An Automatic Dew-point Hygrometer Making Use of β-Ray Backscattering and Controlled at the Constant Amount of Dew

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Received April 16, 1988

A control system which consists of proportional and integral control to maintain the constant amount of dew was developed in this hygrometer. The dew points were measured within an accuracy of ±1 °C in the ranging from −4 to 32 °C. The response time for suddenly changing humidity was about 8 min.

Key Words: beta-ray backscattering, automatic dew-point hygrometer, constant amount of dew

1. Introduction

A new method of determining the dew-point by β-ray backscattering has previously been reported by the authors. It is based on the principle that the β-ray backscattering by the mental plate having a large atomic number decreases when the surface of the plate is covered by dew consisting of small atomic number elements. In this method numerous condensation nuclei formed by β-rays and the rough finish of the plate surface make the formation of dew easy. This method is also free from the errors owing to the incidental rise of the surface temperature caused by the illumination which is indispensable for the mirror type hygrometer. An automatic dew point hygrometer based on this method has also been reported by the same authors. A proportional control system was employed in the hygrometer where the cooling current of a thermoelectronic cooler contacted with the plate was proportional to the counting rate of β-rays backscattered. The dew points were measured in the ranging from −6 to 47 °C with an accuracy of ±1 °C. The maintained amount of dew was dependent on the cooling current which was necessary to follow the dew point. This dependency was the disadvantage in the hygrometer because the amount of dew was expected to be as small as possible and constant.

The hygrometer was developed in this paper to control the constant amount of dew which was independent of the dew point.

2. Construction and Control System of the Hygrometer

The construction of the hygrometer is shown in Fig. 1. 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 GM counter window, facing on the plate. β-rays emitted from the source are scattered by the plate and measured by the GM counter, but direct β-rays from the source are prevented from entering into the counter. Carbon-14 of about 3.7 kBq (0.1 μCi) and gold plate of 25 mm in diameter were used as the β-ray source and the metal plate, respectively. The plate was cooled thermoelectronically and the surface temperature was measured by a thermocouple.

A control system of the hygrometer consists of proportional and integral control. The output signal voltage \( e_1 \) of the counting ratemeter is separated into two signals. One of them is transmitted to the differential amplifier where the fixed voltage \( V_a \) is decided by the amount of dew to be controlled. The amplified differ-
Fig. 1 Control system of the automatic dew point hygrometer making use of β-ray backscattering.

\( V_s \): Fixed voltage corresponding to the constant amount of dew;
\( V_0 \): Fixed voltage corresponding to the initial cooling currents;
\( V_c \): Threshold voltage of the Darlington circuit; \( S \): Switch.

The counting rate of β-rays scattered by the gold plate was 8200 cpm and then the \( V_s \) was fixed at 7.5 mV corresponding to the counting rate of 7500 cpm which was due to the amount of dew deposited slightly on the gold plate.

3. Experimental Results

In order to test the control system, the hygrometer was placed in a cubic box of 30 liters in volume in which the temperature was kept constant and the relative humidity was also regulated by sulfuric acid. The air in the box was stirred gently by a small fan. The temperature of the gold plate and the counting rate were recorded against time at 20 °C and 50% RH where the time constant of RC in the integrator circuit was experimentally set at 100 s and 200 s as shown in Figs. 2 and 3, respectively. The switch \( S \) in the cooling current was turned on at \( t_1 \) in the figures and then the initial cooling current was 0 A by adjusting the \( V_0 \). The temperature and the counting rate were unstable in Fig. 2. On the other hand, the temperature was gradually lowered before the dew point was maintained stably at 9 °C in Fig. 3. The counting rate was decreased to the values corresponding to the fixed \( V_s \) and maintained stably. The time constant was desirably set at 200 s in the dew points ranging from -4 to 32 °C.

The initial cooling current was set at 1 A by adjusting the \( V_s \) to reduce the initial time required to be measured. The counting rate
and the temperature of the gold plate were recorded against time at 20 °C and 50%RH where the correct dew point was 9.3 °C as shown in Fig. 4. In the figure, the switch in the cooling current was turned on at $t_1$. The temperature was lowered rapidly to the dew point which was 9 °C. The initial time was about 5 min.

The errors in the dew point measurements were examined when the $V_a$ corresponding to the amount of dew were set at various values. The counting rate and the temperature of the gold plate were recorded against time at 20 °C and 80% RH when the $V_s$ was set at 7.5 mV,
Fig. 4 Initial time required to be measured at 20°C and 50% RH where the correct dew point was 9.3°C. The switch S was turned on and the initial cooling current was set at 1 A by adjusting V₀ at t₁.

Fig. 5 Temperature of the gold plate and the counting rate recorded against time at 20°C and 80% RH when the Vₘ was set at 7.5 mV, 6.0 mV and 4.0 mV. 6.0 mV and 4.0 mV as shown in Fig. 5. The counting rates were controlled at constant values. Namely, the amount of dew could be controlled at constant. The dew points measured were 16°C in spite of changing the Vₘ and were independent of the amount of dew,
while the correct dew point was 16.5 °C.

In order to examine the response for suddenly changing humidity, the small cubic box was connected with the large cubic box of 100 liters in volume by a shutter plate. The humidities in the small and the large boxes were regulated at 80% RH and 53% RH, respectively. When the shutter plate was removed momentarily, the humidity in the small box was suddenly changed into that in the large box. The counting rate and the temperature were recorded against time as shown in Fig. 6. The switch S in the cooling current was turned on at $t_1$ and the dew point in the small box was 16.5 °C until $t_2$. When the shutter plate was open at $t_3$, the dew point was changed into 10.0 °C and the response time for changing humidity was about 8 min. The counting rate increased temporarily because the dew point was lowered and the dew disappeared. Then the counting rate recovered to the initial value, following the lowered dew point.

Measurements in the dew points ranging from −4 to 32 °C have been done and the dew points could be measured within an accuracy of ±1 °C.

4. Conclusion

A control system which consists of proportional and integral control to maintain the constant amount of dew was developed in the hygrometer making use of β-ray backscattering. The dew points in the ranging from −4 to 32 °C were measured within an accuracy of ±1 °C and the response time for suddenly changing humidity was about 8 min.

References


要 旨

β線の後方散乱を利用し結露量を一定値制御した自動露点計

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比例積分制御回路を用い結露量を一定値に保ちつつ露点を追従する自動露点計を試作した。この自動露点計は結露量を任意の一定値に制御でき、-4℃～32℃の露点を±1℃内の精度で測定できた。また、湿度変化に対する応答時間は約8分であった。