid in the heat exchanger increases.

Fig. 2C shows the inventive test arrangement. In the vertical coordinate system is shown the temperature T of the temperature element, and in the horizontal coordinate system is shown the time t. In the figure, between a time interval t_1-t_2 occurs the cooling of the element at a constant effect. At the time t_k is reached the condensation point temperature T_k, whereby energy is bound to the phase change and the temperature decrease of the element C decelerates and the temperature gradient thus changes. The inventive test may be performed either by increasing or decreasing the temperature T of the temperature element C. It is then essential that the condensation point temperature T_k is by-passed in the change range of the temperature of the temperature element C.

Fig. 2D shows a test arrangement performed during several periods of time. The test may be performed at certain time intervals or continuously, since the condensation point changes according to the changing of the atmosphere conditions of the room H.

Fig. 2E shows as a block diagram representation the inventive condensation-point observation arrangement. The temperature difference between a test surface P of the condensation-point indicator and the temperature element C to be cooled is regulated by cooling/heating the temperature element C at a constant effect. The indicator G produces a temperature communication from the temperature element C to the microprocessor 100, which observes the temperature change of the temperature element C as a function of time and produces a control information to the control circuit of the heat exchanger 12 of the air-conditioning plant 10, preferably to the circulation circuit of the heat transfer fluid, which control information is based on the momentary and last-measured condensation-point temperature information T_k of the room space H. The microprocessor 100 transmits the control communications to the process. The power supply circuit supplies power to the microprocessor as well as to the power regulation circuit.

Fig. 3 shows schematically a solution, in which several room air-conditioning plants 10 are coupled to the same water circulation system. By means of the water circulation is realized the heating/cooling arrangement of the plant. The figure shows three room air-conditioning plants 10. They are located in different room spaces H_1, H_2, H_3. Via the heat exchanger 12 of the room air-conditioning unit 10, the heat transfer fluid, preferably water, is circulated by bringing it into the heat exchanger 12, as shown by an arrow V_1, and by removing it from the heat exchanger 12, as shown by an arrow V_2. The fluid flow may be, according to each plant, regulated by means of a valve K. The inlet flow V_1 is brought from a heating unit C_1 or from a cooling unit C_2 of a central unit F depending on the fact, whether heat is removed from the room H_1, H_2, H_3 or whether heat is brought via the heat exchanger into the room space. Thus, by controlling valves E_1, E_2 and M_1, M_2, the heat transfer medium, preferably water, of frame channels R_1, R_2 is circulated either via the heating unit C_1 or via the cooling unit C_2. The heating and cooling units C_1 and C_2 are located in the central device F.

According to Fig. 3, the water circulation of the heat exchanger 12 of each plant 10 is regulated by means of the condensation observation device 15. The condensation observation device 15 observes the condensation from the surface of the heat transfer pipe. From the observation device 15, preferably a sensor, is transmitted a signal S along a signal line 16a to a central unit 17, which compares the inlet signal S to a set value signal S_1, which represents a state, in which no condensation occurs. In a normal state, the signal $S = S_1$. When the condensation begins, the measurement information S deviates from the set value information S_1. The central unit 17 further controls the temperature of the heat exchanger 12 and preferably closes the water-circulation valve K The control information of the valve K is transmitted from the central unit 17 to the valve K along the signal line 16b.

Thus, when observing the beginning of the condensation, the valve K is shut immediately. This also prevents the condensation, since the cooling water and its circulation stops and the cooling liquid and thereby the temperature of the cooling pipe exceeds the condensation point temperature.

According to Fig. 3, each room air-conditioning plant 10 and the circulation of heat transfer fluid of the room air-conditioning plant 10 are regulated, which is based on the above-mentioned observation of the water condensed.

Fig. 4 shows a second preferred embodiment of the inventive condensation observation device. In the embodiment, the fluid condensed on the surface of the water-circulation inlet pipe is observed optically. According to the invention, a light-refracting prism 18 and a ray of light X are provided, which is controlled from a light source 19 in compliance with the surface of a heat transfer pipe O towards the prism 18. The prism 18 diffracts the ray of light F further into a receiving detector 20, which measures the signal received. When condensation occurs on the surface of the pipe O, an undisturbed travel of the ray of light X to the detector 20 is prevented, and the equipment arrangement observes, on the basis of the above-mentioned change, the occurrence of the condensed water on the surface of the heat transfer pipe and produces thereof a signal information to the central unit 17, which stops the heat transfer fluid circulation by adjusting the valve K opening and shutting the heat-transfer-fluid pipe line into a closed position.

Fig. 5 shows a third preferred, also optical embodiment of the inventive plant, in which a ray of light X is produced optically from a light source 19 via an optical fiber into the vicinity of the heat transfer pipe O and in which it is led in compliance with the pipe to a receiving detector 22. When the condensation of the fluid onto the surface of the heat transfer pipe occurs, a condensation water drop scatters a ray of light, whereby an information in the receiving detector 22 changes and the change is observed in the central unit 17, which further stops the heat transfer fluid the circulation.

Fig. 6 shows a fourth preferred embodiment of the invention, in which an electrical sensor 23 measuring the capacitance is placed in the vicinity of the heat transfer pipe O. When the fluid is condensed between the surface of the pipe O and the sensor 23, the capacitance between the sensor and the pipe changes and the information is further transmitted to the central unit 17, which stops the fluid circulation.

