

COMPARISON OF SCINTILLATION AND GAS FILLED DETECTORS FOR CONTAMINATION MONITORING

Alfred Klett, Peter Haefner, Wilfried Reuter

Berthold Technologies, P.O. Box 100163, 75312 Bad Wildbad, Germany

PRINCIPAL CHARACTERISTICS OF THE DETECTORS

There are now for radioactive contamination monitoring not only instruments with gas filled detectors but also with scintillation detectors in use. These detection techniques are having special advantages and drawbacks for the user and the application. A scintillator is usually a rugged component with a relatively low weight and high detection efficiency. The technical problems with scintillators are mainly in effective and uniform light detection. Gas filled detectors have good uniformities in detection efficiencies. Their main disadvantages are the gas supply and thin entrance windows. These foils can easily be damaged resulting in gas leakage. The physical differences between these two detector types are mainly in

- interaction of ionising radiation with the detector materials
- entrance windows
- collection of electric charge or visible light

The efficiency of charged particle detection is for scintillators and for gas filled detectors not too different, but for photons it strongly depends on the composition of the detector materials and especially on their atomic numbers. Depending on the emissions of a radionuclide the overall efficiency could be completely different for a scintillator or a gas filled detector.

Entrance windows are acting as gas barriers for gas filled detectors, while they are protecting against external light for scintillation detectors. Thin aluminized plastic foils are perfectly shielding against ambient light but the gas tightness would only be sufficient for flow through counters. Permanently sealed gas detectors require thicker metallic materials such as titanium foils. Therefore scintillation detectors and flow through or refillable gas detectors have relatively thin entrance windows, while permanently sealed gas detectors utilize thick entrance windows. Alpha-detection is only feasible with thin plastic foils

Ionising radiation produces light in scintillators and electric charge in gas filled detectors. These quantities are generating the signal of detection. While effective charge collection in gas filled detectors is relatively simple, light collection from the whole sensitive detection area of a flat scintillator could be a challenge. Especially efficient light collection from the corners of a detector is difficult. Innovative and clever reflector geometries are required to achieve a sufficient uniformity in detection across the sensitive surface. We are here comparing three different instruments representing these technologies. They are listed in table 1.

DETECTION EFFICIENCIES

The detection efficiencies for different radionuclides are depending on their specific emissions and were measured with radioactive sources with areas of 10 cm × 10 cm. The sources were manufactured by QSA Global in Braunschweig, Germany. The activities were certified traceable to national standards with a relative uncertainty of 3%. The efficiencies are shown in table 2. Those related to beta-gamma channels are ranging from 1 to 27, while those ranging from 28 to 32 refer to alpha channels. The efficiencies of the scintillator based instrument are for many nuclides by far superior to the gas filled detectors. This is mainly caused by a larger response to gamma radiation and fast beta-particles. For a few nuclides like ⁵¹Cr and ²³⁸Pu there are lower efficiencies compared to the proportional counters. The efficiencies for alpha detection are roughly of the same order of magnitude for the butane filled detector and the scintillator. For most of these nuclides the detection limits with the scintillation detector are considerably lower than that of the gas filled detectors.

The cross talk from the alpha-channel into the beta channel measured with a pure alpha emitter is better than 20% for the LB 124 SCINT. Normally this is a problem for scintillators and there are instruments on the market with alpha cross talks exceeding 100%. The gas filled counters have lower alpha cross talks than the scintillators. The cross talks from beta into alpha channel are much lower for all instruments around 2 × 10⁻².

UNIFORMITY OF RESPONSE ACROSS THE SENSITIVE AREA

The uniformities of the response of the instruments to point sources with diameters below 10 mm were also investigated. Figure 1 shows longitudinal profiles of the relative yield with a ⁹⁰Sr point source. As the gas filled detectors are relatively similar, we compare only a profile of a sealed Xenon proportional counter with the scintillator. The gas filled counter exhibits small variations within a few percent. The periodic structure is generated by the drift cells in the sensitive volume. There is no decrease at the edge of the sensitive area. The scintillator shows larger reductions in efficiency at the borders of the detector on both sides. The profile is asymmetric and the maximum is not centered. The relative yields are well within ± 20%.

DISCUSSION AND CONCLUSION

Gas filled detectors could more easily be destroyed than scintillators. On an average this generates more problems and also higher repair cost. This is certainly one of the reasons that made scintillators so popular in contamination monitoring.

