Comparison Of Scintillation And Gas Filled Detectors For Contamination Monitoring

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INTRODUCTION

There are now for radioactive contamination monitoring not only instruments with gas filled detectors but also devices with scintillation detectors in use. These detection techniques have significant physical differences and utilize hardware with specific properties. Therefore there are 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. For both types of instruments efficiencies, typical background levels, position dependent responses and minimum detectable activities for a wide range of radionuclides are summarized and discussed. Also other handling features, like for instance weight, temperature ranges and aspects of service and maintenance are discussed.

PRINCIPAL CHARACTERISTICS OF THE DETECTORS

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 relatively high and not too different. But the detection efficiency for photons strongly depends on the composition of the detector materials and especially on their atomic numbers. With Xenon or ZnS as detector materials the efficiencies for photon detection would be higher than with butane or with thin plastic scintillators. 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 for gas filled detectors as gas barriers, 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 and the detection efficiencies for weakly penetrating beta-particles would also be reduced by thicker metallic windows.

Ionising radiation produces light in scintillators and electric charge in gas filled detectors. These quantities are generating the signal of detection, which would indicate the radiation level. But there is an important difference in collecting the light respectively in collecting the charge. While effective charge collection in gas filled detectors is relatively simple and straightforward, 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. In order to achieve a sufficient uniformity in detection across the sensitive surface innovative and clever reflector geometries are required, because not only high efficiencies, but also small and compact instruments are needed.

We are comparing three different instruments representing these technologies. These instruments are listed in table 1 together with their most important specifications. The newly developed contamination monitor LB 124 SCINT is based on scintillation detection with a PMT, while the LB 122 A with a refillable butane gas detector and the LB 124 B with a sealed Xenon detector are both utilizing gas proportional counters. The gas filled detectors have metallic housings and therefore these instruments have higher weights.

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 cm²	218 cm²	150 cm²
Entrance Window	Aluminized Plastic	Aluminized Plastic	Titanium
Thickness	0.8 mg/cm²	0.4 mg/cm²	5 mg/cm²
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

DETECTION EFFICIENCIES

The detection efficiencies for different radionuclides are depending on their specific emissions and were measured with radioactive sources with well-known activities. These sources had areas of 10 cm × 10 cm. The activities were homogeneously distributed on a thin foil. QSA Global GmbH in Braunschweig, Germany, the manufacturer of the reference sources, is accredited by the Physikalisch-Technische Bundesanstalt PTB as calibration laboratory for measurements of radioactivity (Deutscher Kalibrierdienst DKD). QSA Global certified the activities traceable to national standards at the PTB with a relative uncertainty of 3%. The reported activities were also traceable to NIST according to ANSI N42.22-1995.The sensitive areas of the detectors are larger than the sources. The efficiencies were calculated as the ratios between the net counting rates in specified channels (alpha or beta-gamma) and the actual activities of the sources. The results are shown in table 2. The data with numbers ranging from 1 to 27 are efficiencies of the beta-gamma channels, while the numbers 28 to 32 refer to efficiencies of the alpha channels. The efficiencies of the scintillator based instrument is for many nuclides like ^{18}F, ^{32}P, ^{33}P, ^{36}Cl, ^{59}Fe, ^{99m}Tc, ^{111}In, ^{113}Sn, ^{137}Cs and for all iodine isotopes 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 ^{51}Cr and ^{238}Pu there are lower efficiencies compared to the proportional counters. These nuclides have emissions with low energy X-rays, where the light yield in the scintillator seems to be relatively low. The efficiencies for alpha detection are roughly of the same order of magnitude for the butane filled detector and the scintillator. The detection limits depend on the probabilities for errors, on the background counting rates, on the efficiencies and on the measuring times. But for most of these nuclides the detection limits with the scintillation detector are considerably lower than that of the gas filled detectors. The minimum detectable amounts are for many nuclides even with relatively short measuring times of a few seconds lower than the required limits according to national regulations of many countries.

The cross talk from the alpha-channel into the beta channel was measured with a pure alpha emitter and it is better than 20% for the LB 124 SCINT with the scintillator. 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 talk from beta into the alpha channel is much lower and it is for all instruments approximately 2×10^{-5}.

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

No.	Radio-nuclide	LB 124 SCINT [%]	LB122A [%]	LB124B [%]	No.	Radio-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	^{123}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	^{239}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

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 ^{90}Sr 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%.

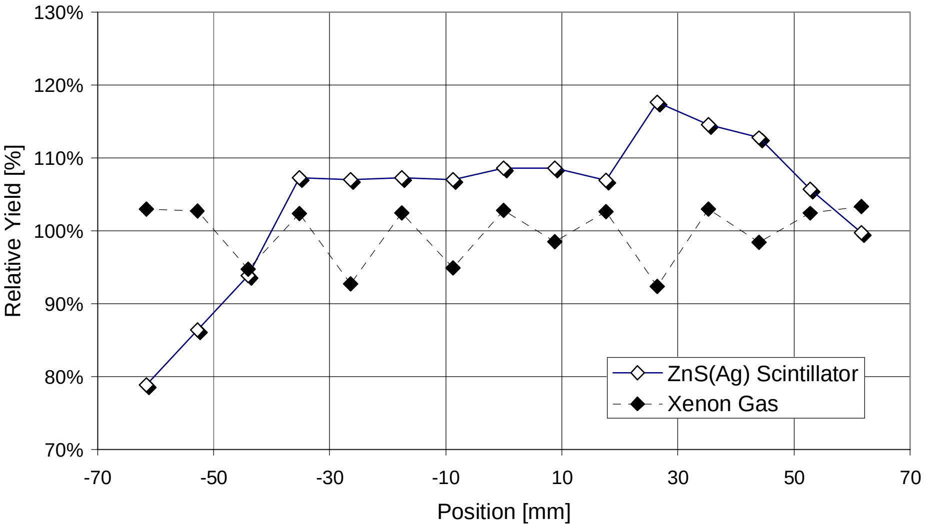

Figure 1: Response Uniformity Profile with ^{90}Sr

DISCUSSION AND CONCLUSION

In addition to the presented data characterizing the different types of contamination monitors it is also important to think about service and maintenance. In general 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 in contamination monitoring so popular.

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.