By utilizing the inventive plant, the operation of the air-conditioning plant 10 may be made more effective. A lower inlet water temperature may be used. A lower inlet water temperature may be used, since the condensation of water is fully in control by means of the inventive plant, and it is not necessary to minimize at the air-conditioning plant the probability of condensation by cutting the minimum values of the inlet water temperature. As the heat transfer effect of the plant increases, water flows can thus be decreased and led into smaller pipes. The costs of the piping are thus reduced to a minimum. By means of the plant, also the water damages due to the condensation are prevented. No condensation water tank is needed. Also, it is not necessary to insulate the pipes, which in the solutions of prior art was a way of avoiding the condensation of water onto the pipe surfaces.

The invention has been described above by way of example only, and modifications may be made within the invention.

Claims

1. A method in the regulation of a room air-conditioning device (10), by means of which the air of a room space (H) is circulated and flown via a heat exchanger (12) of the air-conditioning plant (10), whereby the air-conditioning plant (10) comprises heat transfer means such that the heat of the air of the room space may be transferred by means of the heat exchanger (12) into a heat transfer medium, **characterized** in that in the method, the condensation of water is prevented by means of the heat exchanger (12) in connection with the surface of the heat transfer means by maintaining the temperature of the heat exchanger (12) above a momentary condensation point temperature (T_k), whereby in the method, the condensation point temperature (T_k) of the room space is observed experimentally, and on the basis of said experimental information, the temperature of the heat exchanger (12) of the air-conditioning plant (10) is regulated above said observed condensation point temperature (T_k).

2. A method according to Claim 1, **characterized** in that in the method, the condensation point temperature of the air of the room space (H) is observed experimentally by bringing the air of the room space in contact with a test surface (D), on the other side of which test surface is located a heatable and/or coolable temperature element (C), whereby in the method, the temperature of the temperature element (C) is decreased and/or increased at a constant effect, and the temperature change of the temperature element (C) is observed as a function of time, and that in the method, on the basis of the change rate of the temperature, when observing a vigorous deceleration in the temperature change in connection with the reaching of the condensation point temperature (T_k) on the basis of said temperature information (T_k), the temperature of the heat exchanger (12) is regulated above said condensation point temperature (T_k).

3. A method according to the preceding Claim, **characterized** in that in the method the calculation of said condensation point temperature (T_k) is performed automatically at certain time intervals or continuously.

4. A method according to Claim 1, **characterized** in that in the method the condensation of water is observed in connection with the surface of the heat transfer means (12), and when observing the collection of the condensed water, an information thereof is transmitted to a central unit (17), which further stops the operation of the heat exchanger (12) or adjusts the fluid circulation of the heat exchanger into such a state, wherein the temperature of the heat transfer means increases, whereby the condensation point temperature (T_k) is exceeded and the condensation is thereby prevented.

5. A method according to Claim 4, **characterized** in that in the method, the fluid condensed is observed by using an optical detector (20), whereby by means of the device is produced a ray of light (X) in the vicinity of an observation surface from a light source (19) and it is controlled into the receiving detector (20), and when the water condensates on the travel of the ray of light (X), the central unit (17) observes said change, as the water condensed at least partially refracts the ray of light in other directions than the deflector (20), whereby the central unit (20) of the plant regulates the temperature of the heat exchanger (12) on the basis of the observation information.

6. A method according to Claim 5, **characterized** in that in the method a ray of light is produced towards the detector (20) from an optical fiber (21).

7. A method according to Claim 5 or 6, **characterized** in that in the method the ray of light (X) is transmitted to the detector (20) via a prism (18).

8. A method according of any of preceding Claims 4-7, **characterized** in that in the method, the occurrence of the condensation water is observed by utilizing an electrical circuit, which measures the capacitance between a capacitance sensor (23) and heat transfer means (12), preferably the surface of an inlet pipe (O) of the heat exchanger, and when condensation occurs, this is observed as a change in the capacitance, and on the basis of said change, the temperature of the heat exchanger (12) and of the heat transfer means is adjusted such that the condensation is prevented.

9. A method according of any of preceding Claims 4-8, **characterized** in that in the method, a ray of light is produced from the detector (19) to the central unit (17) as a measurement information (S), whereby the central unit (17) compares the above-mentioned measurement information (S) to the set-value information (S_1) entered into the central unit as a set-value information, which set-value information (S_1) corresponds to a state, wherein no condensation occurs, and when the central unit observes the fact that an inlet signal (S) deviates from the set-value signal (S_1) entered into the central unit (17), the central unit transmits a control information by adjusting the heat exchanger (12) into a state, wherein the temperature of the heat transfer means in-creases, whereby the condensation point temperature (T_k) is exceeded and the condensation of water is prevented.

10. An air-conditioning plant (10), by means of which the air of the room space (H) is circulated and flown via the heat exchanger (12) of the air-conditioning plant (10), whereby the air-conditioning plant (10) comprises heat transfer means such that the heat of the air of the room space may be transferred by means of the heat exchanger (12) into a heat transfer medium **characterized** in that water condensation observation devices (15) are provided, by means of which the condensation point of the air of the room space, or the temperature (T_k), in which the condensation of water onto the surface of the heat transfer means (12) of the air-conditioning plant (10) occurs, and in the method, on the basis of the above-mentioned condensation point temperature (T_k), the temperature of the heat exchanger (12) is adjusted above the observed condensation point temperature (T_k).

