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Preface

The International Conference on Nuclear Capacity Building, Education, Research and Application, **I-Concern'19**, organised by the National Nuclear Energy Agency (BATAN), was held in Yogyakarta, Indonesia on September 6 – 7, 2019. This conference which is a part of the Indonesia Nuclear Expo (**NEXPO**) 2019 event was a fruitful and successful scientific gathering between lecturers, researchers, academics, practitioners and communities, medical specialists, industries, government, and the public on exploring the nuclear technology in terms of human resources, applications, technology, policies, and innovation.

The two days program of I-Concern'19 accommodating 7 keynote and 18 invited speakers, and 108 contributed talks in Plenary and Parallel Sessions. At the same time, 144 posters were also presented in the 2 Poster Sessions, while 15 vendor exhibitors displayed their commercial products on nuclear medical applications, nuclear instrumentation, NDT equipment, and other products. In total, 250 presenters and 37 observers coming from 9 countries of 3 continents had been gathering for the 2 days of the conference.

From this conference, we received 234 manuscripts. All of them have been intensively reviewed and have been decided by the Chief of Editors to publish 145 papers in the IOP Journal of Physics Conference Series 2020, Volume 1436. Other manuscripts were published in the Jurnal Forum Nuklir 2020, Volume 40 (6 papers), Indonesian Journal of Materials Science (Jusami) 2020, Volume 21 (4 papers), and in this Conference Proceeding (79 papers).

We are very much grateful to the esteemed members of the International and Local Advisory Committees for their advice and guidance, the supports from the National Nuclear Energy Agency (BATAN) in collaboration with the Indonesian Society for Nuclear Medicine (PKNI), the International Atomic Energy Agency (IAEA), the Ministry of Health of the Republic of Indonesia, National Standardization Agency of Indonesia (BSN), the World Federation of Nuclear Medicine and Biology, the Clarkson University, USA. We also gratefully acknowledge the sponsorships.

We hope that the present proceedings provide the valuable information to the readers in the field of nuclear science, technology, innovation and human resources development.

March 27, 2020

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Contents

Preface

Papers

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Determination of the width of gamma radiation field of the OB-85 (^{137}Cs source) at calibration facility of PTKMR-BATAN

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Abstract. The OB-85 is one of the main equipments for calibration of Gamma Radiation Measuring Instrument's (RMIs, such as Surveymeter, TLD, pocket dosimeter) at Calibration Facility of PTKMR-BATAN, however, without standard instrument and other supporting tools, the OB-85 will not function properly. To get an accurate calibration result, the width of radiation field of the OB-85, the Air Kerma rate, K_a [μGy/h], the Ambient Equivalent Dose rate, H*(10) [μSv/h], the Personal Equivalent Dose rate, Hp (10) [μSv/h], the Exposure rate, X [mR/h], and the expanded uncertainty, u_{expand} of these quantities must be measured and determined as they are indispensable for calibration or irradiation of the RMIs . The purpose of determining of the width of radiation field of the OB-85 is to fulfil quality audit of the Calibration Facility, for ascertaining what the actual width of radiation field of the OB-85, belong to the PTKMR-BATAN. At the time of calibration, surveymeter or pocket dosimeter must be placed at the center of radiation field and in the width of radiation field because if it was partially outside of the radiation field then the calibration result was inaccurate. This paper presents the determination of the width of radiation field of the OB-85 by three types of ionization chamber detectors. with different shapes and volumes, with two settings of SDD (Source Detector Distance). The width of radiation field of the OB-85 measured by the IC/SN #M23332, IC/TK-30 #SN107, and IC Exradin/A4 were 18 cm for SDD = 50 cm, and 36 cm for SDD = 100 cm. From this experiment, the information was obtained that the width of radiation field of the OB-85 does not depends on the type of the detectors used to measure but it depends on the calibration facility settings (the shape or geometry of the source, SDD, and diameter of collimator).

1. Introduction

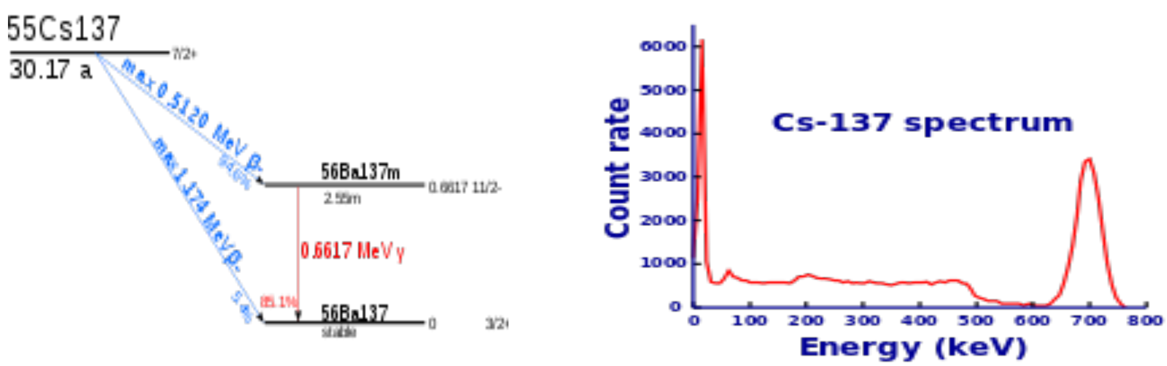
The Secondary Calibration Laboratory Network has been set up by the IAEA in many countries, including Indonesia (SSDL-Jakarta). In the beginning, it was set-up standard therapy but gradually with the development of science and knowledge of nuclear engineering, a calibration laboratory for a radiation protection level is also needed.

