



(22) Date de dépôt/Filing Date: 1995/06/30

(41) Mise à la disp. pub./Open to Public Insp.: 1996/01/07

(45) Date de délivrance/Issue Date: 2004/02/10

(30) Priorité/Priority: 1994/07/06 (6-179587) JP

(51) Cl.Int.⁶/Int.Cl.⁶ E01C 11/26, E01H 5/10, G05D 23/19,
G01N 25/04

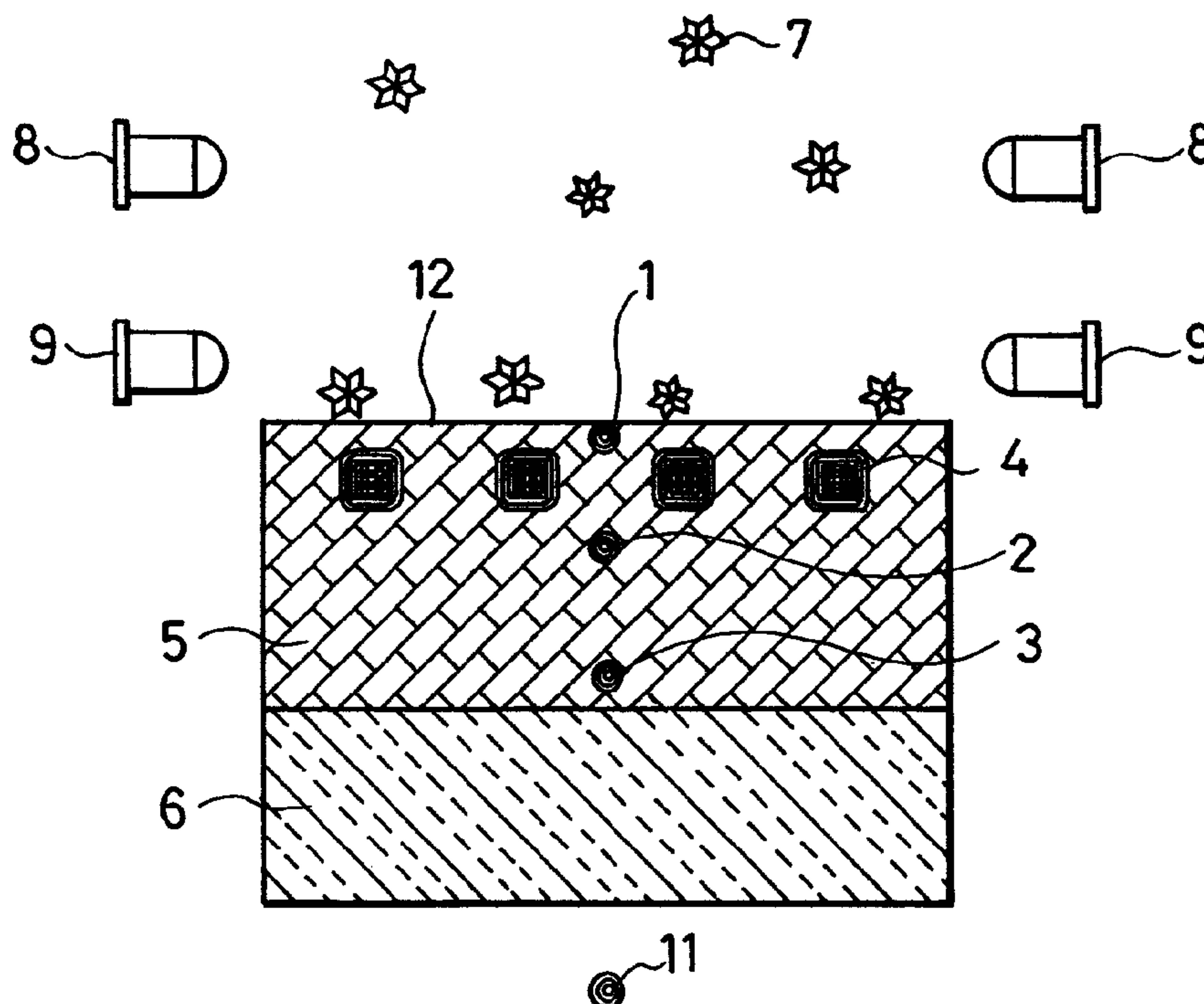
(72) Inventeurs/Inventors:
HACHIKI, KUNIO, JP;
YAMAZAKI, JUNICHI, JP;
YAMADA, TADAYUKI, JP;
YASUMOTO, SATOSHI, JP;
HAGIWARA, MASAOKI, JP

(73) Propriétaires/Owners:
YAMADA TECHNICA CORPORATION, JP;
KOHTARO HASHIMOTO, THE COMMISSIONER OF
KINKI DISTRICT CONSTRUCTION BUREAUS, THE
MINISTRY OF CONSTRUCTION, JP

(74) Agent: MARKS & CLERK

(54) Titre : METHODE ET DISPOSITIF DE MESURE EN CONTINU DE LA QUANTITE DE CHALEUR NECESSAIRE
POUR FAIRE FONDRE LA NEIGE RECOUVRANT UNE CHAUSSEE ET EMPECHER CELLE-CI DE GELER

(54) Title: METHOD AND APPARATUS OF CONTINUOUSLY MEASURING HEAT QUANTITY NEEDED TO MELT
SNOW LYING ON ROAD AND PREVENT FREEZING OF ROAD



(57) Abrégé/Abstract:

In order to provide an integral whole unit for continuously measuring heat quantity needed to melt snow lying on a road, and prevent freezing of the road and for controlling supply of heat to the road for melting the snow lying on the road and for preventing the freezing of the road, it uses a road-simulated device. The road-simulated device is put outdoors while it is snowing, and it is heated and kept at a temperature of -0° C, thus keeping the road-simulated surface free of snows, and preventing the freezing of the road-simulated surface. . In this condition the thermal energy is determined, and every control variable is determined on the basis of the so determined thermal energy.