11. A plant according to the preceding Claim, **characterized** in that the observation means (15) comprise a heat transfer surface (D), with which the air of the room space (H) is in contact, and a temperature element (C) in a thermal contact with said surface, the temperature of which element (C) is changed at a constant heating/cooling effect, whereby the method comprises means, preferably a microprocessor (100), by means of which the change gradient ($\Delta T/dt$) of the temperature of said temperature element (C), i.e. the change in temperature as a function of time, is observed, and when a change occurs in the gradient ($\Delta T/dt$) in the condensation point temperature (T_k), as the temperature change decelerates, said condensation point (T_k) is observed and a control information based on said temperature information (T_k) is produced for means adjusting the temperature of the heat exchanger (12), whereby the temperature of the heat exchanger is increased or maintained above the condensation point temperature (T_k).

12. A plant according to the preceding Claim, **characterized** in that the air-conditioning plant (10) comprises a water-condensation observation device (15), which observes the condensation of water on some surface of the heat transfer means (12), preferably in connection with an inlet water pipe (O), and that air-conditioning plant comprises a central unit (17), into which a control information (S) from a detector (19) is transmitted, and that the plant comprises a signal line (16b) for a valve (K) regulating the fluid circulation for closing the valve, or for adjusting the temperature or a heat transfer medium, preferably water such that the condensation point temperature (T_k) is exceeded and condensation is prevented.

13. A plant according to the preceding Claim, **characterized** in that the plant comprises a light source (19), from which a ray of light (X) is produced to a detector (19), whereby, when the condensed water enters at the ray of light, said condensation phenomenon is observed, measured by the detector (19), as a change in the inlet signal (S), whereby the central unit (17) produces a control information to the heat exchanger (12), preferably to the fluid-circulation valve (K), and adjusts the valve into a closed position.

14. A plant according to Claim 12, **characterized** in that the plant comprises an optical fiber (21), into which the ray of light from the light source (19) is transmitted and controlled from the fiber along the observation surface to a detector (20).

15. A plant according to the preceding Claim, characterized in that the plant comprises a prism (18) af-

ter the observation point, whereby the ray of light (X) is controlled via the prism (18) to the detector (20) and further to the central unit (17).

16. A plant according to Claim 12, characterized in that plant comprises a capacitance sensor (23), which measures the capacitance between the sensor (23) and observation surface of the heat exchanger (12) of the air-conditioning plant, whereby the capacitance information is produced to the central unit (17), which on the basis of the capacitance information regulates the temperature of the heat exchanger (12).

17. A method for the regulation of an air-conditioning device (10), in which air from a space (H) is circulated through a heat exchanger (12) of the air-conditioning plant (10), wherein the heat exchanger (12) may remove heat from the air, characterized in that condensation of water in the heat exchanger (12) is prevented by maintaining the temperature of the heat exchanger (12) above the instantaneous condensation point temperature (T_k), wherein the instantaneous condensation point temperature (T_k) of the air of the space (H) is measured experimentally, the temperature of the heat exchanger (12) being regulated on the basis of the experimental measurements.

18. An air-conditioning plant (10) through which air from a space (H) is circulated, comprising a heat exchanger (12) for removing heat from the air, characterized in that at least one device (15) is provided, by means of which the condensation point of the air (T_k) may be observed, the temperature of the heat exchanger (12) being maintained above the condensation point temperature (T_k) on the basis of the observation obtained from the device (15).

