

# A New Contamination Monitor With Scintillation Detection

Alfred Klett, *Member, IEEE*, Peter Haefner, Wilfried Reuter

**Abstract**—Berthold Technologies designed for the measurement of radioactive contaminations on surfaces a new handheld contamination monitor. The instrument is based on innovative scintillation technology and has high sensitivity and uniform response over the entire detection area of 170 cm<sup>2</sup>. This is achieved by utilizing a sophisticated reflector geometry. The monitor is capable of simultaneous and separate measurement of alpha-particles and of beta-gamma-radiation. The instrument was calibrated with more than 30 radionuclides which are commonly used in research or in nuclear medicine including also several short-lived nuclides like <sup>99m</sup>Tc or <sup>18</sup>F.

## I. INTRODUCTION

Contamination monitoring is an important task in radiation protection. Since decades there are for this purpose mainly gas-filled detectors with large sensitive area in use. These detectors suffer from several severe drawbacks: thin entrance windows can easily be damaged, sealed counters can only be reprocessed by the manufacturer, cost of service and maintenance is relatively high, flow-through counters require gas supply and counting gases may have problems like flammability or being not operable at low temperatures like butane.

Scintillators are much more rugged than gas-filled detectors. Therefore *Berthold Technologies* decided to design a new instrument based on scintillation detection. The technical challenge is to obtain a compact and flat detector module with a high sensitivity and a good uniformity across all over the sensitive area.

## II. DESCRIPTION OF THE INSTRUMENT

The instrument comprises a scintillation detector module with sensitive area 170 cm<sup>2</sup>. The front-end electronics with the high voltage supply for the photomultiplier tube as well as preamplifier and discriminator circuits are part of the scintillation detection module. The detector module, the  $\mu$ -processor board and the batteries are in a housing with handle, display and function keys.

The scintillator is a thin layer of ZnS:Ag powder on an optical transparent, but non-scintillating acrylic glass plate. The entrance window is made out of aluminized plastic with thickness 6  $\mu$ m corresponding to 0.8 mg/cm<sup>2</sup> mass per area. The dimensions of the sensitive detection area are 145 mm in width and 118 mm in length. The uniformity of the response

to ionizing radiation is optimized by the light reflector geometry of scintillation detector module.

The instrument is capable of simultaneous and separate measurement of  $\alpha$ -particles and of  $\beta$ - $\gamma$  radiation. The instrument's software has an easy-to-be-used user interface. With editable user profiles the device could appear as an extremely simple device for unskilled users or as a fancy tool for experts with access to all parameters and utilities. It has acoustic alarm indication with adjustable thresholds, memory for more than 1000 measured data and a serial RS 232 port. The display is a monochrome LCD with 192  $\times$  64 pixel with background illumination. The entrance window is protected with a steel protection grid with a geometrical transparency of 80%. The external dimensions of the handheld instrument are 240 mm  $\times$  140 mm  $\times$  110 mm and the weight with batteries is approximately 1300 g. Maximum operation exceeds 25 h with 3.5 Ah Ni-MH rechargeable batteries or 50 h with 7.8 Ah alkaline batteries. The temperature range is between  $-20^{\circ}\text{C}$  and  $+40^{\circ}\text{C}$  and humidity range between 0% and 95% without condensation. The contamination monitor's type designation is LB 124 SCINT.