ABSTRACT OF THE DISCLOSURE

In order to provide an integral whole unit for continuously measuring heat quantity needed to melt snow lying on a road, and prevent freezing of the road and for controlling supply of heat to the road for melting the snow lying on the road and for preventing the freezing of the road, it uses a road-simulated device. The road-simulated device is put outdoors while it is snowing, and it is heated and kept at a temperature of -0°C , thus keeping the road-simulated surface free of snows, and preventing the freezing of the road-simulated surface.. In this condition the thermal energy is determined, and every control variable is determined on the basis of the so determined thermal energy.

METHOD AND APPARATUS OF CONTINUOUSLY MEASURING HEAT QUANTITY
NEEDED TO MELT SNOW LYING ON ROAD AND PREVENT FREEZING OF ROAD

BACKGROUND OF THE INVENTION

5

1. Field of the Invention

The present invention relates to the art of keeping road free of snows, and of preventing freezing of the road in winter, and more particularly the art of determining the quantity of
10 heat needed to melt snow lying on the road in ceaselessly changeable weather condition, and of determining the quantity of heat needed to prevent the freezing of the road while it is snowing and after it has stopped snowing. Also, the present invention relates to the art of providing useful pieces of infor-
15 mation available for permitting the making of a timely decision of scattering anti-freezing agent on the road.

2. Description of Related Art

The removing and/or melting of the snow lying on the road
20 is useful in preventing the road from freezing in winter. The removing and/or melting of the snow lying on the road can be effected by scattering water or anti-freezing agent over the road or by raising the temperature of the road with the aid of boiled-water pipes or electric heating wires buried under the
25 road. These approaches necessitate the making of decision at correct moment, depending on reliable information sources. As for the latter approach the road must be heated to raise its temperature high enough to melt snows and prevent the freezing of the road. From the economical point of view the quantity of
30 heat needed to keep the road free of snow must be correctly determined.

To obtain required pieces of information such as detection of the falling of snow or determination of the quantity of snowfall infrared rays are used. The falling of snow can be
35 detected at the beginning by intercepting the infrared rays or by permitting the infrared rays to reflect from the falling flakes of snow. The quantity of snowfall can be determined in

terms of the number of interceptions or reflections of the infrared rays by the falling flakes of snow.

As for detection of the freezing of the road the temperature of the road is determined according to the contact or non-contact temperature measuring method, and the freezing can be detected in terms of the descent of temperature below the freezing point. Japanese Patent 63-274838(A) discloses use of a road-simulated surface, which is kept wet all times, and the freezing is detected in terms of the electric conductivity of the wet road-simulated surface. To control the melting of the snow lying on the road the temperature of the boiled water is determined after circulating under the ground to melt the snow, and the quantity and/or temperature of the boiled water is controlled in terms of the lost quantity of heat thus determined. Japanese Patent 2-173536(A) discloses use of a thermal gauge for determining the quantity of heat needed to melt the snowfall on the road.

The matter of great concern in the road conditioning installation is to prevent the freezing of the road after washing and removing snows away from the road. The unfreezing of the road is difficult increasingly with the increase of the scale of the road conditioning installation, and accordingly the increase of the area of the road under the supervision of the so large-scaled road conditioning installation. To prevent the freezing of the road the scattering of water is made to cease when the atmospheric temperature falls. If temperature falls during the scattering of water, the scattering of water is continued until temperature rises.

As for the former the snow lying on the road cannot be removed, and as for the latter a lot of water will be wasted. The wasting of water may cause depletion of underground water, which is used as a water source for removing snows by scattering water.

As for detection of road freezing in terms of the electric conductivity of the wet surface of a road-simulated plane such detection is liable to be delayed because of the roofing of the road-simulated plane to shield it from snow, accordingly sup-

pressing the heat loss by radiation. Thus, it cannot detect the freezing of the road at the beginning. The difficulties for detecting the freezing of the road at the beginning are partly attributable to the complexities of road cooling phenomena by radiation as for instance follows: the road is most liable to be frozen at night in cloudless sky; when temperature falls close to 0°C, and the sky is closed thick with cloud, there will be much snow; and as the sky is less cloudy, the snow falls less and less; when it stops snowing and when the sky is almost cloudless, heat will be lost from the road quickly by radiation to cause the gradual fall of the atmospheric temperature; no road freezing will be caused when the sky is so cloudy that it looks like snow; when the sky is cloudy thick and when it is snowing, the atmospheric temperature ranges from +1°C to -4°C, causing no freezing of the road.

When stars begin to appear in the sky after the cease of snowing, the road is easy to be frozen, and when the sky is less cloudy, the freezing is caused suddenly even at the temperature of +1°C. This reveals the fact that the freezing cannot be detected only with recourse to the measuring of the atmospheric temperature.

