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IAEA/RCA光子線に対する線量計とサーベイ機器の校正に関するワークショップ

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PNC TN8410 95－319

１ ９ ９ ５ 年　１ １ 月

IAEA/RCA
光子線に対する線量計とサーベイ機器の校正に関するワークショップ

平成６年度

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要　旨

平成６年１１月２８日から１２月２日にかけて開催されたＩＡＥＡ／ＲＣＡに基づく「光子線に対する線量計とサーベイ機器の校正に関するワークショップ」において、標準校正場の品質保証（ガラス線量計による校正場の相互比較方法の提案）について発表機会を得た。また、動燃東海計測機器校正施設においてワークショップ参加者による基準校正場の設定およびサーベイメータの校正に関する実習を行った。

本書は、筆者らが行った発表、あるいは実習の概要を報告するものである。

*安全管理部放射線管理第一課
**安全管理部安全対策課

目 次

1.はじめに

平成6年11月28日から12月2日にかけて、日本原子力研究所東海研究所（以下、原研）において国際原子力機関によるアジア地域原子力協力協定（ＩＡＥＡ／ＲＣＡ）に基づく「光子線に対する線量計とサーベイ機器の校正に関するワークショップ」が開催された。日本からは原研保健物理部、動燃安全管理部が参加し、海外からはＲＣＡ加盟の近隣アジア諸国１２か国、ＩＡＥＡ等から１６名の参加があった。筆者らは2日目（11/29）の「国別報告セッション（Country Report Session）」における日本代表発表の場で、標準校正場の品質保証”ガラス線量計による校正場の相互比較方法の提案”について発表した。また、３日目（11/30）には動燃東海事業所計測機器校正施設において「計測技術実習（Technical Exercise）」として基準線量計による校正場の設定および電離箱型サーベイメータの校正実習を行った。以下に、ワークショップの概要について紹介する。

2.ワークショップの概要

本ワークショップは、個人線量計やサーベイ機器の校正に関して国際的に標準化された校正技術をＲＣＡ加盟の近隣アジア諸国に対して普及を図ることを目的としたものである。　ワークショップでは、原研の南氏、IAEAの Grifith氏らによるＩＣＲＵで示されている放射線防護の実用計測線量（Operational Quantities）に関する特別講義、および参加国各国における実用計測線量の適用状況を含めた校正技術の現状の紹介等があった。さらに計測技術の実習として、動燃東海事業所の計測機器校正施設において電離箱型サーベイメータの校正実習を行った。

この他、ワークショップでは今後の具体的な計画として、各国の標準校正場および個人線量計の相互比較を行うことが提案された。今回のワークショップおよび今後の相互比較を通じて各国の校正技術の向上が期待される。

なお、本ワークショップの議事日程を別添1に、参加者一覧を別添2に示す。

3.発表「標準校正場の品質保証：ガラス線量計による校正場の比較方法の提案」

ワークショップ2日目（11/29）の「国別報告セッション（Country Report Session）において発表した内容の概要を以下に示す。なお、発表要旨、発表原稿、およびOHP原稿を資料1.に収録した。

「標準校正場の品質保証：ガラス線量計による校正場の比較方法の提案」

要約

標準校正場における基準線量の相互比較にガラス線量計を用いる方法が開発された。この方法を動燃の５事業所（東海事業所、大洗工学センター、もんじゅ建設所、ふげん発電所、人形峠事業所）の標準校正場の相互比較に適用した。その結果、全事業所で４％以内で一致した。従って、各事業所の標準校正場は適切な精度で維持されており、かつガラス線量計が校正場の照射精度のチェックに適用できることが示された。この方法はRCA加盟各国間での校正場の相互比較プログラムに利用し得るであろう。

はじめに

放射線防護のために線量評価の品質保証を図る目的で、線量計や放射線モニタの校正を実施することは非常に重要である。校正場の基準線量値は国家標準につながるトレーサビリティ体系の中で電離箱型基準線量計を用いて評価されなければならない。

1992年に、電離箱型基準線量計を用いて動燃５事業所を対象とした基準照射線量値の相互比較を実施し、全事業所で３％以内で一致している。

このような相互比較試験は定期的に実施することが望まれるが、電離箱型基準線量計を用いる方法は、事業所間を輸送する際に基準線量計を破損する恐れがあることや評価に多くのマンパワーや時間を要することから定期的な実施には不向きである。そこで、より簡便な方法として、ガラス線量計を用いる方法が提案された。

