Determination of the Dew Point and the Frost Point below 0°C Making Use of the β -Ray Backscattering and the Electric Conductivity on the Narrow Surface of Insulated Layer

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It is necessary to distinguish between the dew point and the frost point below 0°C. The freezing of the dew and the melting of the frost are respectively detected by the rapid decrease and the increase of the conduction current on the narrow surface of insulated layer made of epoxy, 0.5 mm in width and 10 mm in length, on which the dew deposits. The dew point -9°C and the frost point -8°C in the humidity 21% at the temperature 13°C are clearly distinguished in this method.

Key Words: dew point, frost point, β -ray backscattering, conduction current

1. Introduction

A new method of determining the dew point using the low energy β -ray source of ^{14}C has been developed by H. Kobayashi et al.^{1),2)} and the two essential defects in the mirror type dew point hygrometer could be removed in this method. One is that the incidental rise of the surface temperature of the mirror is caused by illumination. The other is that the surface of the mirror on which the dew deposits makes super saturation easy.

The dew point hygrometer using β -ray source is based on the principle that the β -ray backscattering depends on the atomic number of the scattering materials and on the energy of β -rays³⁾. The dew point is given by the temperature at which the counting rate of scattered β -rays begins to decrease and then to increase, because the dew consisting of small atomic number elements begins to deposit and to disappear on the gold plate having large atomic number. The rough finish of the plate surface makes the condensation of water vapour easy.

In determination of the dew point below 0°C, it is necessary to distinguish between the dew point and the frost point and to detect the freezing of the dew which can not be detected in the above mentioned methods.

2. Detection of the freezing of the dew by the conduction current

Two electrodes of the gold needles are contacted with the water droplet of 0.8 cc placed on the glass plate and a potential of 10 volts is applied to the electrodes. The temperature of the glass plate and the conduction current through the droplet are recorded simultaneously against time as shown in Fig. 1. When the temperature was lowered gradually until $T_f - 3^\circ\text{C}$, the droplet began to freeze. Then, the conduction current decreased suddenly from 14

Fig. 1 The conduction current through the water droplet of 0.8 cc placed on the glass plate.

The water droplet froze at $T_f - 3^\circ\text{C}$ and also melted at $T_m 0^\circ\text{C}$.

μA to $0.5 \mu\text{A}$ and was kept at the constant value of $0.5 \mu\text{A}$ during freezing of the droplet. The conduction current increased rapidly to $20 \mu\text{A}$ at T_m 0°C when the freezing droplet melted. The freezing and the melting were observed with the microscope. The difference in the conduction currents between the freezing and the melting droplets was so larger than the values expected from the specific electric resistances of the ice and water because the water droplet was not pure.

This result indicates the possibility that the freezing of the dew could be detected by the rapid decrease of the conduction current.

3. Experimental apparatus

The apparatus is schematically shown in Fig. 2(a). The β -ray source of ^{14}C is about $0.1 \mu\text{Ci}$. The Geiger-Müller counter which has a mica window of 1.4 mg/cm^2 thickness and 25 mm in diameter is fixed behind the β -ray source for detecting the β -rays backscattered. The β -ray source is fixed in a hollow in a small lump of plastics attached to the cross fibers and placed in front of the counter window, facing on the gold plate. The direct β -rays from the source are prevented from entering into the counter by the plastic lump. The plate which is 25 mm in diameter and 0.01 mm in thickness is cooled by the thermoelectronic cooler. The temperature of the plate is measured by the thermocouple sheet of copper-constantan of 0.15

Fig. 2(a) Schematic illustration of the experimental apparatus.

A: Geiger-Müller counter, B: β -ray source of ^{14}C , C: Gold circular plate of 25 mm in diameter, D: Thermoelectronic cooler, E: Thermocouple sheet of copper-constantan, F: Insulated layer made of epoxy.

Fig. 2(b) Four parts of the gold plate and a narrow surface of insulated layer on which the dew deposits.

G: a narrow surface of insulated layer, 0.5 mm in width and 10 mm in length, for measuring the conduction current, V: 40 volts, R: electric resistance of $10 \text{ k}\Omega$.

mm in thickness which is contacted with the back of the plate. The geometrical arrangement of the apparatus are taken as follows; the distances between the β -ray source and the plate and between the β -ray source and the counter window are adjusted to 7.5 mm and 5 mm, respectively.

To detect the freezing of the dew, the conduction current on the narrow surface of insulated layer is measured as shown in Fig. 2(b). The insulated layer made of epoxy, 0.2 mm in thickness, of high electric resistance more than $10^9 \Omega$ is placed between the thermoelectronic cooler and the plate. The plate is divided into four parts by the narrow surface of 0.5 mm in width of insulated layer. Since the temperature difference between the center and the circumference of the plate is within 0.5°C , the conduction currents on the narrow surface of 10 mm in length across the center of the plate are measured by the potential difference at the resistance R of $10 \text{ k}\Omega$ and a potential of 40 volts is applied to the plates.