The transforming from water to ice can be hardly detected in terms of the temperature of the road surface. As a matter of fact such a detection is even impossible if the temperature of the road surface is measured with the aid of non-contact temperature gauge; the temperature at which a decision of freezing is made must be set, in fact, above 0°C in consideration of errors appearing in measuring devices.

In case of scattering water on the road for removing snows from the road water cannot be scattered evenly, and therefore the temperatures detected at selected measuring points cannot represent the road condition accurately, and therefore, the road conditioning installation cannot be appropriately controlled so far as it relies on such temperature detection.

On-and-off controlling type of snow sensors are used for detecting the snow lying on the road in terms of the falling of snow. These detectors work before snow lies on the road, and

therefore, they are liable to falsely work when it is snowing at a relatively high temperature, or when it is snowing lightly. Also, it may be falsely affected by mist, insects or falling leaves. Even if such on-and-off controlling type of snow sensors works correctly, the road conditioning installation is not permitted to supply heat in a continuously controlled fashion. Disadvantageously such non-adaptive heating control tends to waste thermal energy when the heating capability is large compared with the quantity of snow lying on the road, or stop heating prior to removal of snows from the road when the heating capability is small compared with the quantity of snow lying on the road.

With recourse to detection of the temperature of the boiled water returning after heating the road the required control is made with the temperature of the returning boiled water kept at a given positive value because the quantity of the latent heat contained in water at 0°C cannot be determined, and therefore waste of thermal energy is inevitable. Japanese Patent 2-173536(A) provides the art of controlling the quantity of heat needed to melt the snow lying on the road, but not capable of detecting the lying of snow on the road at the beginning, and the freezing of the road, either. Conventional sensors are unable to store data pertaining to the condition of snowfall, the melting of snows by heating or the freezing of the road, and therefore no useful data is available for references and investigations for designing of road conditioning installations and for energy and water-source saving projects.

SUMMARY OF THE INVENTION

The road conditioning installation must be controlled to supply the quantity of heat just needed to melt the snow lying on the road and prevent the freezing of the road. If not, extra quantity of heat would be supplied and wasted, or insufficient quantity of heat would be supplied to permit snows to remain on the road or permit the road to be frozen.

In view of this one object of the present invention is to provide an integral whole unit for continuously measuring the

quantity of heat needed to melt the snow lying on the road and prevent the freezing of the road, and for controlling the supplying of the heat to the road for melting the snow lying on the road and for preventing the freezing of the road.

5 Another object of the present invention is to provide a method of preventing the freezing of the road surface without wasting thermal energy.

These objects can be attained according to the present invention by: putting a road-simulated device outdoors while it is
10 snowing; heating and keeping the road-simulated device at the temperature of -0°C , thus preventing the freezing of the road-simulated surface; measuring the thermal energy needed to prevent the freezing of the road-simulated surface; and determining every control variable on the basis of the so determined
15 thermal energy.

Specifically an integral whole unit for continuously measuring the quantity of heat needed to melt the snow lying on the road and prevent the freezing of the road, and for controlling the supplying of the heat to the road for melting the snow
20 lying on the road and for preventing the freezing of the road, is improved according to the present invention in that it comprises: a thermal quantity measuring device comprising a snow-receptor plane of a material which provides a similitude of the road surface, having electric heaters and temperature sensors embedded therein, means for detecting the falling of snow
25 and the snow lying on the snow-receptor plane, and means for determining the water content of snow; means to control the supplying of electric power to the electric heaters of the snow-receptor plane, thus generating the quantity of heat needed to
30 keep the snow-receptor plane at -0°C , and keeping the snow-receptor plane free of snow; a central processor unit responsive to different signals from the thermal quantity measuring device for determining the quantity of heat needed to melt the snow lying on the snow-receptor plane while keeping the snow-receptor
35 plane at -0°C , and means to control an associated road conditioning installation in terms of the so determined quantity of heat needed to melt the snow lying on the snow-receptor plane.

A method of preventing the freezing of the road surface is improved according to the present invention in that it comprises the steps of: a) putting a road-simulated plate outdoors; b) measuring the quantity of heat needed to keep the road-simulated
5 plane at -0°C , thus keeping it free of snow; c) determining the quantity of heat needed to prevent the freezing of the road in terms of the quantity of heat measured at step (b); and d) controlling a road conditioning installation to supply the thermal energy to the road for keeping the road in unfreezing condition.

10 The road-simulated surface may be made of a material whose thermal capacity and thermal conductivity are nearly equal to those of asphalt or any other pavement material, thereby permitting the road-simulated surface to behave like an actual pavement surface when exposed to the heat radiated by the sun, the
15 cooling caused by heat radiation from the ground and other weather conditions. The road-simulated surface may be lined with a heat insulation material to prevent the losing of heat from the bottom of the simulated pavement. The temperature of -0°C , is a temperature below, but close to 0°C .

20 Means for detecting the falling of snow and the snow lying on the snow-receptor plane may be photoelectric devices. Photoelectric devices for detecting the falling of snow may be placed on the road-simulated surface whereas photoelectric devices for detecting the snow lying on the road-simulated sur-
25 face may be placed at a level somewhat higher than the road-simulated surface. Means for determining the water content of snow may have a heating unit equipped therewith.

