Proceedings of the Korean Nuclear Society Spring Meeting
Cheju, Korea, May 1996

Intercomparison of KAERI Reference Photon Radiation Fields

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ABSTRACTS

A series of measurements was performed between KAERI and PNNL, U.S.A. at KAERI secondary calibration laboratory to intercompare and verify the KAERI reference photon radiation fields by using air equivalent plastic walled ionization chambers. Different ionization chambers of two laboratories were used to determine the air kerma rate, free-in-air, at reference positions in the KAERI photon radiation fields. As the results, the agreement in the cross measurements between two laboratories was found to be within less than ± 3 %. This degree of consistency was considered to be encouraging, because each laboratory maintains independently its calibration traceablity with its national primary standard

I. INTRODUCTION

Radiation measuring instruments and personal dosimeters used for radiation protection purpose should be periodically calibrated to maintain the reliability and precision of the measured results. For this reason, an establishment of proper reference radiation fields and national secondary calibration facility (or laboratory) are inevitable. General requirements for a secondary calibration laboratory are well described in the International Standard Organization Guide 25. [1]

The national primary calibration laboratory normally provides calibration of insrruments used at the secondary calibration laboratory and maintains a national calibration traceability. In some cases, the calibration interactions between the primary and the secondary laboratory may be formalized by means of an accreditation program or by specific measurement quality assurance programme to maintain a national calibration standard traceability system.

The degree of consistency required for calibration in a secondary calibration laboratory is generally accepted to be within about ± 3 % [2], and the overall uncertainty in calibration measurements is usually maintained to be within about ± 5 %.

Since 1978, KAERI, one of the national secondary calibration laboratory in Korea for the radiation measurement, traceable to the national primary standard has provided calibration services of various radiation measuring instruments and irradiation of personal dosimeters for the performance evaluation, and performed studies to maintain and enhance the reliability of the results of radiation measurement.

This paper describe the KAERI reference radiation fields established by recent mid and long term project of nuclear energy development and explains the results of international intercomparison measurement of KAERI reference radiation fields between KAERI and PNNL, an U.S. secondary calibration laboratory to investigate and confirm the degree of consistency of reference radiation fields and beam qualities being independently maintained by each calibration laboratory.

2. EXPERIMENTAL METHODS

The methods used for determination of the air kerma (rate), free-in-air, at KAERI and PNNL are quite similiar. Both laboratory use the air-equivalent plastic walled ionization chamber as a reference device to measure the radiation.

The method of the intercomparison is to measure and compare the responses of the PNNL ionization chamber, which was initially calibrated at the U.S. National Institute of Standards and Technology (NIST), at the given reference distance of KAERI reference radiaition field with those measured by the KAERI ionization chamber. In this measurement, in order to exclude the possible error attributable to the variation of environmental conditions and the distance from the photon source, the KAERI ionization chamber and the PNNL ionization chamber were placed side by side at the same position to measure simultaneously an exposure and the resulting air-kerma, free-in-air at the KAERI reference radiation field.

2.1. Reference Photon (X-Gamma) Fields

The photon irradiation facilities at KAERI are composed of the Gamma-ray and the X-ray irradiation rooms. The dimension of these two irradiation room is 5.5 m Wide x 12 m Long x 3 m High. The thickness of the concrete shielding wall and ceiling is 0.5 m. The height of the beam line is approximately one meter above the floor.[3]

In the gamma irradiation room Cs-137 irradiator (Germany, Buchler; 3.7 GBq, 185 GBq, 3700 GBq), Co-60 irradiator (Germany, Buchler; 3.7 GBq) and remotely operating irradiation cart system are installed. Table 1 shows the KAERI refernce gamma fields [3].

Table 1. KAERI Reference Gamma Ray Fields

Source	Activity	Reference Date	Dose Rate (R/hr) @ 1m
Cs-137	3.7 GBq (100 mCi)	'91. 9.	3.3×10^{-2}
	185 GBq (5 Ci)	〃	16.5
	3700 GBq (100 Ci)	〃	330
Co-60	3.7 GBq (100 mCi)	〃	0.132

In the X-ray irradiation room, low energy X-ray generator (England, EG&G Pantak; 0 to 75 kV_{cp}), high energy X-ray generator (Germany, Philips MG-325; 0 to 320 kV_{cp}) and remotely operating irradiation cart system are installed with the X-ray filter system to generate the standard X-ray beams according to the U.S. NIST [5] and ISO [6] criteria..