4. Experimental results

The apparatus was set in a cubic box, 70 liters in volume, in which the humidity and temperature were regulated constant by the dilute sulphuric acid in petri dish and by the water at the constant temperature around the box, respectively. Also, the air was stirred gently with a fan during the measurements. The counting rate of β -rays backscattered, the temperature of the plate and the conduction current are recorded simultaneously against time.

The time constant of the counting rate-meter is 30 sec.

The experimental results in the humidity 21% at 21°C are shown in Fig 3 and the dew point is -2.1°C . The counting rate is kept at the constant value of 7800 cpm until the temperature reaches $T_d - 2^{\circ}\text{C}$, and then the counting rate begins to decrease. That is, T_d indicates the dew point. After the temperature became lower than the dew point, the counting rate decreased and the conduction current increased, respectively, by the reason why the amount of the dew became large. The cooling was stopped and then the temperature was risen. The counting rate recovered gradually to 7800 cpm and also the conduction current decreased to $0\ \mu\text{A}$ again when the deposited dew disappeared. The dew does not freeze during the measurements as known in the conduction current curve because the conduction current does not make the rapid decrease at the freezing of the dew as shown in Fig. 1.

The other results that the dew freezes during the measurements in the humidity 21% at 20°C are shown in Fig. 4. The measured dew point T_d at which the counting rate begins to decrease is -3°C and is almost equal to the correct dew point -2.9°C . The conduction current decreases suddenly at the temperature T_f in the same way as shown in Fig. 1. It indicates that the dew freezes at $T_f - 6^{\circ}\text{C}$. Also, the temperature T_m 0°C at which the conduction current increases rapidly gives the melting point of the frost. In this way, the dew point is determined and the freezing of the dew and the melting of the frost are detected.

The dew point and the frost point in the humidity 21% at 13°C are obtained by changing the temperature stepwise as shown in Fig. 5. The counting rate is not varied while the temperature is kept at $T_1 - 8.5^{\circ}\text{C}$. But, the counting rate begins to decrease gradually at the tem-

Fig. 3 Determination of the dew point.

The measured dew point T_d in the humidity 21% at 21°C is -2°C . The deposited dew does not freeze because the conduction current does not decrease rapidly.

Fig. 4 Determination of the dew point and detection of the freezing of the dew.

The measured dew point T_d in the humidity 21% at 20°C is -3°C . The freezing of the dew is detected at $T_f - 6^{\circ}\text{C}$ and also the melting of the frost is detected at T_m 0°C .

Fig. 5 Determination of the dew point and the frost point by changing the temperature stepwise.

The dew point and the frost point in the humidity 21% at 13°C are determined. The dew point is lower than $T_1 - 8.5^{\circ}\text{C}$ and higher than $T_2 - 9.5^{\circ}\text{C}$. The frost point is higher than $T_3 - 8.5^{\circ}\text{C}$ and lower than $T_4 - 7.4^{\circ}\text{C}$.

perature $T_2 - 9.5^\circ\text{C}$. Therefore, the dew point is $-9.0 \pm 0.5^\circ\text{C}$. When the temperature reached the dew point the conduction current increased rapidly and then decreased rapidly, too. The decrease indicates the freezing of the dew. The counting rate decreases continuously while the temperature is kept at $T_3 - 8.5^\circ\text{C}$. Because the temperature T_3 is slightly lower than the frost point. The frost stops depositing and begins disappearing gradually at the temperature $T_4 - 7.4^\circ\text{C}$ which is slightly higher than the frost point. The frost point, therefore, could be determined to an accuracy of $\pm 0.5^\circ\text{C}$ at -8.0°C conclusively. The counting rate recovered to the initial value again when the deposited frost disappeared perfectly. The rapid increase of the conduction current by the melting of the frost does not occur because the deposited frost almost disappeared simultaneously with the melting.

5. Conclusion

The freezing of the dew and the melting of the frost can be respectively detected by the rapid decrease and the increase of the conduction current on the narrow surface of insulated layer made of epoxy on which the dew deposits. The dew point -9°C and the frost -8°C in the humidity 21% at the temperature 13°C are clearly distinguished by making use of the β -ray backscattering and the electric conductivity on the deposition surface.

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要 旨

後方散乱 β 線と伝導電流による 0°C 以下の露点と霜点の測定

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後方散乱 β 線を利用した 0°C 以下の露点測定でエポキシ絶縁体の微小表面, 幅 0.5mm , 長さ 10mm の伝導電流によって露の氷結を検出した。露の氷結が, 伝導電流の急激な減少により検出でき, また, 霜の融解が伝導電流の急激な増加によって検出できることを示した。温度 13°C , 湿度21%での露点 -9°C と霜点 -8°C を後方散乱 β 線と伝導電流により区別して測定した。