Regulation of the Head of the Nuclear Energy Supervisory Agency Number 1 of 2006 concerning Dosimetry Laboratory, Radiation Measurement Calibration Instrument and Radiation Source Output, and

Radionuclide, in Article 7 states that the National Level Laboratory (NLL) is responsible for fostering and providing technical guidance to the Secondary Standard Dosimetry Laboratory (SSDL) and the Tertiary Standards Dosimetry Laboratory (TSDL) and in article 10 it is said that for a new of RMIs or after being repared, the RMIs must be calibrated before used and must be recalibrated every year. This is to ensure that the RMIs works properly, according to its designation and is traced to higher laboratories (national and international) [1,2].

The Gamma Calibration Facility of PTKMR-BATAN which is an IAEA assistance, currently only uses ^{137}Cs (OB-85) and ^{241}Am sources for Gamma RMIs calibration. In 1985, there were three sources installed in the Calibration Facility of PTKMR-BATAN namely ^{226}Ra. ^{137}Cs, and ^{60}Co. At the moment, ^{60}Co was very low its activity because the half-life of ^{60}Co was 5.27 years [3], while the shutter for ^{226} Ra was broken.

^{137}Cs has a half-life of about 30.17 years, it decays to ^{137}Ba by emitting 0.6617 MeV of gamma energy, with the decay chart presented in Figure 1a and its Spectrum presented in Figure 1b. Because of its long half life, ^{137}Cs are widely used for various specific purposes, for example as a Radiation Measuring Instrument (RMIs) calibrator, in the field of medicine, it used for diagnosis and radiation therapy, in the Industry, it is used as a flow meter, for measuring thickness, leveling, and density of fluid [3,4].



(a) (b)

Figure 1. (a) Decay scheme of ^{137}Cs, (b) Spectrum ^{137}Cs

The ^{137}Cs source used as the RMIs Calibrator in PTKMR BATAN Calibration Facility is OB-85, made by Buchler GmbH, with the activity was 74 GBq, at Reference Time: May 1985 (Figure 2a). The OB-85 was placed in the middle of the calibrationfacility, about 2 m from the door. The calibration table can be adjusted from 0.5 m to 4.5 m from the OB-85. Laser alignment was mounted on the wall of the calibration room, about 9.5 m away from the source, facing the source, OB-85. The meter was mounted on the wall to the right of OB-85, with the zero point exactly at the source position. The telescope is mounted on the calibration table, left of OB-85, to adjust Source Detector Distance (SDD) and central of the detector. Pressure, Temperature, and Humidy meter (P, T, H) were mounted on the wall to the right of OB-85. The Calibration Room of PTKMR-BATAN was presented in Figure 2. Calibration/irradiation of the RMIs were controlled from the control room. Room conditions are recorded when taking measurement/calibration data.