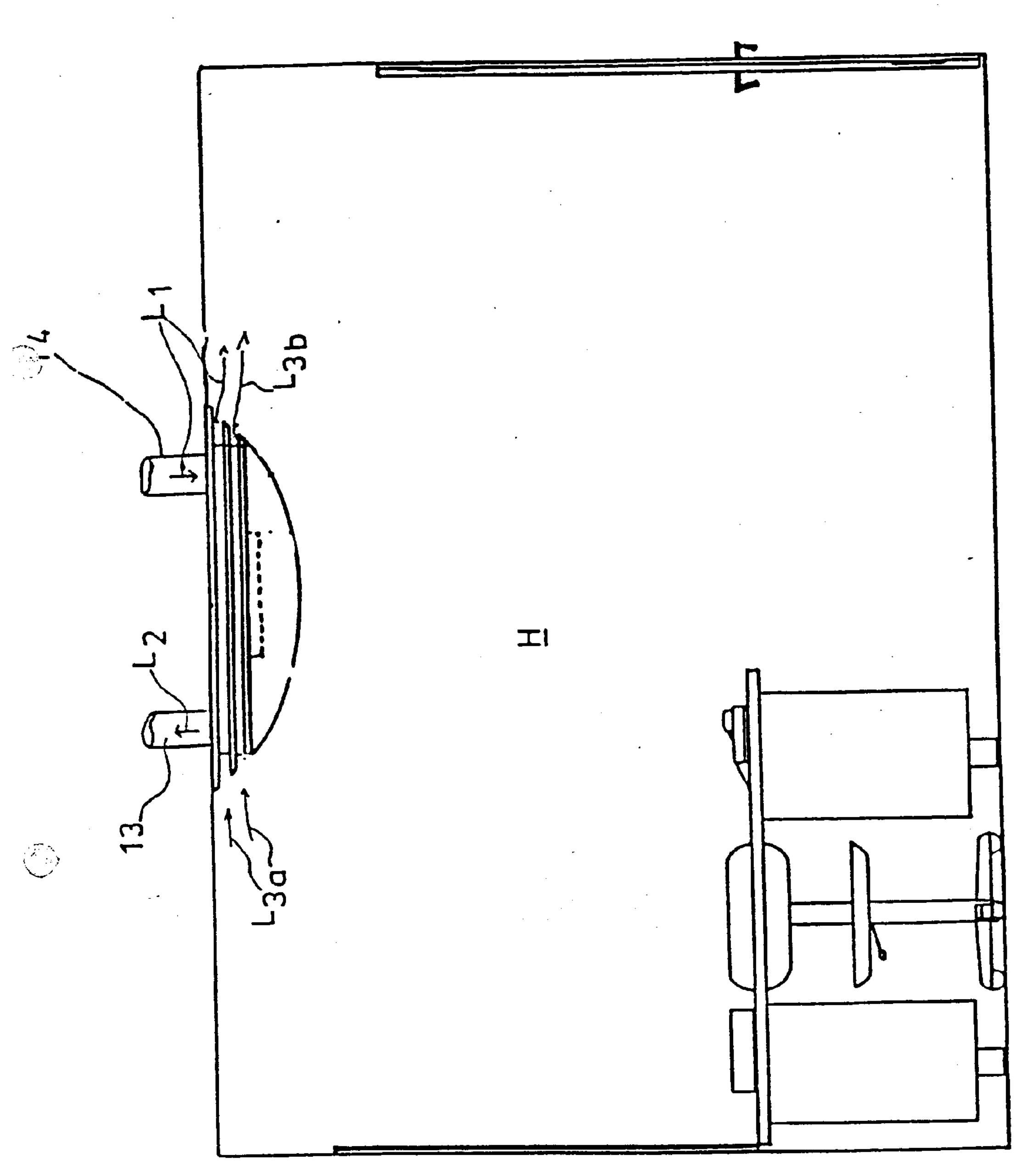


FIG 1A

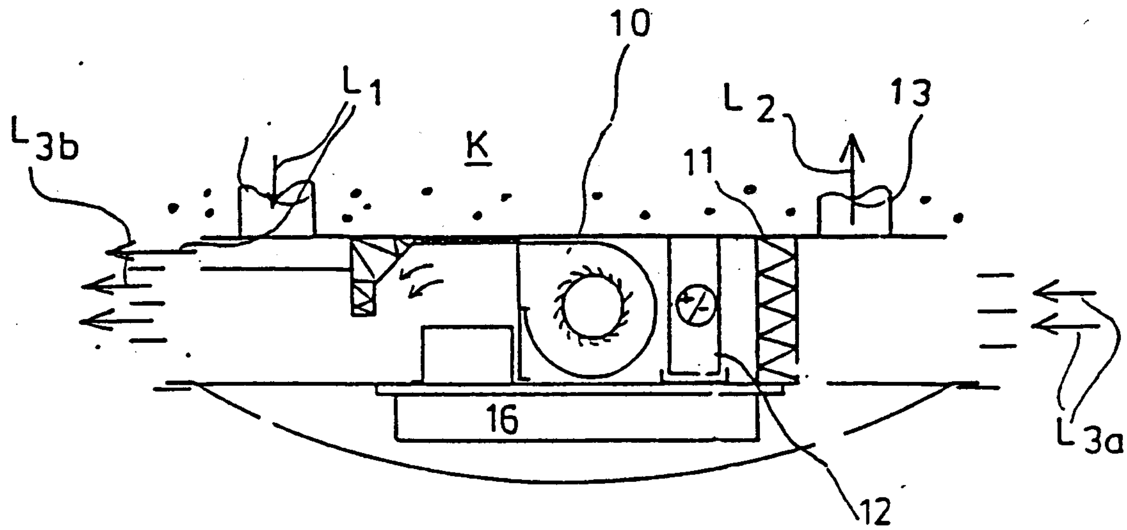


FIG. 1B

