Note

A Gas Replacement Monitor for β -ray Cameras[†]

Takahiko AOYAMA, Shigeaki MATSUNAGA and Tamaki WATANABE

Department of Nuclear Engineering, Nagoya University

Furo-cho, Chikusa-ku, Nagoya-shi 464

Received March 17, 1980

Key Words: spark chamber, β -ray camera, gas replacement, counting gas monitor

1. Introduction

Beta-ray cameras using self-triggering spark chambers as a detector are widely used for the rapid measurement of radionuclide distributions on thin layer and paper chromatograms^{1),2)}. Both thin windowed and windowless gas flow types of the chamber are used to detect low energy β -rays such as those from ^{14}C and ^3H . The most important matter to obtain good images corresponding well to the radionuclide distributions in specimens with these cameras is uniformity of sensitivity over the whole detection area of the chambers. The uniformity depends partly on the performance of the chambers but in larger part on the uniformity of replacement of the air to the counting gas. In commercially available β -ray cameras, as the air cannot be replaced uniformly over the whole detection area, uniformity of the sensitivity lowers when the replacement is incomplete. Recognition of the completeness has however been relied on the sense of the operators so far, since commercial β -ray cameras have no systems to detect it. The present paper describes a method to detect the completeness of the replacement by using a gas flow GM counter, possessing a β -ray source inside, which is connected to the gas outlet of the chamber. With this system, the completeness can be determined by monitoring the operation of the GM counter.

2. Apparatus

Figure 1 shows the schematic layout of the apparatus. The β -ray camera used in the present experiment is the Aloka BCC-101 Betachromatogram Camera, which uses as a detector the hybrid spark chamber³⁾ operating on Q gas. In usual operational conditions, the gas flows into the chamber from both sides of the chamber and flows out directly to the atmosphere from a pinhole made on the bottom of the chamber. However, in the present experiment, the gas was made to flow from one side of the chamber to the other, with the pinhole being filled, in order to connect the GM counter to the chamber. The GM counter used here is of cylindrical type, made of brass, being 28 mm diameter $\times$ 124 mm long, with an anode made of stainless steel wire of diameter 0.05 mm. If the gas regularly flows into the counter at a rate of 500 cm³/min, it is expected that all the gas in the counter will be replaced by new one in about ten seconds. Actually, it took about one minute for the air in the counter to be replaced with Q gas at the same flow rate, which is however short enough compared with a replacing time

Fig. 1 Schematic layout of the apparatus.

[†] β 線カメラ用ガス置換監視器. 青山隆彦, 松永繁秋, 渡辺鑑: 名古屋大学工学部原子核工学科, 464 名古屋市千種区不老町.

of about 20 minutes for the spark chamber. The GM counter has a ^{14}C β -ray source within the counter which is made of barium stearate monomolecular two-layer films deposited on a square brass plate with a side of 10 mm and covered with a silvered Mylar film of a total thickness of about 0.9 mg/cm^2 .

The block diagram of the electronic circuitry is shown in Fig. 2. Stabilized high voltage was

Fig. 2 Block diagram of the electronic circuitry.

supplied to the GM counter through a resistor of $1 \text{ M}\Omega$, and the output signal of the counter was amplified and led to a rate meter which can inform the counting rate above an arbitrary defined level by buzzing. These electronic units are packed in a case, denoted as the rate meter with a buzzer in Fig. 1 and 2, and the output signal of the amplifier, if necessary, can be led to an extra scaler. The amplifier and the rate meter used in this system have an over-all input sensitivity of 0.6 V which is slightly larger than the pulse size 0.4 V at the starting of the Geiger discharge. The time constant of the rate meter was set to 2.2 seconds. As the counting rate at the plateau was nearly 5000 cpm , the fractional standard deviation of the counting rate became about 5% at plateau regions.

3. Results and Discussion

The gas entering the GM counter is the mixture of Q gas and various percentages of the air corresponding to the degree of Q gas replacement. Hence we examined the operational characteristics of the counter for various mixing rates of the air by adding the air with various flow rates below $10 \text{ cm}^3/\text{min}$ to Q gas which is flowing at a constant rate of $200 \text{ cm}^3/\text{min}$. The results are shown in Fig. 3 in which the counting characteristic curves were measured with the scaler. In this case, the input sensitivity of the scaler was equalized to that of the rate

Fig. 3 Counting characteristic curves of the GM counter at various air contents.

meter by adjusting the discriminator level of the scaler. Though both dry air having a dew-point below -70°C and humid air produced by bubbling the dry air through water at 22°C were used in the experiment, there was no difference between counting characteristic curves at the same air content (In Fig. 3, an example is shown at an air content of 4.5%). It is seen in Fig. 3 that each curve has the plateau having nearly the same counting rates at air contents below 2.9% though slightly larger counting rates are obtained at an air content of 4.5% . It is also seen in Fig. 3 that the starting voltage increases with air content. Since the applied voltage offering the half of the plateau counting rate can accurately be found out, this voltage,

Fig. 4 Dependence of the effective starting voltage of the GM counter on air content. The points (a) and (b) in this figure correspond to the images (a) and (b) in Fig. 5.

here termed the effective starting voltage V_s , was examined for various air contents. The results are shown in Fig. 4, which indicate that the value of V_s increases almost linearly with air content below 5%.

Figure 5 shows the images of a ^{14}C plane source actually obtained with the β -ray camera at different degrees of Q gas replacement. It is seen from Fig. 5 that good uniformity is obtained

Fig. 5 Uniformity test for the β -ray camera. Total counts: 6000; Camera stop: $f/4.5$; Film: Polaroid ASA 3000. (a) $V_s=1020$ V, (b) $V_s=1080$ V.

at a V_s of 1020 V though the image is distorted when the value of V_s is 1080 V. The residual air content at a V_s of 1020 V is found to be 0.1% and that at 1080 V to be 1.1% from Fig. 4.

Based on the results described above, we can actually utilize the present gas monitor as follows. First, the buzzer sensitivity of the rate

meter with a buzzer should be set at 2500 cpm—i.e. the half of the plateau counting rate, and an applied voltage of the GM counter at 1020 V. After the starting of Q gas supply, measurement with the β -ray camera should be started when the gas monitor informs the counting rate increase above 2500 cpm by buzzing, which is the condition we can obtain good uniformity with the β -ray camera.

4. Conclusion

The present monitor system allows to determine explicitly and absolutely the time when the air in the spark chamber is completely replaced with Q gas. Though, with the present β -ray camera and the gas flow system, satisfied uniformity was obtained when the air in the spark chamber was almost completely replaced with Q gas, with another types of the camera having improved gas flow systems, the larger content of residual air, therefore the smaller amount of Q gas to be supplied may be allowed. By applying the present method we will be able to construct the system in which β -ray cameras start measurements automatically when the air is sufficiently replaced with the counting gas.

References

- 1) S. Prydz: *Anal. Chem.*, **45**, 2317 (1973)
- 2) I. Smith, S.E. March, P.E. Mullen and P.D. Mitchell: *J. Chromatogr.*, **82**, 75 (1973)
- 3) T. Aoyama and T. Watanabe: *Nucl. Instr. and Meth.*, **150**, 203 (1978)