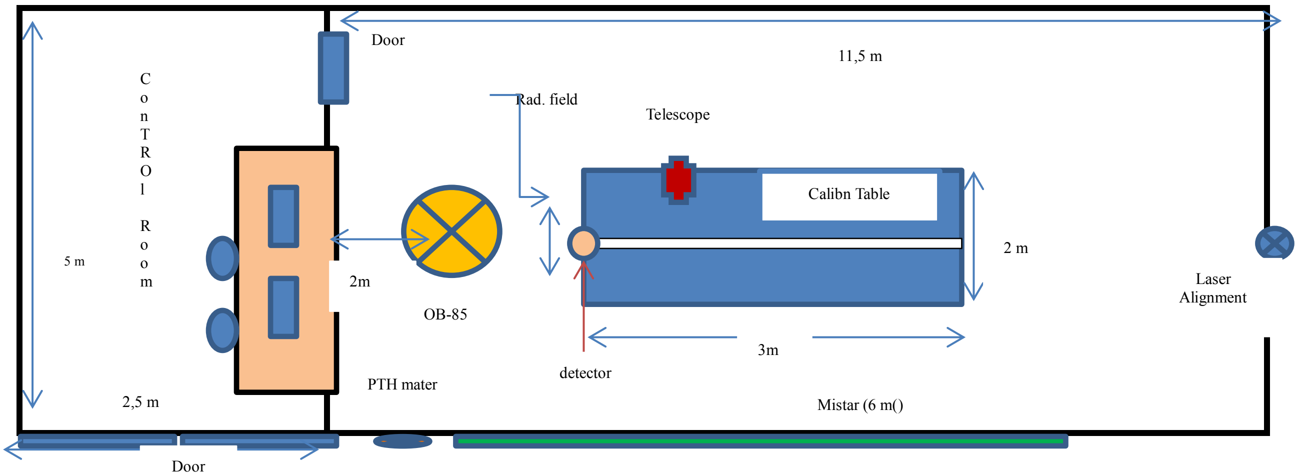


Figure 2. The Calibration Room of PTKMR-BATAN

For the purposes of Quality Audit of the RMIs Calibration Facility and for the National Accrediation Committee (NAC), the width of the OB-85 source radiation field must be known exactly, as well as the Air Kerma Rate, K_a, Personal Equivalent Dose Rate, Hp (10), Ambient Equivalent Dose Rate, H* (10), and the Exposure Rate, X at several calibration points because these quantities are needed in the calibration activities. This information is very useful when performing RMIs calibration or TLD irradiation.

In this paper, determination of the width of radiation field of the OB-85 has been done, using 3 types of ionization chamber detectors: Ionization Chamber/SN #M23332, cylindrical shape, volume 0.3 cc, IC/TK-30/SN107, spherical shape, volume ± 30 cc and Exradin/A4, ball shape, volume 30 cc.

2. Method

2.1. Detector stability

To do a measurement, the detector must be checked firstly. The detector of IC was connected to electrometer and turned ON and let them ± 30 minutes to warm up. To check the stability of the instrument, it can be used the available ^{90}Sr check source. To determine the stability of the detector, a Standard Operational Procedure (SOP) was required, for example, determine the stability of the he stability check is within the range of ± 1%, then we consider that the detector was stable and ready for measurement.

Control Charts should be made every year to see the stability of the detector because this is very important for quality control (QC) and it is needed when there is an assessment from the National Accreditation Committee (NAC). This stability range will contribute to the measurement/calibration uncertainty. For evaluation of QC's detector stability, the equations (1) and (2) can be used.

$$B_t = B_i.\ e^{-(0.693xt)/T} \quad (1)$$

$$\text{Stability} = \frac{B_t - B_i}{B_i} x100\% \subseteq 1\% \quad (2)$$

B_t : Detector reading of check source at time t
B_i : Detector Reading of check source in the first time
$T_{1/2}$: Half-life of check source, $T_{1/2}$ (^{90}Sr) = 28.7 years
t : Time difference between B_i and B_t

2.2. Detector repeatability

Repeatability: is the ability of a measuring instrument to show the same results from a measurement process that is repeated and identical. Repeatability of the detector, can be seen from the results of repeated measurements. Repeatability is the standard deviation of the measurement. If the results of repeated measurements in the range of ± 1%, the repeatability is good. This repeatability will contribute to the measurement/calibration uncertainty.

2.3. Determination of the width of the radiation field of the OB-85

To determine the width of radiation field of the OB-85, we should have a Standard Operational Procedure (SOP) for limiting the saturation curve / peak measurement within a certain range, for example ±2.7%. In that range, we consider it is still within the wide range of the radiation field. To get that range, the measurement results are normalized to the central position. If the reading of the measuring instrument is still in the range of ± 2.7%, then we consider that it was in the range of the width of the radiation field.

After checking the stability and repetability, the detector -1 can be used to determine the width of radiation field of OB-85. Detector-1 was .placed at the central source of OB-85 with SDD 50 cm. The data was taken 5 data at each measurement point. The detector was moved every 2cm to the right, and the data collection is done in the same way, until a significant decrease in reading occurs. Measurements are made to the left of the source's central point, until a significant reading decrease is obtained. Measurements are also made at SDD of 100 cm with the same steps. Determination of the field width of the OB-85 was also carried out using detectors 2 and 3. After obtaining the data, an evaluation was conducted.

2.4. Measurement of Air Kerma Rate, $\check{K}_a$ [2]

The air Kerma rate. $\check{K}_a$ of the OB-85 was measured using calibrated Ionization chamber [5,6], at the reference point along the X-axis of the radiation field. For the calculation of air kerma rate, it can be used equation (3) under standard STP conditions (20^o, 101.3 kPA). If the conditions are not standard, the correction shoeld be done using equation (4).

$$\check{K}_a = M \times N_k \times K_{PT} \tag{3}$$

$$K_{PT} = \frac{1013{,}25}{P} \times \frac{T+273}{293{,}15} \tag{4}$$

M : The average reading of a dosimeter/electrometer

N_k : Calibration Factor for the detector [μGy / nC]

K_{PT} : Pressure and Temperature Correction Factors

2.5. Uncertainty in Measurement of Air Kerma Rate [9, 10, 11, 12]

All measurement instruments have an uncertainty value associated with the measurement. This uncertainty can vary from time to time. The measurement results can only be declared true if the value of the measured is provided with a deviation limit from the measurement results. Tolerance or deviation limit is known as uncertainty.

For the calculation of the uncertainty of Air Kerma Rate, the ISO-Guide to the Expression of Uncertainty of Measurement can be used [9, 10, 11, 12]. Basically, measurement uncertainty can be grouped into Type A and Type B. Type A, evaluated by the statistical method while type B is evaluated by other methods, usually Type B uncertainty data comes from the calibration certificate of the equipment used.