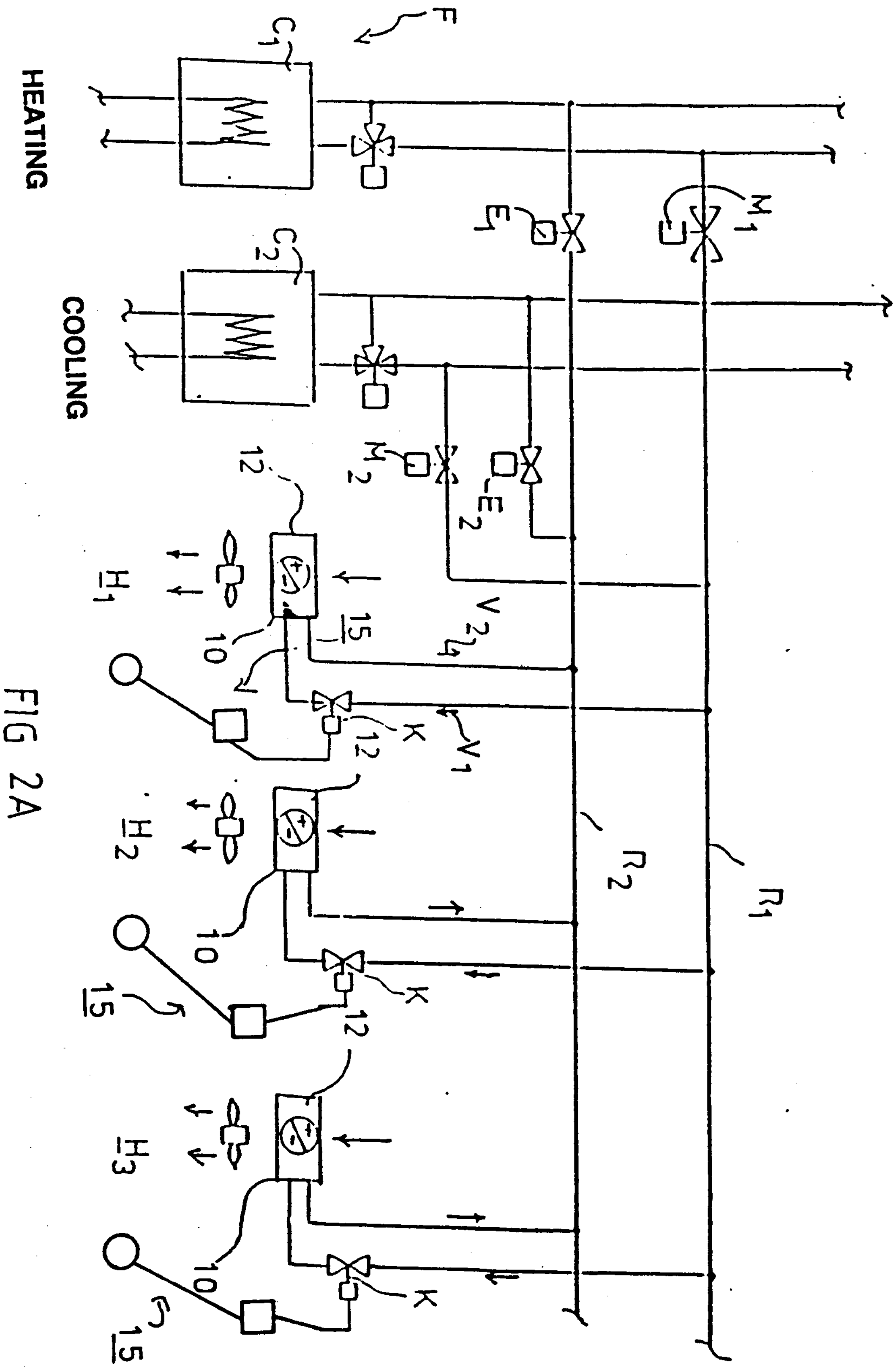


FIG 2A

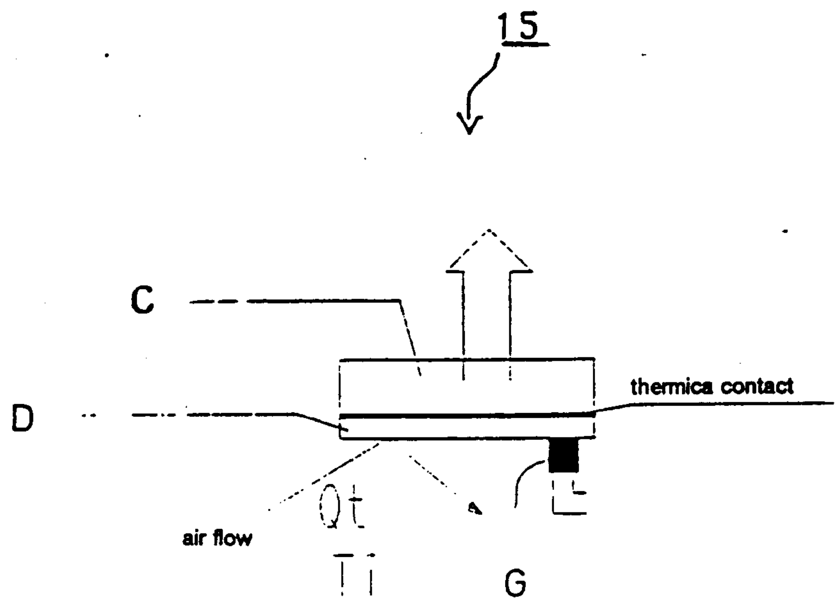
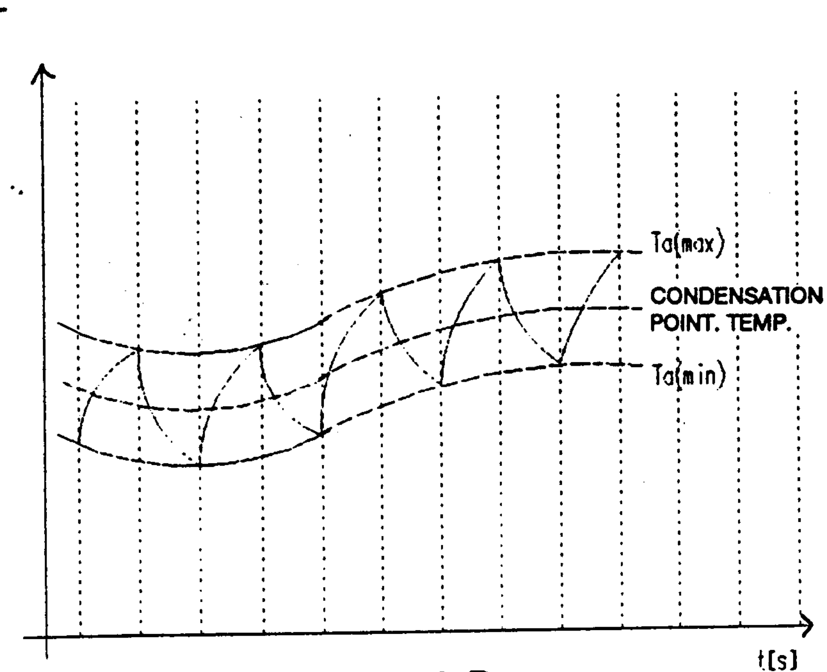


