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Verification of Effectiveness of Gamma Irradiator Calibration Result

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1. Introduction

The main purposes for calibrating radiation instruments, used for radiation protection, is to verify that the instruments appropriately perform their required function, are able to correctly measure a known quantity of radiation under pre-set reference conditions, and, if necessary, to adjust the equipment operating conditions to improve measurement accuracy. In order to be able to satisfy the above purposes and to assure the accuracy of calibrations that are performed, laboratories that calibrate radiation instruments must be able to produce a radiation field that meets national and international standards and be able to maintain traceability of the radiation measurements.

Through this experiment, intermediate surveillance of the gamma irradiator was conducted in order to verify the integrity of the reference radiation field produced by the gamma irradiator. By verifying the radiation field produced by the gamma irradiator meets national and international standards, reliability of instruments calibrated using the irradiator can be secured through regular surveillance.

2. Methods and Results

The surveillance methods are as follows:

First, calculate the reference radiation dose rate using the gamma irradiator calibration result and make the correction for the radiation source half-life to radiation dose rate at the reappearance equipment reference point. Second, measure the ionization current at the reference point, using the ionization chamber and current measuring equipment, and calculate the measured dose rate by applying the calibration factor of the ionization chamber. Third, calculate the relative expanded uncertainty for the ionization current measurement. Fourth, calculate the |En| value.

2.1 Surveillance Procedure

- Measure the air kerma rate of the gamma radiation field created by the gamma irradiator within the free air space and conduct calibration of the gamma radiator to identity the correlation between the distance and kerma rate. After that, measure the ionization current at the reference point of the reappearance equipment using the ionization chamber (laser or goniometer) and set the measured current as the reference point.

- Measure the ionization current at the reference point and reverse-correct the value using the radioactive half-life.

- Calculate the |En| value using the formula below:

$$En = \frac{(X_r - X_m) \cdot 100/X_r}{\sqrt{U_r^2 + U_m^2}}$$

Here, X_r: Reference Value
X_m: Measurement Value
U_r: Relative Expanded Uncertainty of Reference Value
U_m: Relative Expanded Uncertainty of Measurement Value

- The calibration result is considered effective if |En|≤1, and, if |En|≤1, the result can be utilized as the reference radiation field for calibration until the next surveillance period.

Table 1. Calibration Data

Area	Radiation Source		
	795 GBq	203 GBq	1.85 GBq
Recent correction date	2012-04-05	2012-04-04	2012-04-03
Regression linear term(a)	4.74262	6.80994	5.24506
Regression constant term(b)	2.00706	2.01133	2.02018

2.2 Measurement of Ionization Current

Based on the conditions that Exradin A5 and A6 Ion chambers are in external feedback mode, high voltage is set at -300 V for the chamber wall, and the measurement distance, which is the reappearance equipment reference point, is set at 100 cm, the average ionization current was calculated using the values obtained when the radiation sources were each measured five times. In addition, average BKG (background) was gained by measuring the value five times (100 seconds) both before and after measuring the ionization current. The measurement results are listed in the table below:

Table 2. Result of Measurement

Area	Radiation Source		
	795 GBq	203 GBq	1.85 GBq
I_i(A)	5.25E-11	9.97E-11	1.12E-12
I_b(A)	-2.71E-15	-2.45E-15	-4,19E-15
Net I(A)	5.25E-11	9.97E-11	1.13E-12
Standard Uncertainty(A)	5.50E-15	8.27E-15	9.15E-16
Relative Standard Uncertainty (%)	0.01	0.01	0.08

2.3 Calculations of Uncertainty

Table 3. Estimation of Uncertainty

Uncertainty Factor		Relative Standard Uncertainty (%)			Probability Distribution /Degrees Of Freedom
		795 GBq	203 GBq	1.85 GBq	
Irradiator Calibration Factor		1.650	1.650	1.700	N / ∞
Measuring Current		0.010	0.008	0.081	T / 4
Current Measuring Equipment	Capacitor	0.027	0.027	0.015	N/ ∞
	Voltage	0.026	0.026	0.026	R / ∞
	Timer	0.058	0.058	0.058	R / ∞
	Combined	0.069	0.069	0.065	R / ∞
Environment Correction Factor	Pressure	0.0025	0.0025	0.0025	N / ∞
	Temperature	0.027	0.027	0.027	N / ∞
	Combined	0.027	0.027	0.027	N / ∞
Position Reproducibility		0.18	0.18	0.18	R / ∞
Relative Combined Standard Uncertainty		1.66	1.66	1.71	
Relative Expanded Uncertainty		3.32	3.32	3.43	

2.4 Calculation of |En| Value

Table 4. Calculation of |En| Value

Area		Radiation Source		
		795 GBq	203 GBq	1.85 GBq
Reference Value	Radiation Dose Rate	57.1 mGy/h	13.5 mGy/h	154.1 uGy/h
	Relative Expanded Uncertainty (%)	3.3	3.3	3.4
Measurement Value	Radiation Dose Rate	56.7 mGy/h	13.6 mGy/h	153.5 uGy/h
	Relative Expanded Uncertainty (%)	3.32	3.32	3.43
$\lvert En \rvert$		**0.145**	**0.025**	**0.071**

3. Conclusions

A comparison of |En| values is used to verify that the deviation between the reference value and the measurement value is within the range of combined uncertainty. Based on this, obtaining an |En| value that is less than or equal to 1 considers the calibration result of the reference equipment (gamma irradiator) to be effective. According to the surveillance result, the range of the |En| value is from 0.025 to 0.145, but does not exceed 1. Thus, the result proves that the final calibration result of the gamma irradiator for each radiation source is effective and is able to be used as a reference radiation field for calibration.

In the future, after calibration is conducted, regular surveillance is required in order to verify the continued integrity of the high level gamma irradiator and to secure the reliability of calibrations by proving that there is an effective reference radiation field for calibration.

REFERENCES

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