As X-rays are not the R.I. source, the beam qualities differ laboratory by laboratory depending on the X-ray generation·technique and the adopted X-rays filters. In order to avoid this problem the U.S.A adopts the NIST-ANSI N13.11 criteria [5] and the ISO defines ISO-4037 criteria [6] as the X-ray beam standard.

KAERI, from the results of recent study, established different X-ray beams complying with both the U.S. standard (5 beams) and the ISO standard (4 narrow beams and 8 wide beams). Table 2 shows the KAERI reference X-ray fields and their beam qualities.

Table 2. KAERI Reference X-Ray Fields.

ANSI X-ray Beam

Beam Code	KAERI		ANSI N13.11	
	Eav (keV)	Homogeniety (%)	Eav (keV)	Homogeniety (%)
M30	19.9	63.4	20	64
M60	34.6	68.2	35	35
M100	54.2	74.4	53	53
M150	76.7	87.8	73	73
H150	118.7	95.2	118	118

ISO X-ray Beam (Narrow Series)

Tube Potential (keV)	KAERI		ISO-4037	
	Eav (keV)	Homogeniety (%)	Eav (keV)	Homogeniety (%)
60	48.2	92.1	48	92.3
80	65.3	94.9	65	93.5
100	83.4	93.9	83	94.8
120	100.6	97.1	100	96.6
150	118.3	94.8	118	95.5
200	163.4	98.3	164	98.5
250	207.6	99.1	208	99.2
300	250.2	99.6	250	99.5

ISO X-ray Beam (Wide Series)

Tube Potential (keV)	KAERI		ISO-4037	
	Eav (keV)	Homogeniety (%)	Eav (keV)	Homogeniety (%)
60	45.4	85.8	45	85.7
80	57.1	81.6	58	79.5
110	79.1	90.4	79	86.5
150	104.6	86.6	104	88.6

2.2. Instrument and Measurment Procedure

The air equivalent plastic walled ionization chamber used by PNNL was a Capintec Model PM-30 chamber (volume 30 cm^3) initially calibrated at the U.S. NIST. The electrical charge produced in this chamber was measured by a Keithley Model 617 HIQ electrometer. The polarizing potential of this chamber was provided by either a power supply or a 300 V battery.

KAERI used an Exradin Model A-3 (volume 3.5 cm^3) and A-4 (volume 30 cm^3) air equivalent plastic walled ionization chambers with Keithley Model 35617 electrometer. Connection between the chamber, the power supply and the electrometer was made with low noise triaxial cable.

The two chambers was positioned side by side at the same distance from the phton beam source within the colimated beam diameter to measure the exposure and the resulting air kerma in free air. Since the two chambers were mounted sufficiently far apart on the air, there was no possibility of photon beam scattering between one chamber and the other. Electrical signals from the respective chambers were recorded automatically by the KAERI and PNNL electrometer, situated at the control consol outside the irradiation room.

The X-rays and beam qualities adopted in the measurement were the standard X-ray codes M30, M60, M100, M150 and H150, defined by the U.S. NIST in the ANSI N13.11 criteria.[5] These standard X-ray codes was chosen because they are currently used in the U.S. National Voluntary Laboratory Accreditation Program (NVLAP) for the profciency test of personnel dosimetry program, and these same beam codes are being adopted in KAERI in the standard irradiation and performance evaluation of personal dosimeters in Korea[4].

2.3. Results and Discussions

From the electrical charges measured directly by respective reference chamber of KAERI and PNNL in the reference photon fields, exposures and the resulting air kermas, free-in-air, were determind by using the following relationship between the exposure and the air-kerma..

$$K_{air} = X\ (W/e)/(1-g)$$

where, K_{air} is the air kerma, X is the exposure, W/e is the mean energy per unit charge expended in air by electrons, and g is the mean fraction of the energy of the secondary electrons which is lost to bremsstrahlung radiation. The values used in the conversion factor, (W/e)/(1-g) are given in Table 3.