FIG 2 B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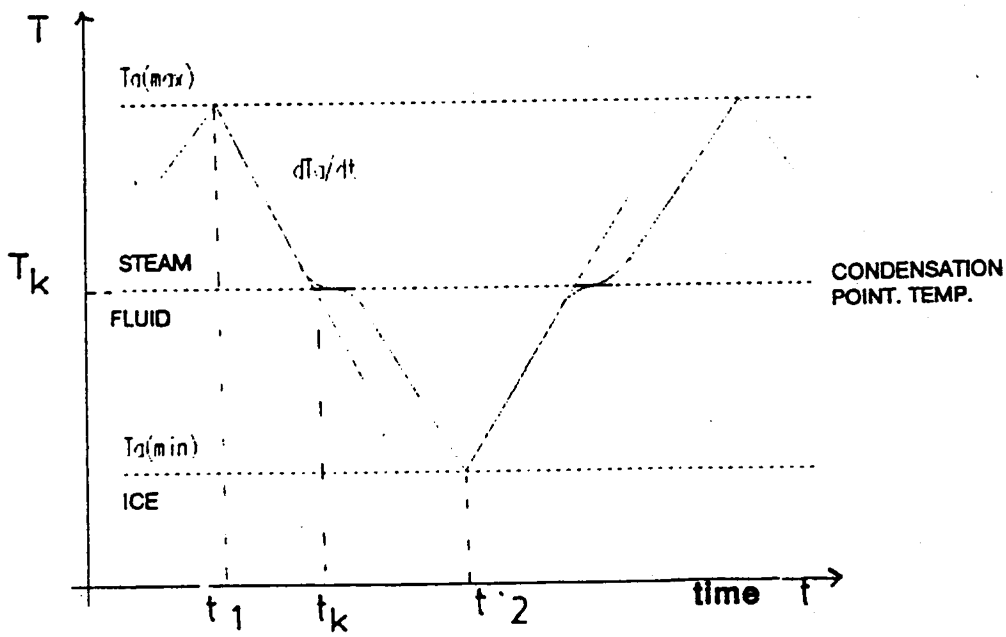
CONDENSATION
POINT. TEMP.
Ta(min)
t[s]

FIG 2D


T
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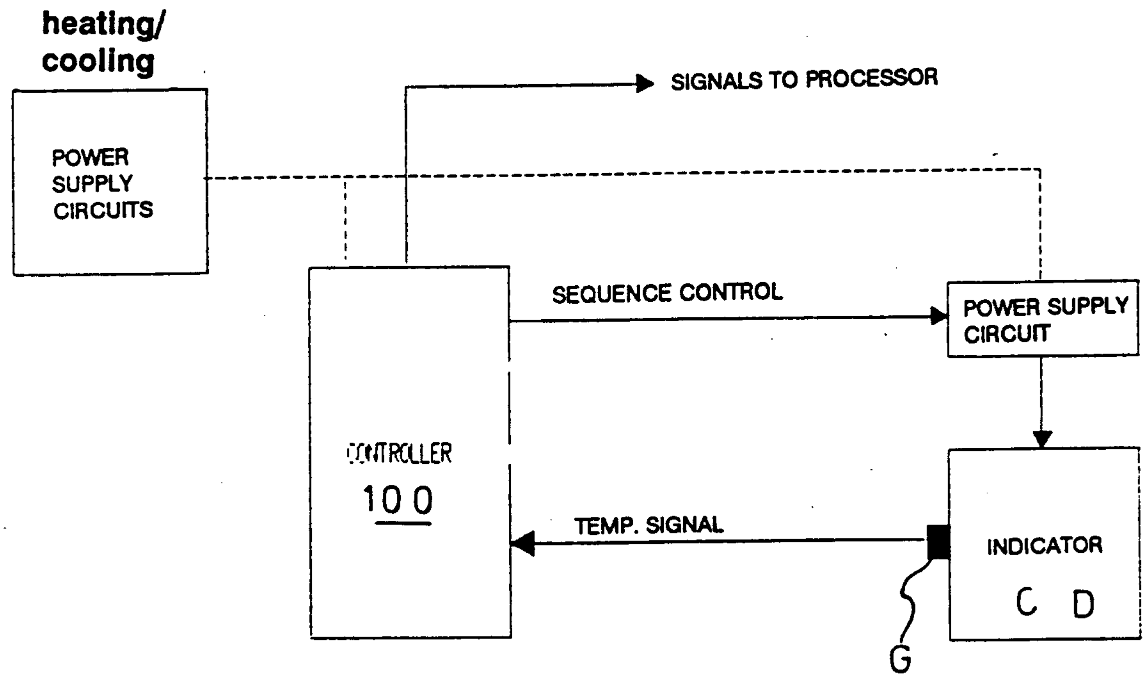
dTa/dt
Tk
STEAM
FLUID
Ta(min)
ICE
CONDENSATION
POINT. TEMP.
t 1
tk
t 2
time t