The measurement uncertainty related to the Air Kerma Rate, $\check{K}_a$ is calculated from equation (3).

$$K_a = M \text{ x } Nk \text{ x } KPT \quad (3)$$

The related parameters used to calculate the combined uncertainty were standard uncertainties of M, u_M (Type A), standard uncertainties of calibration factor, u_{NK}, standard Uncertainty of thermometer, u_T and barometer, u_{bar}. Standard uncertainty of meter, $u_{m;}$ standard uncertainty of timer, u_t; standard uncertainty of distance, u_D.

The combined uncertainty of Air Kerma Rate was:

$$(u_c)^2 = (c_1u_1)^2 + (c_2u_2)^2 + (c_3u_3)^2 + (c_4u_4)^2 + (c_5u_5)^2 + (c_6u_6)^2\ )^2$$

$$(u_c)^2 = (c_Mu_M)^2 + (c_{NK}u_{NK})^2 + (c_Pu_P)^2 + (c_Tu_{CT})^2 + (c_tu_t)^2 + (c_Du_D)^2 \quad (5)$$

$$c_1 = c_M = \frac{\partial K}{\partial M} = \frac{N_kK_PK_T}{t} \quad (6)$$

$$c_2 = c_{NK} = \frac{\partial K}{\partial N_K} = \frac{MK_PK_T}{t} \quad (7)$$

Pressure Correction Factor $= \frac{1013,25}{P}$, $c_3 = c_P = \frac{\partial K}{\partial P} = -\frac{1013.25}{P^2} x\ K_T \text{ x } M \text{ x } \frac{N_K}{t}$ (8)

Temperature correction factor $\frac{T+273}{293,15}$, so $c_4 = c_T = \frac{\partial K}{\partial T} = \frac{1}{293,15} \text{x} K_P \text{x} M \text{x} \frac{N_K}{t}$ (9)

$$c_5 = c_t = \frac{\partial K}{\partial t} = M\text{x } N_k \text{ x } K_P \text{ x } \frac{K_T}{t^2} \quad (10)$$

$$c_6 = c_D = \frac{\partial K}{\partial D} = -\frac{2}{D^3} \quad (11)$$

Finally, u_c can be calculated using equation: (5), (6), (7) to……. (11) and u_M from measurement (type A), U_{NK}, U_P, U_T. U_t, U_D can be obtained from certificate (type B).
Furthermore, the degree of effective freedom, ν_{eff} is calculated using equation (12)

$$\nu_{eff} = \frac{u^2(Y)}{u_i^4 / \nu_i} \quad (12)$$

Finally, the expanded uncertainty, U_{exp} ($\check{K}_a$) was calculated using equation (13)

$$U_{expanded}\ \check{K}_a) = k \text{ x } u_c\ (\check{K}_a) \quad (13)$$

K: coverage factor, k depends on ν_{eff}, use *confidence level* (CL) 95%.

3. Working Procedure

3.1. Material and Equipment

- Source ^{137}Cs (OB-85) made by Buchler GmbH, activity 74 GBq (May 1985), with shielding, collimator, and control panels (shutter and timer)
- Check-source: ^{90}Sr/No:23261/035 to check detector stability
- IC Detector/M23332/SN #204, volume 0.3 cm^3, cylindrical and Keithley/PTW Unidos
- IC Detector, Exradin A4, ball, volume 30 cc and electrometer Keithley #6487 (Figure 3i)
- IC Detector TK-30/SN #107, spherical, and PTW Unidos Webline/T10001/11814
- Calibration table, meter, telescope and laser alignment (Figure 3a)
- Measuring devices (room temperature, pressure, humidity) meter (Figure 3b)

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Vol. 1, 2020

In Figure 3a; 3b; 3c; ……… to 3i are the equipments used to determine the width of radiation field of the OB-85 at Calibration Facility in PTKMR-BATAN.

