Analysis of Minimum Detectable Activity for Noble Gas Monitor Using System Modeling

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1. Introduction

Krypton is one of the noble gas isotopes. It has mostly generated from reprocessing of the spent fuel and fault of nuclear fuel cladding. Krypton monitoring is an important factor in determining in spent fuel's reprocessing or nuclear fuel's fault.

Radiation measurement is based on random processing; this results in inherent statistical fluctuation. By causing unwanted errors like false alarm, it may adversely affect facility operation and management.

In this paper, an analysis of minimum detectable activity (MDA) for a noble gas monitor using system modeling is presented. A determination of the suitable MDA contributes to reduction of the error by the fluctuation and the correct use of the monitor.

2. Analysis of MDA for noble gas monitor using system modeling

2.1 International Standard, ANSI N42.17B

The MDA concept which one of the most has been widely used was introduced by Currie [1]; it is a kind of guidelines for a decision whether a certain sample has activity or not.

Some regulatory agencies have their standards related to MDA such as *NUREG 1576*, *ISO 11929*, *DIN 25482*, *ANSI N42.17B*. They require that a certain minimum detectable amount of activity be measurable while monitoring for the possible presence of radioactive contaminants.

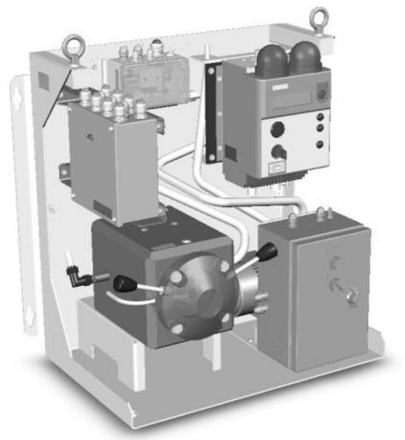

Fig. 1. Noble gas monitor, NGM204 (MGPI).

ANSI N42.17B standard is based on the deriving MDA without signal; it means only the blank signal uncertainties are considered. The MDA in *ANSI 42.17B* is defined as

$$MDA_{ANSI42.17} = 4.65 \cdot u(0) \qquad (1)$$

where $u(0)$ is the uncertainty of target system with the blank signal [2].

2.2 MDA Calculation using mathematical of a noble gas Monitor

Fig. 1 shows a monitor NGM204 which has developed by MGPI; it monitors the fluid noble gas activity inside its sample chamber. With dual silicon detector, it provides dynamic gamma compensation.

Considering its hardware configuration and calculation algorithm, noble gas volumetric activity *VA* is derived as

$$VA = \frac{C_p - kC_c - C}{Eff} \quad (2)$$

where C_p and C_c are count rate [c/s] in primary and compensation channels. They are yielded by first and second detectors, respectively. C is background noise [c/s]. As k and Eff are The system parameters, k is a weighting coefficient of the compensation channel, and Eff is detection efficiency [c/s/Bq/m^3].

For the model in (2), each term can be specified as:

$$\mu_{cp} = Eff \cdot s + \varepsilon_{\gamma p} \cdot s_\gamma + b_p \ and \ \sigma_{Cp}^2 = \frac{\mu_{cp}}{t} \quad (3)$$

$$\mu_{cc} = \varepsilon_{\gamma c} \cdot s_\gamma + b_c \ and \ \sigma_{Cc}^2 = \frac{\mu_{cc}}{t} \quad (4)$$

where

μ_{cp} : Mean of the random variable of C_p

μ_{cc} : Mean of the random variable of C_c

s : Volumetric activity [Bq/m^3]

s_r : External gamma dose rate [Sv/h]

ε_{rp} : Efficiency of gamma in the primary channel [c/s/Sv/h]

ε_{rp} : Efficiency of gamma in the compensation channel [c/s/Sv/h]

b_p : Noise in the primary channel [c/s]

b_c : Noise in the compensation channel [c/s]

t : Measurement time [s].

The variable μ_{cp} can be rearranged with Eq. (4) as

$$\mu_{cp} = Eff \cdot s + k\mu_{cc} + \mu_c$$
$$\text{where } k = \frac{\varepsilon_{\gamma p}}{\varepsilon_{\gamma c}} \text{ and } \mu_c = b_p - kb_c. \quad (5)$$

From (2)-(5), the measurement uncertainty for the noble gas volumetric activity in NGM204 is derived as

$$u^2(s) \cong \frac{Eff \cdot s + k\mu_{cp} + k^2\mu_{cp} + \mu_c}{Eff^2 t}. \quad (6)$$

Because *ANSI N42.17* considers only blank signal uncertainties, the MDA in (7) is obtained as

$$MDA = 4.65u(0)$$
$$= \frac{4.56}{Eff}\sqrt{\frac{k(1+k)C_c + C}{t}}. \quad (7)$$

Table 1 shows MDA of NGM204 according to the measurement time. In this case, ambient gamma is set 10µSv/h.

Table 1. MDA of NGM204

Measurement time (min)	MDA(kBq/m^3)
2	57.9
10	25.9
60	10.6
600	3.34

3. Conclusion

In this paper, analysis of MDA for the noble gas monitor is introduced. Besides measurement time and background noise, the understanding for the characteristics of the target monitor such as processing algorithm and hardware configuration gives more accurate MDA.

REFERENCES

[1] L. A. Currie, “Limits for qualitative detection and quantitative determination”, *Anal. Chem.*, 40 (3), 586-593 (1968).

[2] “ANSI N42.17B-1989”, Occupational airborne radioactivity monitoring instrument-ation.