The arithmetic section of the central processing unit determines the quantity of electric power to the electric
30 heaters of the road-simulated surface, which quantity of electric power is just needed to keep the road-simulated surface at the temperature of -0°C , thereby keeping it free of snows. and then the arithmetic section converts the electric power into the quantity of heat (calories), which is outputted as an
35 unfreezing heat quantity signal "B", which represents the quantity of heat needed to prevent the freezing of the road. The road conditioning installation is responsive to an unfreezing

operation command signal "H" for running, and the road conditioning installation is responsive to a signal representing an installation capability controlling value "D" (i.e. the ratio of the unfreezing heat quantity signal "B" to the maximum heating capability of the road conditioning installation) for supplying an adequate quantity of heat to the road for preventing the freezing of the road.

As for determination of the quantity of heat to melt the snow lying on the road, a snowfall sensor signal "E" appears upon simultaneous appearance of a snow flake signal "a", a simulated-road temperature signal "d" and an atmospheric temperature signal "d" each exceeding certain limits. A snow lying sensor signal "F" and a snow-melting operation command signal "G" are outputted upon simultaneous appearance of the snowfall sensor signal "E", a snow lying signal "c" and a water content signal "i", and electric power is supplied to the electric heaters during simultaneous appearance of these signals. Then, the quantity of electric power is determined and converted to calories, providing a snow-melting heat quantity signal "C".

Other objects and advantages of the present invention will be understood from the following description of a heat quantity measuring section of road conditioning installation according to one preferred embodiment of the present invention, which heat quantity measuring section is shown in accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a plane view of the heat quantity measuring section;

Fig.2 is a longitudinal section of the heat quantity measuring section;

Fig.3 shows diagrammatically what signals are provided by which parts of the heat quantity measuring section;

Fig.4 shows diagrammatically what signals are provided in a central processing unit; and

Fig.5 shows diagrammatically what signals are processed and how such signals are related in the central processing unit.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figs.1 and 2, a heat quantity measuring device comprises a snow-receptor plane 12 of a material which provides a similitude of the road surface, and snow-flake detecting sensors 8 and snow-lying detecting sensors 9 encircling the snow-receptor plane 12. As shown in Fig.1, these sensors are arranged in opposing relationship. Also, water-content gauges 10 are arranged around the snow-receptor plane 12 at regular angular intervals. As shown in Fig.2, the snow-receptor plane 12 has a road-surface simulated layer 5 lined with a thermal insulator 6. The road-surface simulated layer 5 has temperature gauges 1, 2 and 3 embedded at upper, intermediate and lower levels. Also, it has electric heaters 4 embedded close to its surface.

The temperature of the surface of the snow-receptor plane 12 is measured continuously by the temperature gauge 1 ("d" in Figs.3 and 4), and electric power to the electric heater 4 ("e" in Figs.3, 4 and 5) is controlled so that the surface of the snow-receptor plane 12 may be kept at a given constant temperature, for example around -0°C . The electric power needed to keep the surface of the snow-receptor plane 12 at the temperature of -0°C is converted into calorie, and the so converted value can be used in estimating the heat quantity needed to keep the actual road in unfreezed condition.

The Manner of Detecting the Falling of Snow at the Beginning:

The flakes of snow 7 can be detected by intercepting the light to the snow-flake detecting sensors 8 intermittently ("a" in Figs.3 and 4). A snow-flake signal generator 31 is connected to the snow-flake detecting sensors 8 (Fig.3). In the snow-flake signal generator 31 the optical signal from the snow-flake signal generator 31 is converted into the electric signal representing the quantity of falling flakes of snow; the amplitude of the so converted electric signal is compared with a given threshold value ("b" in Figs.3 and 4) to make a decision as to whether it is above the threshold value or not; and then in the affirmative case the signal generator provides a snow-flake signal of "HIGH" ("a" in Figs.3 and 4).

A high-speed inputting circuit 20 in the arithmetic section

of the central processing unit 26 (Fig.4) determines how long incoming snow-flake signals ("a" in Figs.4 and 5) last by counting the snow-flake signals, provided that each snow-flake signal is found to have a predetermined duration. The counted value is compared with a predetermined value in the arithmetic section of the central processing unit 26, and when the counted value is found to exceed the predetermined value, a snow detecting signal E is outputted, indicating the beginning of the falling of snow ("E" in Figs.4 and 5).

10 The Manner of Detecting the Lying of Snow:

Assume that the snow is lying on the surface of the snow-receptor plane 12 until the light to the snowfall detecting sensors 9 are intercepted ("C" in Figs.3, 4 and 5). A snow-lying signal generator 32 is connected to the snowfall detecting sensors 9 (Fig.3). When the light to the snowfall detecting sensors 9 is intercepted, the snow-lying signal generator 32 sends a snowfall signal "c" of "HIGH" to an input signal processing circuit 22 (Figs.3 and 4). In addition to confirmations of arrival of the snowfall signal "c" and the water content signal "i" (Fig.3), the arithmetic section 26 of the central processing unit makes decisions as to: (1) whether or not the atmospheric temperature detected by a temperature gauge 11 is within the temperature range in which it can be snowing, and (2) whether or not the temperature of the surface of the snow-receptor plane 12 measured by the temperature gauge 1 is within the temperature range in which snow can lie on the snow-receptor plane 12. In the affirmative cases the central processing unit permits an associated power supply 24 to send required electric power "e" to the electric heaters 4 of the road simulated device 12, and at the same time, a snow lying signal "F" is outputted (Figs.4 and 5).