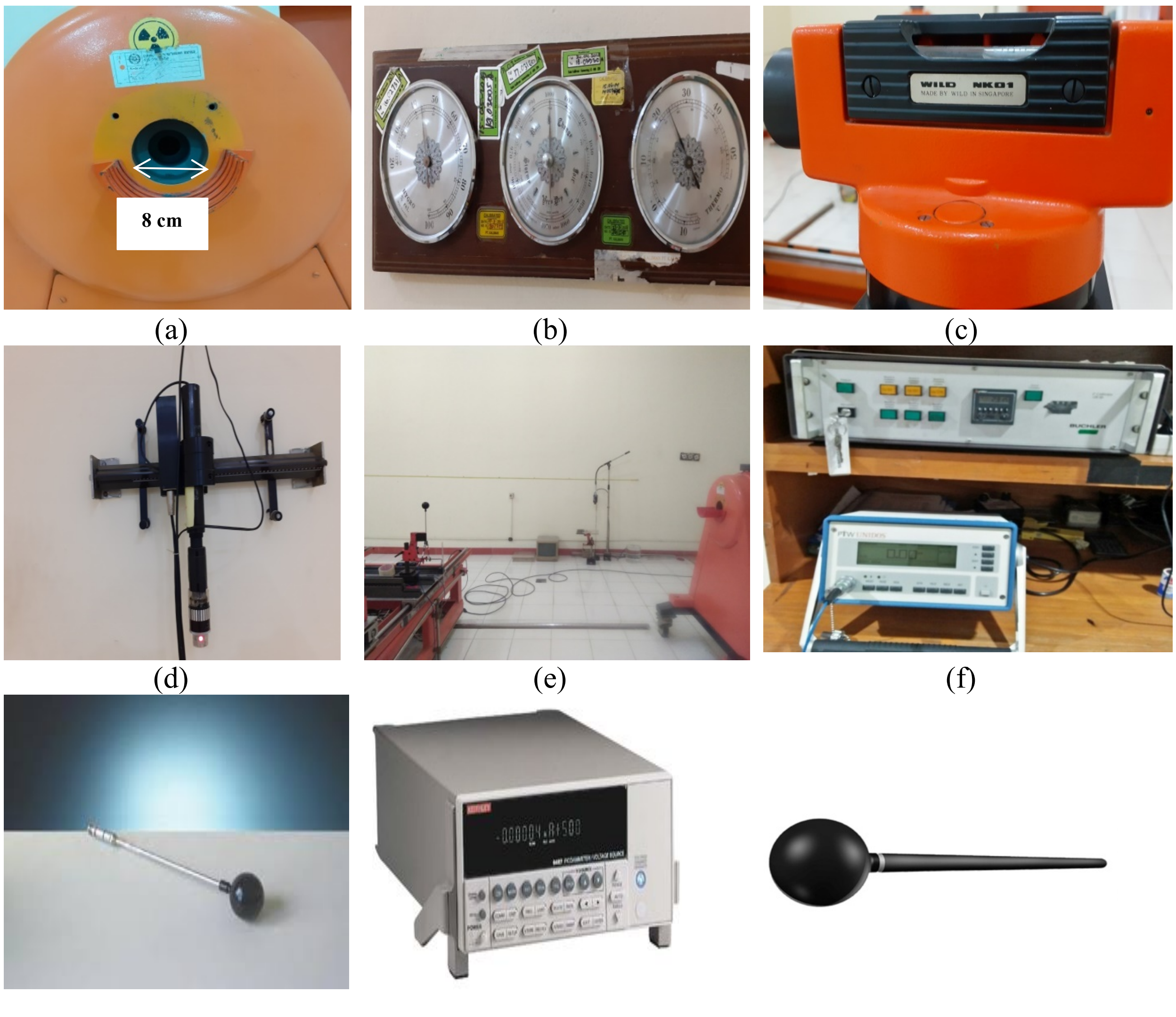

Figure 3. (a) ^{137}Cs (OB-85) in the shielding and collimator, (b) The device for measurig temperature, pressure and humidity, (c). Telescope for adjusting the detector's position, (d) *Laser alignment* for aligning detector's positions with respect to sources, (e) Setting the measurement of the radiation field width of the OB-85 field, (f) Unidose Webline PTW, control panel and electrometer, (g) Ionization Chamber Detector TK-30 / SN # 107, (h) electrometer Keithley #6487, and (i) Detector Exradin A4

3.2. Detector repeatability

Tables 3. and 4. present the repetability of the detector in the radiation field measurements at detector positions 0, 2, and 4 cm from the central, at SDD = 50 cm and at the detector position: 0, 4, 8 cm from the central, at SDD 100 cm.

3.3. Determination of the width of the radiation field

To find out the width of radiation field of the OB-85 using the three types of Ionization Chamber, the equipment settings as shown in Figure 2e. The detector was placed on a calibration table using statips, adjusting the height so that the radiation field hits the center of the detector. The detector is placed in front of the source (in the central position) at the Source Detector Distance (SDD) = 50 cm, with the help of laser alignment.

The detector is connected to a Unidose PTW electrometer/Keithley electrometer, depending on the type of detector and its connector. For M23332/SN #204 detector, the working voltage is set at 400 volts. As for the TK-30/SN #107 detector, the working voltage is set at 300 volts. At each detector, the device was heated for 30 minutes to get an electronic balance.

Source ^{137}Cs (OB-85) is opened by pressing the button on the control panel. Gamma radiation from ^{137}Cs will travel in the air and hit the Ionization chamber detector. Gamma radiation that interacts with air in the detector, will ionize the air and will produce an ionization current. The ionization current was measured by the Unidos Webline PTW electrometer/Keithley electrometer. From each measurement position, 5 data were taken. The position of the detector is shifted from central to right and left every 2 cm for SDD = 50 cm and 4cm for SDD = 100 cm. Average current data obtained at detector position: 0; ± 2; ± 4 ... ± 20 cm (SDD = 50 cm) and the average current data at the detector position: 0; 4; 8 ... 40 cm (SDD = 100 cm), was plotted and presented in Figure 4b; 4c; 4d, and 4e.