Scintillation detection has been proven to be a reliable and competitive technology for contamination monitoring. The efficiencies and detection limits are in general superior to comparable gas filled detectors. This is also true for many nuclear medicine nuclides with photon emitters. Simultaneous and separate measurement of alpha- and beta-gamma radiation can easily be achieved by pulse analysis. The overall weight of a scintillation based instrument can be substantially lower than the weight of an instrument with a gas proportional counter. The temperature range of scintillators is not limited by condensation, which is a severe constraint for butane counters. Even regarding uniformity of the response across the sensitive area new developments made scintillation detectors comparable to gas filled counters. And after all it is convenient to abandon gas supply or gas refilling. Berthold Technologies as a designer and manufacturer of both types of technologies considers scintillation detection in contamination monitoring as an extremely promising technique for the future.



Table 1: Compared Instruments with scintillation detection or with gas-filled detectors

| Berthold Type | LB 124 SCINT | LB 122 A | LB 124 B |
|-----------------------------------|-------------------------------------|----------------------------------|---------------------------------|
| Detector Type | Scintillation Detector | Proportional Counter | Proportional Counter |
| Scintillator/Gas | ZnS(Ag) | Butane | Xenon/Methane |
| Sensitive Area | 170 cm ² | 218 cm ² | 150 cm ² |
| Entrance Window | Aluminized Plastic | Aluminized Plastic | Titanium |
| Thickness | 0.8 mg/cm ² | 0.4 mg/cm ² | 5 mg/cm ² |
| Detection Mode | Simultaneous and separate α and β-γ | Selectable α or β-γ | Only β-γ |
| Typical Background Counting Rates | 0.05 cps for α 15 cps for β-γ | 0.05 cps for α 10 cps for β-γ | 12.5 cps |
| Weight(incl. batteries) | 1300 g | 2175 g | 1620 g |
| Temperature Range | -20°C to +40°C | +5°C to +50°C | -15°C to +50°C |
| External Dimensions | 240 x 140 x 110 mm ³ | 234 x 140 x 126 mm ³ | 240 x 140 x 110 mm ³ |

Table 2: Efficiencies of contamination monitors with scintillation and gas filled detectors

| No. | Nuclide | LB 124 SCINT [%] | LB122A [%] | LB124B [%] | No. | Nuclide | LB 124 SCINT [%] | LB122A [%] | LB124B [%] |
|-----|--------------------|------------------|------------|------------|-----|-------------------|------------------|------------|------------|
| 1 | ¹⁴ C | 11.4 | 11.0 | 2.2 | 17 | ¹¹¹ In | 21.9 | 2.8 | 3.9 |
| 2 | ¹⁸ F | 62.3 | 21.0 | 17.6 | 18 | ¹¹³ Sn | 31.3 | 10.4 | 12.1 |
| 3 | ³² P | 60.4 | 30.6 | 30.0 | 19 | ¹²⁵ I | 20.0 | 4.5 | 5.1 |
| 4 | ³³ P | 36.0 | 18.3 | 7.6 | 20 | ¹²⁵ I | 12.2 | 1.7 | 3.6 |
| 5 | ³⁵ S | 15.2 | 13.8 | 2.9 | 21 | ¹³¹ I | 56.0 | 23.1 | 16.9 |
| 6 | ³⁶ Cl | 50.0 | 27.4 | 24.4 | 22 | ¹³⁷ Cs | 49.3 | 25.2 | 20.5 |
| 7 | ⁵¹ Cr | 0.2 | 30.0 | 1.8 | 23 | ²⁰¹ Tl | 8.5 | 7.1 | 6.0 |
| 8 | ⁵⁷ Co | 5.2 | 1.4 | 3.2 | 24 | ²⁰⁴ Tl | 35.9 | 23.5 | 19.5 |
| 9 | ⁵⁸ Co | 10.6 | 4.4 | 4.3 | 25 | ²³⁸ U | 36.6 | 82.6 | 40.1 |
| 10 | ⁵⁹ Fe | 47.1 | 21.0 | 12.6 | 26 | ²³⁸ Pu | 2.8 | 17.4 | 8.9 |
| 11 | ⁶⁰ Co | 33.7 | 18.8 | 26.3 | 27 | ²⁴¹ Am | 9.0 | 23.1 | 11.2 |
| 12 | ⁶⁷ Ga | 16.9 | 6.4 | 4.8 | 28 | ²¹⁰ Po | 23.5 | 17.9 | n/a |
| 13 | ⁷⁵ Se | 7.8 | 1.8 | 5.0 | 29 | ²³⁸ U | 12.3 | 27.7 | n/a |
| 14 | ⁸⁹ Sr | 57.0 | 27.8 | 27.3 | 30 | ²³⁸ Pu | 23.5 | 15.4 | n/a |
| 15 | ⁹⁰ Sr/Y | 48.8 | 57.3 | 49.1 | 31 | ²³⁶ Pu | 23.0 | 15.3 | n/a |
| 16 | ^{99m} Tc | 9.5 | 3.0 | 2.6 | 32 | ²⁴¹ Am | 22.5 | 15.7 | n/a |

Figure 1: Response Uniformity Profile with ⁹⁰Sr