The Manner of Determining the Heat Needed to Melt the Snow Lying on the Road-Simulated Device:

The electric power "e" which has been supplied to the electric heaters 4 of the road-simulated device 12 is integrated while the snowfall signal "c" remains at "HIGH", and the so integrated electric power is converted into calorie. This value

indicates the quantity of heat needed to melt the snow lying on the actual road. The quantity of heat "B" needed to keep the actual road in unfreezing condition and the quantity of heat "C" needed to melt the snow lying on the actual road can be calculated as follows.

The quantity of heat provided by the electric heaters 4 in the form of electric power is calculated for each of sequential sampling intervals "L" (Fig.5). In case of calculating the quantity of heat needed to keep the road in unfreezing condition the first sampling interval begins with the supplying of electric power "e" to the electric heaters 4 for keeping the surface of the snow-receptor plane 12 at the temperature of -0°C (so that the temperature of the snow-receptor plane 12 given by the surface temperature signal "d" may be kept at the temperature of -0°C in Figs.3 and 4), whereas in case of calculating the quantity of heat needed to melt the snow lying on the road the first sampling interval begins with the supplying of electric power "e" to the electric heaters 4 after appearance of the snowfall signal "c" of "HIGH" (Figs.3 and 4). The electric power supplied to the snow-receptor plane 12 is converted into calorie for each sampling interval TS (Fig.5), and the thermal value is divided by the time length of the sampling interval to provide a thermal quantity of calorie per minute. Finally, this value is divided by the area of the snow-receptor plane 12 (square meters). Thus, the reference value of the quantity of heat needed to prevent the freezing of the road or melt the snow lying on the road can be given in terms of $\text{Cal./min.}\cdot\text{m}^2$.

The anti-freezing heat quantity can be distinguished from the snow-melting heat quantity as follows: the electric power supplied to the electric heaters 4 while the snowfall signal "c" of "HIGH" appears is used to calculate the snow-melting heat quantity whereas the electric power supplied to the electric heaters 4 to keep the snow-receptacle plane 12 at the temperature of -0°C is used to calculate the anti-freezing heat quantity.

As for the continuity of the snow detecting signal E the signal-to-signal interval varies with the degree of heaviness

when it is snowing. The signal continues if the signal-to-signal interval remains the sampling duration TS , and if the signal-to-signal interval exceeds the sampling duration TS , the signal disappears.

5 As for the continuity of the snow lying signal "F" the signal begins when the snowfall signal "c" of "HIGH" appears, and when the prescribed weather and thermal conditions are satisfied to supply the electric power as described earlier, and the signal "F" ends with disappearance of the snow detecting signal E.

10 Installation capability controlling value D is defined as the ratio of unfreezing heat quantity "B" plus snow-melting heat quantity "C" to the maximum heat quantity available (per minute per square meters), and such installation capability controlling value D is given by the central processing unit 26. This value
15 D is recalculated for each sampling interval TS (Fig.5). At the first sampling interval $T1$ or $T7$, however, the unfreezing heat quantity "B" and snow-melting heat quantity "C" cannot be obtained. At the outset the installation capability controlling value D is estimated to be 100%. This has the effect of the road
20 being guaranteed to be free of snows at the outset.

If the installation capability controlling value D increases beyond one, the extra quantity exceeding one indicates the degree of shortage of the heat quantity supplied by the road conditioning installation, and then the extra quantity exceeding
25 one is added to the next calculation result at the following sampling interval to provide a correct installation capability controlling value D .

Assume that the quantity of heat needed to melt the snow lying on the ground or prevent the freezing of the road exceeds
30 the heating capability of the installation. Then, the extended running results inevitably. The extended running can be made to stop by generating a reset signal "K" by an operator.

The central processing unit provides atmospheric temperature signal "A", simulated-road temperature signal "d",
35 intermediate-level temperature signal "f", lower-level temperature signal "g", unfreezing heat quantity signal "B", snow-melting heat quantity signal "C", installation capability con-

2153113

trolling value "D", snowfall sensor signal "E", snow lying sensor signal "F", snow-melting operation command signal "G", unfreezing operation command signal "H", extended-running confirmation signal "I", snow flake count-and-water content signal
5 "i", road-surface temperature signal "d", inner temperature signal "f", snow-melting running confirmation signal "j", snow-melting installation failure signal "k" and other signals. These signals along with time and days of the calendar are recorded in integrated circuit cards at each sampling interval.
10 Also, the values set in the central processing unit 26 are recorded every time such values are reset.

15

20

25

30

35

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An integral whole unit for continuously measuring quantity of heat needed to melt snow lying on a road and prevent the freezing of the road, and for controlling supply of the heat to the road for melting the snow lying on the road and for preventing freezing of the road characterized in that it comprises:

a thermal quantity measuring device comprising a snow-receptor plane of a material which provides a similitude of the road surface, having electric heaters and temperature sensors embedded therein, means for detecting falling of snow and the snow lying on the snow-receptor plane, and means for determining water content of snow;

means to control supply of electric power to the electric heaters of the snow-receptor plane, thus generating the quantity of heat needed to keep the snow-receptor plane at -0°C , and keeping the snow-receptor plane free of snow;

a central processor unit responsive to different signals from the thermal quantity measuring device for determining the quantity of heat needed to melt the snow lying on the snow-receptor plane while keeping the snow-receptor plane at -0°C , and

means to control an associated road conditioning installation in terms of the so determined quantity of heat needed to melt the snow lying on the snow-receptor plane.