FIG 2C



PRINCIPLE OF CONTROL

FIG 2E

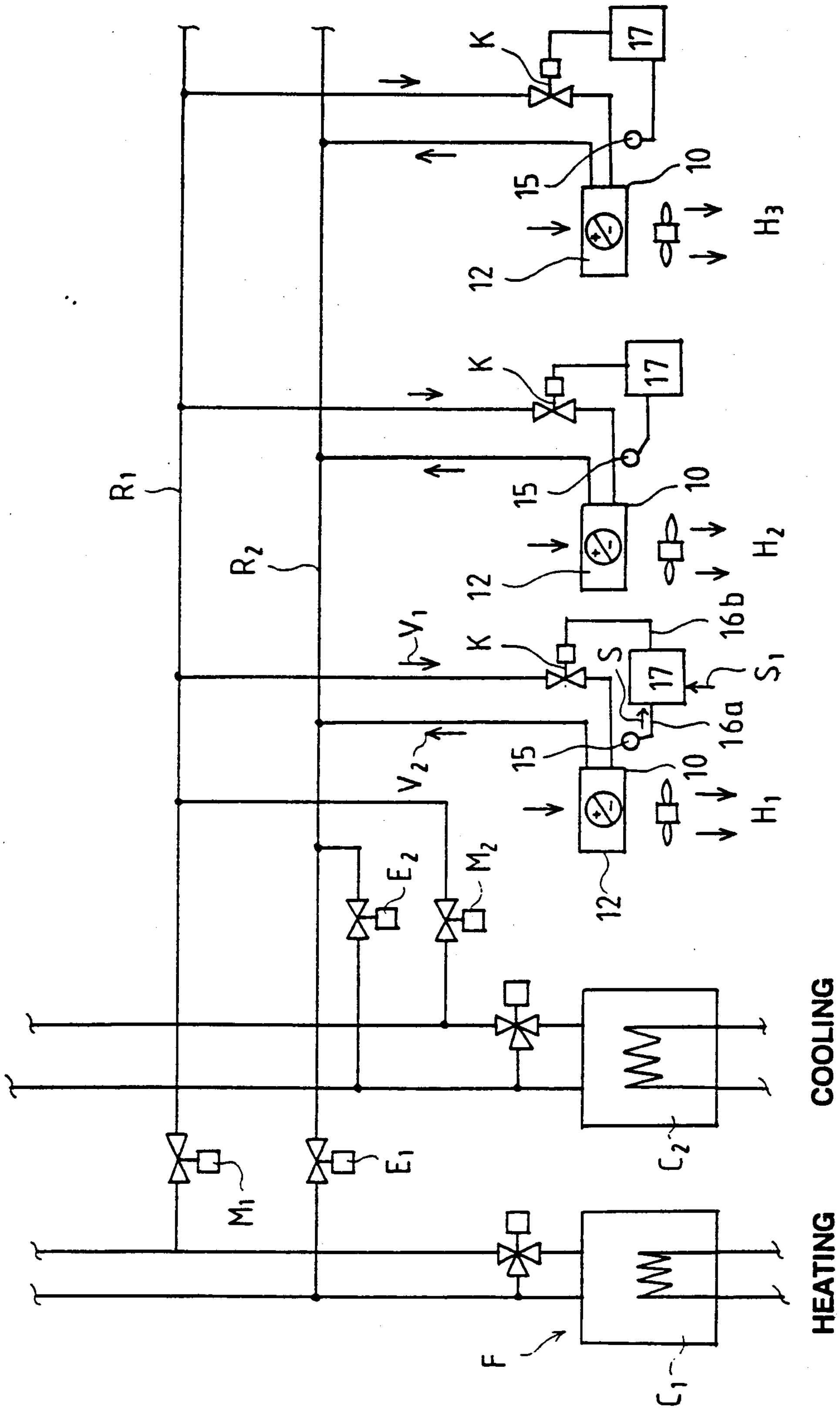

R1
R2
K
K
K
17
17
17
15
15
15
10
10
10
12
12
12
H3
H2
H1
V1
V2
S
S1
16a
16b
E1
E2
M1
M2
C1
C2