Table 3. Air Kerma to Exposure Conversion Factor, (W/e)/(1-g).

(W/e) : 33.97 J/C

Radiation Fields	g-value	(W/e)/(1-g)
Cs-137	0.0016	34.024
Co-60	0.0032	34.079
X-ray beams	negligible	33.970

As seen in Table 4 and 5 the results of air kerma measurements between KAERI and PNNL agreed well each other within about less than ± 3 %, in which the results of second measurements ('95) is further improved than the first measurements ('96).

The degree of agreement between KAERI and PNNL in photon beam measurement is encouraging enough, when considering both laboratories used different ionization chambers calibrated in different countries.

Table 4. First Photon Field Intercomparison between KAERI and PNNL('94).

Photon Beam	KAERI	PNNL	KAERI/PNNL
● Gamma ray			
Cs-137	14.11 R/hr	13.87 R/hr	1.0172
Co-60	102.79 mR/hr	100 mR/hr	1.0279
● X-ray			
M30	1468.55 mR/min	1313 mR/min	1.1181
M60	1563.69 mR/min	1510 mR/min	1.0356
M100	470.44 mR/min	468 mR/min	1.0052
M150	630.71 mR/min	623 mR/min	1.0124
H150	54.92 mR/min	54.5 mR/min	1.0076
Ion Chamber Electrometer	A3 Shonka (3.6 ml) Keithly 35617	PM-30 (30 ml) Keithly 617 HIQ	

Table 5. Second Photon Field Intercomparison between KAERI and PNNL('95).

Photon Beam		KAERI	PNNL	KAERI/PNNL
Cs-137		31.037 R/hr	30.421 R/hr	1.020
		2.086 R/hr	2.047 R/hr	1.019
M30	1 mA	491.3 mR/hr	494.1 mR/hr	0.994
	10 mA	1639 mR/hr	1647.6 mR/hr	0.995
M60	1 mA	126.84 mR/hr	127.59 mR/hr	0.994
	10 mA	1216 mR/hr	1227 mR/hr	0.991
M100	1 mA	125.78 mR/hr	123.93 mR/hr	1.015
	10 mA	1202 mR/hr	1184 mR/hr	1.015
M150	1 mA	148.73 mR/hr	146.26 mR/hr	1.017
	10 mA	1436.5 mR/hr	1412.1 mR/hr	1.017
H150	10 mA	30.99 mR/hr	31.16 mR/hr	0.994
	20 mA	59.89 mR/hr	60.01 mR/hr	0.998
Ion Chamber Electrometer		A3 Shonka(3.6 ml) Keithley 35617	PM30 (30 ml) Keithley 35617	

3. CONCLUSIONS

The uncertainty in the quantity of air kerma determined by the national primary calibration laboratory is usually in the range of approximately ± 1 % with 95 % confidence. level. When this quantity is transferred to a secondary calibration laboratory under the national standard traceability system, it may result in a larger uncertainty of ± 1.5 ~ 2.0 %. This means that if all the controls on the transfer of such calibrations from primary to secondary laboratory operate perfectly, it would be expected that calibration of air kerma by two independent secondary laboratories should agree at the level of about ± 2.0 %.

Therefore, the fact that the most of the intercomparison measurement by KAERI and PNNL agree within about ± 2.0 % was evaluated to be very encouraging. For some of the radiation measurements, the agreement was extremely good within a few tenth of a percent.

This tells that the reference photon fields and the beam qualities produced by KAERI is in the level of international top class. Therefore, the KAERI reference radiation fields as well as realted calibration technique will play an important role as a national basic dosimetry laboratory for radiation protection for in the precise calibration of radiation instruments, the precise standard irradiation of personal dosimeters and the further studies in the radiation protection dosimetry in Korea.

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ACKNOWLEDGEMENTS

This paper describes a part of the study "Development of Radiation Protection and Measurement Technology" performed by Health Physics Department, KAERI under the contract with the Ministry of Science and Technology (MOST). The authors wishes to thank to our colleagues in the Calibration Research and Accreditation Group, Health Protection Department, PNNL, U.S.A. for their support of this intercomparison exercise.