## III. CALIBRATION OF THE CONTAMINATION MONITOR

The instrument's reading indicates measured activities per area  $A_{\text{surface}}$  in units of Bq/cm<sup>2</sup>. The values are calculated by multiplying measured net counting rates with a nuclide specific calibration factor  $C_{\text{nuclide}}$  according to (1).

$$A_{\text{surface}} = C_{\text{nuclide}} \times (\text{Rate}_{\text{gross}} - \text{Rate}_{\text{background}}) \quad (1)$$

For the determination of these calibration factors there are several different definitions in use. Equations (2) and (3) are describing the approach following the international ISO 7503-1 standard.

$$C_{\text{nuclide}} = \frac{1}{\varepsilon_{\text{detection}} \times \varepsilon_{\text{source}} \times W} \quad (2)$$

$$\varepsilon_{\text{detection}} = \frac{\text{Rate}_{\text{source}} - \text{Rate}_{\text{background}}}{q_{2\pi}} \quad (3)$$

In these formulas  $\varepsilon_{\text{detection}}$  is the detection efficiency of the detector,  $q_{2\pi}$  is the surface emission rate of the emitted particles into  $2\pi$  solid angle,  $\varepsilon_{\text{source}}$  is the so-called source efficiency, which would normally be 0.5 to take into account the emission in a hemisphere and  $W$  is the sensitive detection area of the detector.

Another definition is based on activity  $A$  rather than surface emission rate  $q_{2\pi}$  and on a defined reference source area  $W_{\text{source}}$ , where in some countries 100 cm<sup>2</sup> has to be used. This

---

Manuscript received November 11, 2005. Authors are with Berthold Technologies, P. O. Box 100163, 75312 Bad Wildbad, Germany. Corresponding author is Alfred Klett (e-mail: Alfred.Klett@Berthold.com).

method with equations (4) and (5) we designate here according to the standard DIN 44801.

$$C_{\text{nuclide}} = \frac{1}{\varepsilon_{\text{detection}} \times W_{\text{source}}} \quad (4)$$

$$\varepsilon_{\text{detection}} = \frac{\text{Rate}_{\text{source}} - \text{Rate}_{\text{background}}}{A} \quad (5)$$

The net counting rates were measured with radioactive sources manufactured by AEA Technology QSA GmbH in Braunschweig, Germany. This company is accredited by the Physikalisch-Technische Bundesanstalt PTB as calibration laboratory for measurements of radioactivity (Deutscher Kalibrierdienst DKD). The DKD is signatory to the multilateral agreements of the European co-operation for Accreditation (EA) and of the international Laboratory Accreditation Cooperation (ILAC). The sources had areas of 10 cm × 10 cm<sup>2</sup>. The activities were homogeneously distributed on a thin foil. AEA technologies provided certificates for 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 values of the detection efficiencies  $\varepsilon$  and of the calibration factors C are given in table I. In this table there is a first group of 28 nuclides (<sup>14</sup>C through <sup>241</sup>Am) with the calibration factors for the  $\beta$ - $\gamma$ -channel, while the calibration data for the  $\alpha$ -channel for <sup>210</sup>Po, <sup>238</sup>U, <sup>238</sup>Pu, <sup>239</sup>Pu and <sup>241</sup>Am are in the 2<sup>nd</sup> group of nuclides at the bottom of the table. The nuclides cover most of the widely used isotopes in nuclear medicine, industry or in research. The shortest half-live with approximately 110 minutes had the PET nuclide <sup>18</sup>F.

#### IV. CALCULATION OF MINIMUM DETECTABLE ACTIVITIES

The minimum detectable activities (MDAs) were calculated according to the German standard DIN 25482-1. We used 300 s background measuring time, 30 s sample measuring time, 5% error probabilities for false positives and for false negatives, 0.05 cps for  $\alpha$ -background and 15 cps for  $\beta$ - $\gamma$ -background as parameters. The average background counting rates in most environments are normally lower than these values. The results are also shown in table I in column MDA in units of Bq/cm<sup>2</sup>. The minimum detectable amounts are lower than the required limits in many countries according to national regulations.

#### V. UNIFORMITY OF RESPONSE ACROSS SENSITIVE AREA

The uniformity of the response of the instrument to point sources with diameters below 10 mm was also investigated with <sup>14</sup>C, <sup>90</sup>Sr and with <sup>241</sup>Am. The variations in response as a function of the source position was found to be below  $\pm 20\%$ . This holds for the  $\alpha$ -channel as well as for the  $\beta$ - $\gamma$ -channel.