F
HEATING
COOLING

FIG. 3

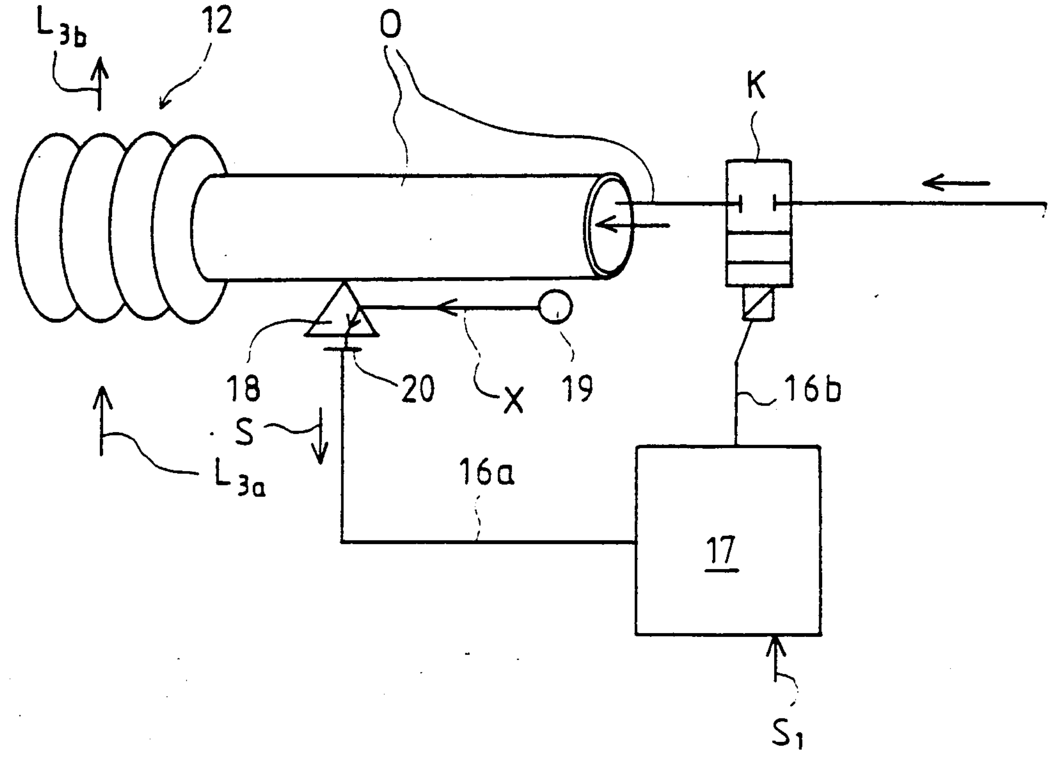


FIG.4

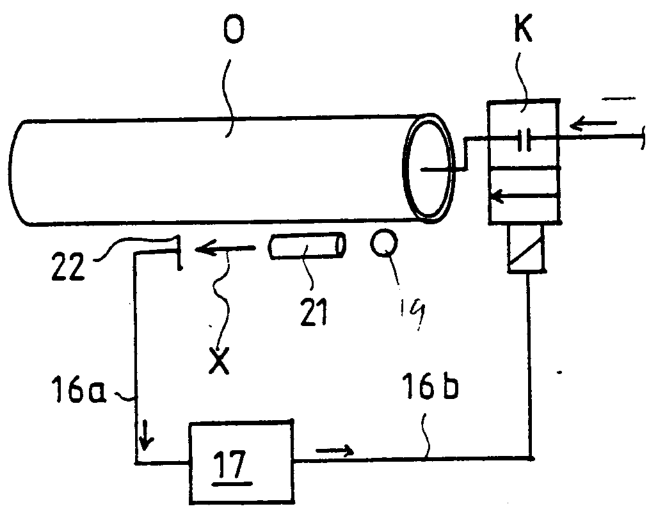


FIG. 5

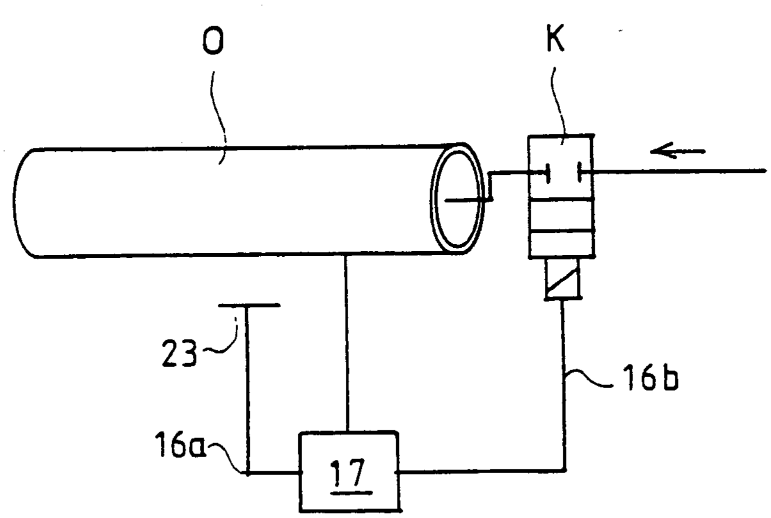


FIG. 6