2. A method of preventing freezing of a road surface characterized in that it comprises steps of:

a) putting a road-simulated plane outdoors;

b) measuring quantity of heat needed to keep the road-simulated plane at -0°C , thus keeping the plane free of snow;

c) determining quantity of heat needed to prevent freezing of the road in terms of the quantity of heat measured at step (b); and

d) controlling a road conditioning installation to supply thermal energy to the road for keeping the road in unfreezing condition.

Fig. 1

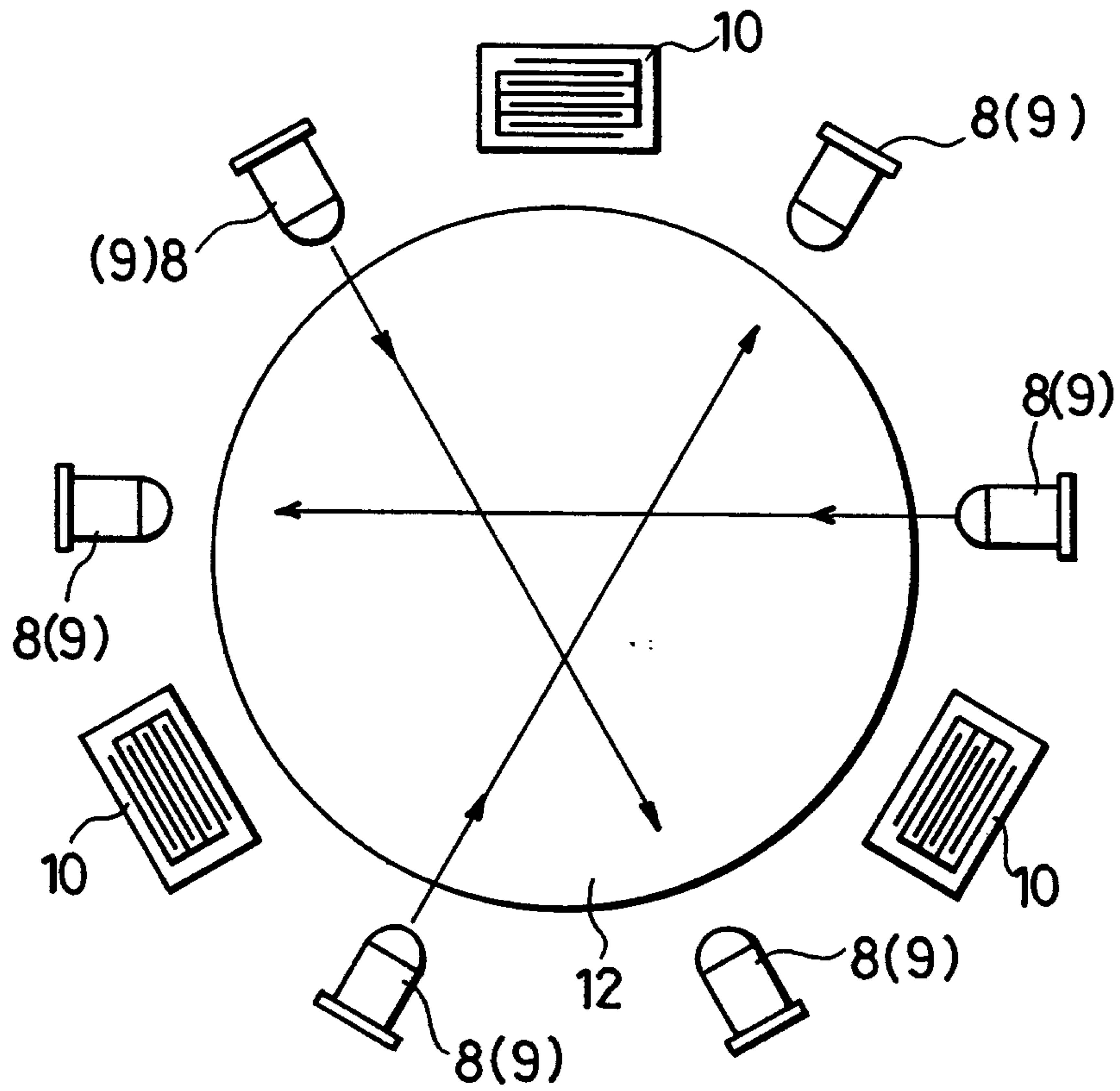


Fig. 2

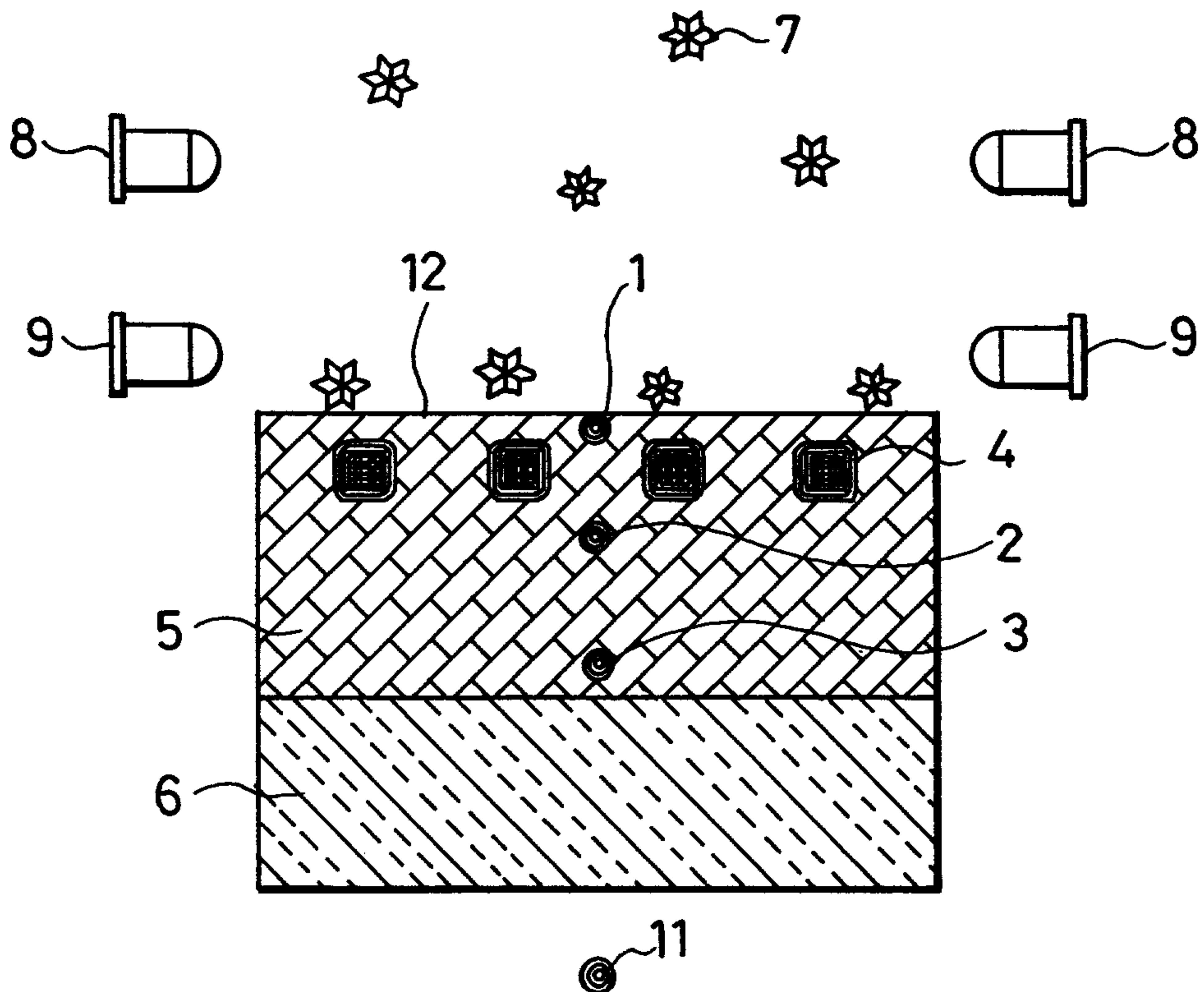


Fig.3

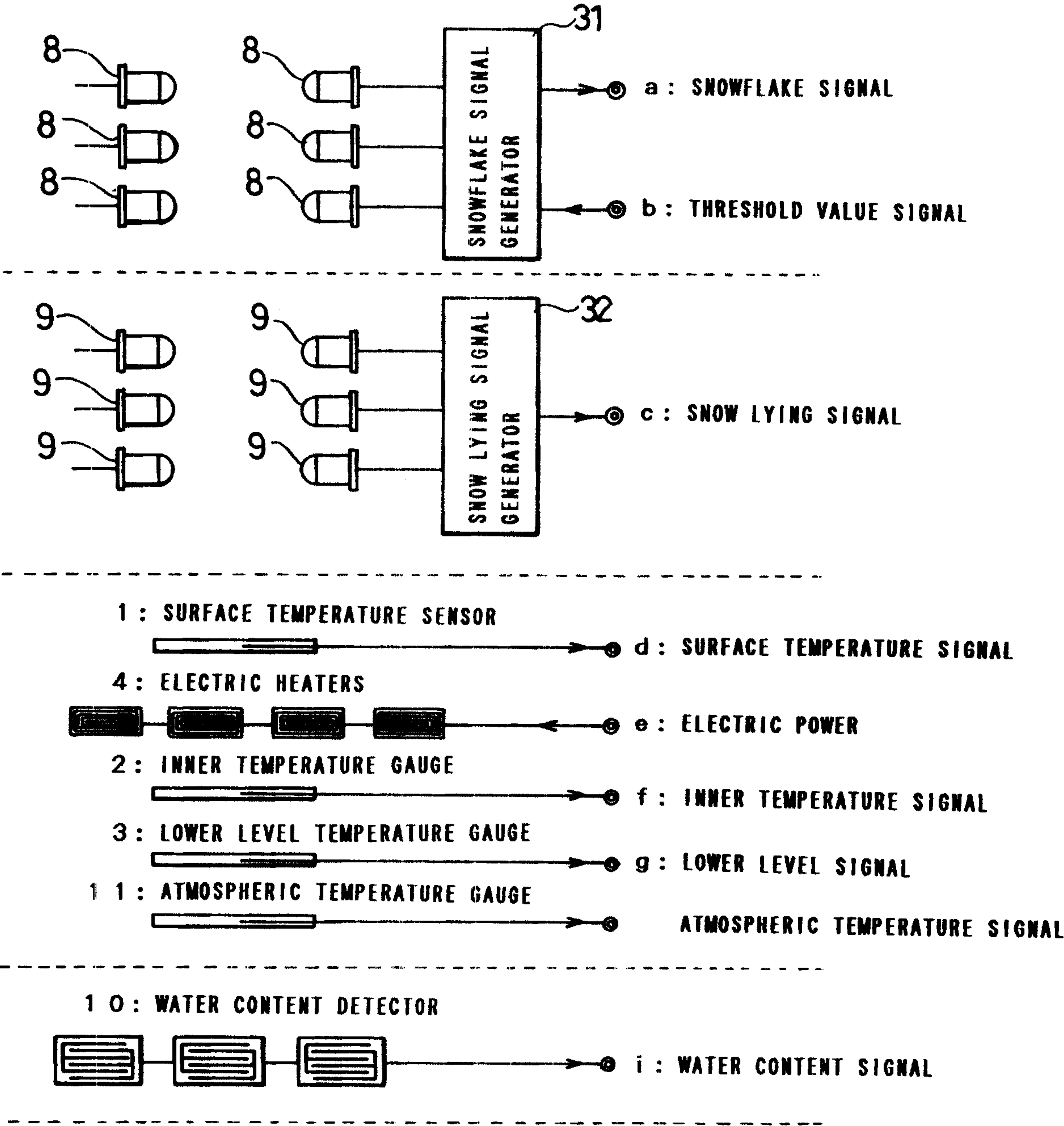


Fig. 4

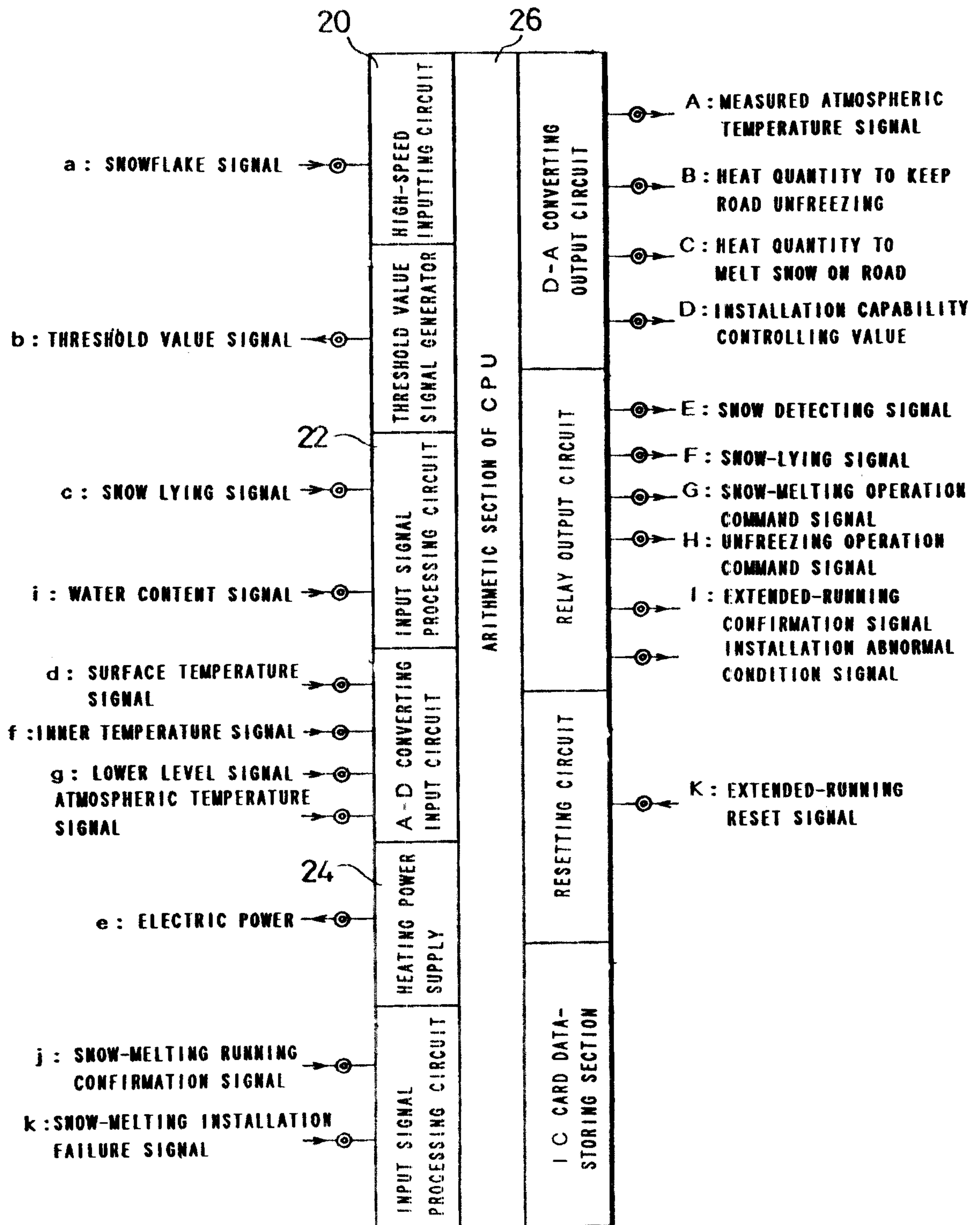


Fig. 5