TABLE I  
EFFICIENCIES, CALIBRATION FACTORS AND MINIMUM DETECTABLE ACTIVITIES

Radio-Nuclide	DIN 44801			ISO 7503-1		
	$\varepsilon$ [%]	C [s Bq/cm <sup>2</sup> ]	MDA [Bq/cm <sup>2</sup> ]	$\varepsilon$ [%]	C [s Bq/cm <sup>2</sup> ]	MDA [Bq/cm <sup>2</sup> ]
C-14	11.4	0.0874	0.23	30.2	0.0780	0.20
F-18	62.3	0.0160	0.04	124.7	0.0094	0.02
P-32	60.4	0.0166	0.04	120.7	0.0097	0.03
P-33	36.0	0.0278	0.07	72.0	0.0327	0.09
S-35	15.2	0.0657	0.17	30.4	0.0773	0.20
Cl-36	50.0	0.0200	0.05	79.3	0.0150	0.04
Cr-51	0.19	5.2632	13.7	0.4	3.0694	7.98
Co-57	5.2	0.1934	0.50	10.4	0.1130	0.29
Co-58	10.6	0.0941	0.24	21.3	0.0553	0.14
Fe-59	47.1	0.0212	0.06	94.2	0.0125	0.03
Co-60	33.7	0.0297	0.08	67.8	0.0347	0.09
Ga-67	16.9	0.0592	0.15	33.8	0.0348	0.09
Se-75	7.8	0.1290	0.34	15.5	0.0759	0.20
Sr-89	57.0	0.0175	0.05	114.0	0.0103	0.03
SrY-90	48.8	0.0200	0.05	77.6	0.0150	0.04
Tc-99	30.5	0.0330	0.09	62.0	0.0380	0.10
Tc-99m	9.5	0.1053	0.27	19.0	0.0619	0.16
In-111	21.9	0.0456	0.12	43.9	0.0268	0.07
Sn-113	31.3	0.0319	0.08	62.6	0.0188	0.05
I-123	20.0	0.0500	0.13	40.0	0.0294	0.08
I-125	12.2	0.0818	0.21	24.4	0.0963	0.25
I-131	56.0	0.0179	0.05	111.9	0.0105	0.03
Cs-137	49.3	0.0203	0.05	81.2	0.0145	0.04
Tl-201	8.5	0.1183	0.31	16.9	0.0696	0.18
Tl-204	35.9	0.0280	0.07	63.8	0.0180	0.05
U-238	36.6	0.0270	0.05	73.1	0.0320	0.06
Pu-238	2.8	0.3560	0.93	5.6	0.4190	1.09
Am-241	9.0	0.1111	0.29	19.0	0.1238	0.32
Po-210	23.5	0.0430	0.01	46.1	0.0510	0.01
U-238	12.3	0.0810	0.01	27.5	0.0860	0.01
Pu-238	23.5	0.0420	0.01	50.7	0.0460	0.01
Pu-239	23.0	0.0430	0.01	46.0	0.0510	0.01
Am-241	22.5	0.0440	0.01	47.8	0.0490	0.01

#### VI. SUMMARY

The efficiencies of the new contamination monitor LB 124 SCINT were accurately measured with traceable sources with area 10 cm × 10 cm<sup>2</sup>. They were found to be typically 20% for  $\alpha$ -particles, 50% for penetrating  $\beta$ -particles and 10% for photon emitters like <sup>99m</sup>Tc. Very low minimum detectable activities can be achieved. The uniformity of the response is better than  $\pm 20\%$ . Scintillation detection seems to be superior to comparable gas filled detectors.

#### REFERENCES

- [1] ISO 7503-1 *Evaluation of surface contamination – Part 1*, August 1988
- [2] DIN 25482-1 *Detection Limits and Decision Levels*, April 1989