3.4. Air Kerma Rate, Ambient Equivalent Dose Rate and Exposure Rate

The Table 5. presents the Reference value of OB-85 output (Air Kerma Rate, $\check{K}_a$, Personal Equivalent Dose rate, Hp (10), Ambient Equivalent Dose Rate, H* (10) and Exposure Rate), X at SDD 50, 100 and 200 cm, with Reference Time: August 7, 2019. This Reference Value is used as a comparison in determining of RMIs Calibration Factor (CF). CF = $\frac{Reference\ Value}{RMI\ Reading}$ [IAEA / SRS-16-2000]. Based on the gamma of RMIs calibration SOP, if the CF is in the range of 0,8-1.2, a Calibration Certificate will be issued.

3.5. Uncertainty in Measurement of Air Kerma Rate [9,10, 11, 12]

The mathematical equation (3) can be used to calculate the air Kerma rate, K_a.

$$K_a = M \text{ x } N_k \text{ x } K_{PT} \tag{3}$$

Mathematical equation (5) can be used to calculate the combined uncertainty of the Air Kerma rate, u_c (K_a).

$$u_c^2\,(K_a) = (c_M u_M)^2 + (c_{NK} u_{NK})^2 + (c_P u_P)^2 + (c_T x u_{CT})^2 + (c_t u_t)^2 + (c_D x u_D)^2 \tag{5}$$

The degrees of effective freedom, ν_{eff} is calculated by equation (12).

$$\nu_{eff} = \frac{u^2(Y)}{u_i^4/\nu_i} \tag{12}$$

Finally, the expanded uncertainty, U_{exp} (K_a), can be calculated using equation (13).

$$U_{exp}\,(K_a) = k \text{ x } u_c(K) \tag{13}$$

k: coverage factor, it depemds on the ν_{eff}, k for confidence level (CL) 95%.

4. Result and Discussion

In Figure 4a, The Schematic for measuring the width of radiation field of OB-85 was set-up. From this schematic, we get the information that the more radiation field will we get if the more diameter of the collimator and the more of SDD (Source Detector Distance).

In Figure 4b, 4c and 4d, the width of radiation field of the OB-85 were obtained, they were 18 cm for SDD = 50 cm, and 36 cm for SDD = 100 cm, using the Ionization chamber/SN #M23332, TK-30/SN #IC107 and Exradin A4. The results are a little less symmetrical. This may be because of the position of the source (inside the collimator) slightly to the right. By getting this information, the calibration operator should place calibration object (surveymeter or APD) in this radiation field range. If the RMIs exceeds 18 cm, use SDD more than 50 cm, so the width of radiation field was more than 18 cm. where D_1, D_2, D_3 are collimators, diameter 1, 2 and 3 are 2, 4, 8 cm, respectively. S_1, S_2 are distance of source to collimator 1 and 2 which are 6 and 8 cm. SDD_1, SDD_2 are source detector distance 1 and 2 whics are 50 and 100 cm, respectively.

At SDD = 50 cm, the average current measured by the IC detector M23332 was (27.99 ± 2%) pA and at SDD = 100 cm, the average current was (7.43 ± 1.4%) pA, see Table 2 and 3, column 4, at one standard deviation.

In Figure 4c. at SDD = 50cm, the average current measured by the IC TK-30/SN #107 was (24.72 ± 1.7%) pA, and at SDD 100 cm, the measured current was (6.49 ± 2%) pA, at one standard deviation. In Figure 4d. at SDD = 50cm, the average current measured by the IC Exradin A4 was (25.88 ± 2.7%) pA, and at SDD 100 cm, the measured current was (6.76 ± 2.3%) pA, at one standard deviation.

By using three types of Ionization Chamber detectors, it was obtained that the width of radiation field of the OB-85 was 18 cm and 36 cm, at SDD = 50 cm and 100 cm, See Table 1. The width of radiation field was not depending on the kind of the detector used to be measured but it depends on the geometry of the source, collimator, and SDD (Source Detector Distance) (see Figure 4a).

In Figure 4d, at SDD = 50 cm and SDD=100 cm, the width of radiation field of the OB-85 was presented, that are 18 cm and 36 cm, measured by three types of detector. Tables 2 and 3 present the repeatability for the three types of Ionization chamber detectors. The repeatability of the three types of detectors is less than 1%. These data are obtained from measurements of the width of the radiation field at SDD = 50 cm, at the position of the detector (0-4) cm from the source center and (0-8) cm at SDD = 100 cm, the detector's repeatability is quite good/quite small, but it will contribute to uncertainty in the calibration of the radiation gauge.

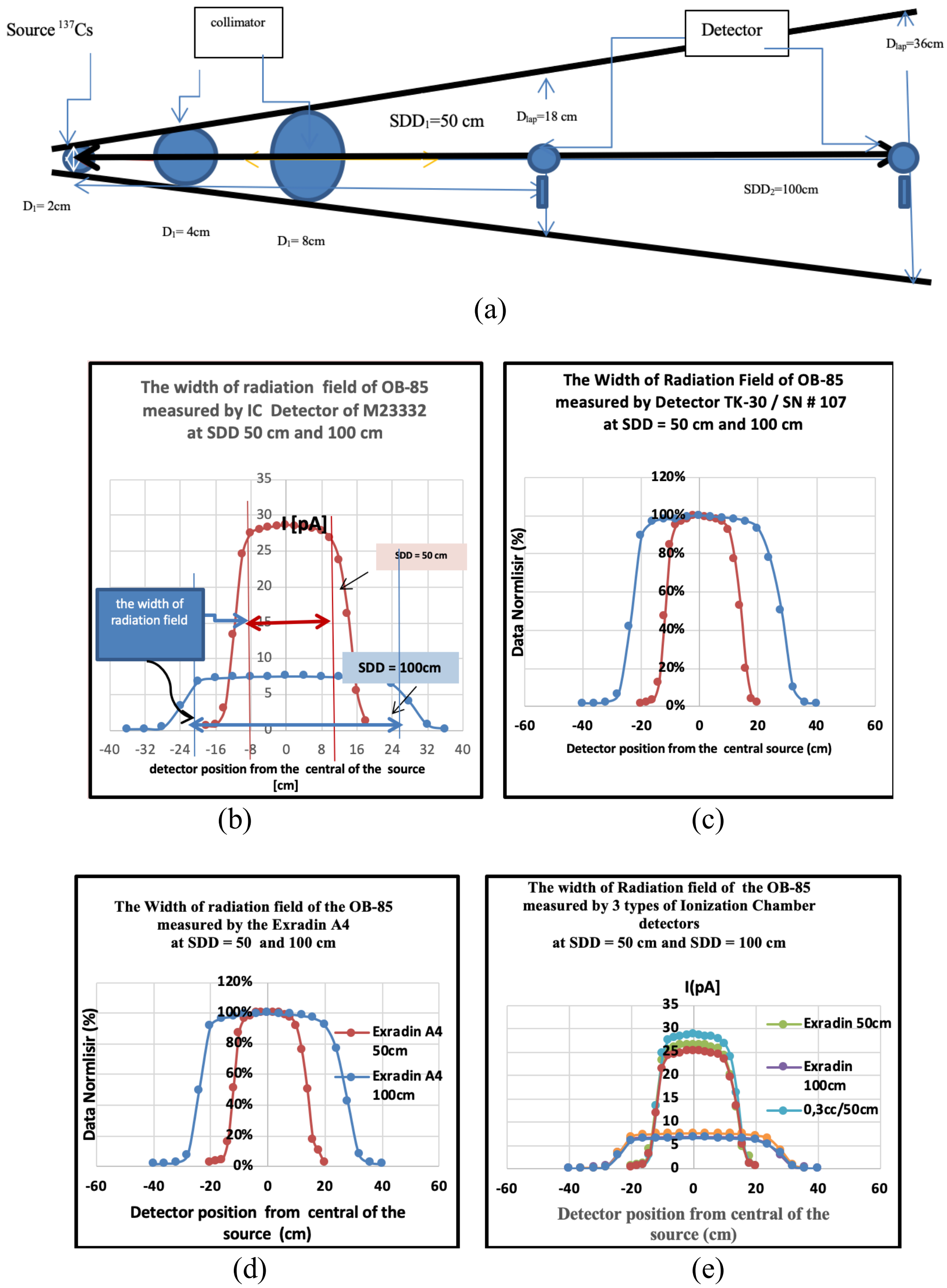

Figure 4. (a)The Schematic for measuring the width of radiation of the OB-85, (b) The width of radiation field of OB-85 measured by IC Ionization chamber of M2333, (c) The Width of Radiation Field of OB-85 measured by IC TK-30/SN #107, (d) The width of radiation field of the OB-85, measured by the Exradin A4, and (e) The width of radiation field of the OB-85 Measured by three types of the detectors

Table 1. Radiation Field of the OB-85 measured by three types of ionization chamber detectors and keithley electrometer at SDD 50 and 100 cm

Horizontal position		**TK-30/107 [pA]**		**EXRADIN/A4 [pA]**		**M23332 [pA]**	
SDD=50cm	SDD=100cm	SDD=50cm	SDD=100cm	SDD=50cm	SDD=100cm	SDD=50cm	SDD=100cm
-8	-16	24.00	6.40	25.42	6.67	27.51	7.23
-6	-12	24.41	6.50	25.87	6.76	27.97	7.35
-4	-8	24.73	6.49	26.32	6.85	28.28	7.47
-2	-4	25.16	6.60	26.34	6.86	28,47	7.5
0	0	25.20	6.63	26.36	6.91	28.63	7.53
2	4	25.06	6.60	26.35	6.85	28.46	7.53
4	8	24.92	6.56	26.35	6.86	28.31	7.48
6	12	24.68	6.52	25.98	6.80	28.16	7.41
8	16	24.33	6.43	25.60	6.69	27.78	7.34
10	20	23.30	6.18	24.18	6.37	26.80	7.05
Average =		**24.72**	**6.49**	**25.88**	**6.76**	**27.99**	**7.43**
Stdev =		**0.41**	**0.13**	**0.69**	**0.16**	**0.56**	**0.10**
Stdev (%) =		**1.7**	**2.0**	**2.7**	**2.3**	**2.0**	**1.4**
The width of radiation field of OB-85		**18 cm**	**36 cm**	**18 cm**	**36 cm**	**18 cm**	**36 cm**

Table 2. The Repeatability of three types of ionization chambers for current measurement of the OB-85 in the range of radiation field of (0-8) cm, at SDD = 100 cm

	I(EXRADIN/A4) pA			**I(TK-30//SN#107) pA**			**I (M-23332/0,3 cc) pA**		
Detector position (cm)	0	4	8	0	4	8	0	4	8
	6.89	6.87	6.86	6.60	6.60	6.55	7.55	7.55	7.50
	6.90	6.86	6.86	6.60	6.50	6.50	7.55	7.55	7.45
	6.91	6.85	6.85	6.65	6.55	6.60	7.50	7.50	7.45
	6.92	6.84	6.86	6.60	6.60	6.55	7.50	7.50	7.50
	6.92	6.84	6.86	6.70	6.65	6.60	7.55	7.55	7.50
Average	6.91	6.85	6.86	6.63	6.60	6.56	7.53	7.53	7.48
Stdev (%)	0.46	0.14	0.48	0.63	0.41	0.42	0.36	0.36	0.37
Repeatability	Good (below 1%)			Good (below 1%)			Good (below 1%)		

Table 3. The Repeatability of three types of ionization chambers for current measurement of the OB-85 in the range of radiation field of (0-4) cm, at SDD = 50 cm

	EXRADIN/A4			**TK-30//SN#107**			**M-23332/0,3 cc**		
Detector Position (cm)	**0**	**2**	**4**	**0**	**2**	**4**	**0**	**2**	**4**
	26.31	26.35	26.34	25.20	25.00	24.90	28.60	28.50	28.30
	26.32	26.35	26.35	25.25	25.05	24.85	28.55	28.50	28.35
	26.31	26.35	26.35	25.15	25.00	24.95	28.75	28.45	28.30
	26.32	26.35	26.36	25.20	25.15	24.95	28.65	28.35	28.30
	26.53	26.35	26.36	25.20	25.10	24.95	28.60	28.50	28.30
Average	**26.36**	**26.35**	**26.35**	**25.20**	**25.06**	**24.92**	**28.63**	**28.46**	**28.31**
Stdev (%)	**0.24**	**0.02**	**0.75**	**0.18**	**0.36**	**0.11**	**0.26**	**0.23**	**0.08**
Repeatability	Good (below 1%)			Good (below 1%)			Good (below 1%)		

Table 4. The Output of OB-85 RT: August 7, 2019 at the Gamma Calibration Facility in PTKMR-BATAN

SDD	Without Absorber			
r [cm]	K_u [μGy/h]	Hp (10) [μSv/h]	H*(10) [μSv/h]	X [mR/h]
50	103672	125444	124408	11820
100	25918	31361	31102	2955
200	6480	7840	7775	739

The output of OB-85 in Table 4 was used for calibration of gamma RMIs (Surveymeter and APD). If the surveymeter reading unit is μGy/h, use the Air Kerma rate. Surveymeter was put at SDD 50, 100 or 200 cm, it depends on the maximum reading of the Surveymeter (SM). If the maximum reading was 10,000 μGy/h, the calibration should be carried out at SDD 200 cm. If the unit of SM reading is μSv/h, use the reference reading of the ambient equivalent dose rate, H*(10) μSv/h. Calibrate the SM at SDD 50, 100 or 200 cm. depending on the maximum reading of the SM. If the maximum reading was 10,000 μSv/h, then the calibration should be carried out at SDD 200 cm.

If the RMIs reading unit is mR/h, use the reference reading of Exposure rate, X. Perform calibration at SDD 50, 100 or 200 cm depending on the maximum RMIs reading. If the maximum reading wais 1000 mR/h, then calibration should be carried out at SDD 200 cm.

The uncertainty of RMIs calibration depends on the magnitude of Type A and Type B uncertainties. The Calibration Factor of RMIs = $\frac{Reference\ Reading}{Reading\ of\ RMI}$. The Reference Reading has uncertainty, u_{Ref} and the reading of RMIs has uncertainty, u_{RMI}. So, the combined uncertainty of CF, u_c (CF) = $\sqrt{u_{Ref}^2+u_{RMI}^2}$. And the U_{exp} = k x u_c, k = coverage factor.

The combined uncertainty value is useful in knowing the level of success in taking measurements. If the type A uncertainty value is too large there is the possibility of the measurement was wrong or the equipment used does not match the range, if there is such a case then the measurement must be repeated in various ways, for example repeating the measurement several times or replacing experimental devices with tools that have a higher accuracy limit (more accurate).

5. Conclusion

To determine the width of the radiation field of the OB-85, stability and repeatability check of the detector should be performed. Determination of the width of the OB-85 was done by three kind of IC. The width of radiation field of the OB-85 was 18 cm for SDD = 50 cm and 36 cm for SDD = 100 cm. The width of the radiation field does not depend on the type of detector used to measure but it depends on the set-up of calibration facility, geometry/shape of source, diameter of collimator, and SDD.

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