ガラス線量計を用いた基準線量の相互比較

ガラス線量計を用いた簡便な相互比較方法が日本原子力研究所の努力により開発された。1993年から1994年にかけて動燃５事業所を対象に相互比較が試みられた。その結果は、全18の比較ポイントのうち2ポイント（3.7％、2.7％）を除いて２％以内のずれ(各事業所校正場の評価値とガラス線量計による測定値とのずれを偏差で評価した。)でよく一致した。

結論

ガラス線量計を用いた相互比較により校正場の基準照射線量値が簡便にかつ迅速にチェックできることがわかった。また、今回ガラス線量計の総合的な測定精度は1.5％

まで高めることができた。ガラス線量計を用いる方法はRCA加盟各国間での相互比較に役立つものであろう。

4.計測技術実習

ワークショップ3日目（11/29）の「計測技術実習（Technical Exercise）」として基準線量計による校正場の設定および電離箱型サーベイメータの校正実習を行った。以下に、校正実習のテキストとして作成、使用した「校正実習要領」の概要を示す。なお、「校正実習要領」は資料2.に収録した。

「校正実習要領」

1.概要

実習では電離箱型基準線量計による基準照射線量の測定および評価を行い、次に基準照射線量値を基準1cm線量当量値に換算する。その後セシウム照射装置を使用して、置換法により電離箱型サーベイメータの校正を行う。

2.装置

1）基準電離箱：ラドコン線量計（米国ビクトリーン社製）
計測部、500型
検出器、500-3型（330cc電離箱）
電子技術総合研究所にて校正

2）電離箱型サーベイメータ：808DDE型（ネスコ社製）

3）γ線照射装置：^{137}Cs（1.11TBq）自動校正装置

4）気圧計および温度計

3.手順

A.基準照射線量値の評価

（1）γ線照射装置と基準電離箱（ラドコン線量計）のセット

1.線源-検出器間距離は1m。^{137}Cs（1.11TBq）線源を使用する。

2.ラドコン線量計の測定レンジを2にセットする。

(2) 測定

1.基準電離箱（ラドコン線量計）でバックグラウンドを測定する。［測定時間300秒。タイマーによる。］

2.照射前に、照射室内の気圧及び気温を測定する。

3.照射を実行し基準電離箱（ラドコン線量計）により基準照射線量を測定する。[線源-検出器間距離が1mのとき測定時間60秒。1.5mのとき120秒。2mのとき180秒。タイマーによる。］

線量指示値は2回読み取る。（測定の前後）そして照射線量の測定値は次式による。

照射線量測定値=指示値（前）－指示値（後）

測定は３度繰り返す。

4.測定値の平均値を求める。［Appendix 1-1のA参照］

5.３度目の測定終了後、照射室内の気温、気圧を再度測定する。

そこで、気温、気圧の補正係数を求める。

(3) 環境条件補正係数

1.気温及び気圧の補正は以下の通り。

環境条件補正係数（F）＝（273.15+T／273.15+22）×1013.3／H

ただし、T：気温（℃）、H：気圧（hPa）［Appendix 1-1および1-2の*1および*2参照］

2.照射の前後に評価したそれぞれの補正係数から環境条件補正係数の平均値（Fa）を求める。

(4) 1mにおける基準照射線量

1.基準照射線量値（D）　［Appendix 1-1および1-2の*3参照］

＝（測定値の平均値）－（バックグラウンド値）

×環境条件補正係数の平均値（Fa）

×電総研による校正定数（CF）

2.基準照射線量率（Dr）［*4参照］

＝（D）×（3600／60）

3.基準1cm線量当量率（De）［*5参照］
＝（Dr）×（線量当量換算係数（Appendix 5のTable7参照））

（5）（1）から（4）までの手順を距離1.5mおよび2mについても同様に繰り返す。［Appendix2および3参照］

B.電離箱型サーベイメータの校正

（1）γ線照射装置と電離箱型サーベイメータのセット

1.線源と電離箱間距離は１m。^{137}Cs（1.11TBq）線源を使用する。

2.電離箱型サーベイメータのレンジを100mSv／hにセットする。

（2）測定　［Appendix 4参照］

1.照射前にバックグラウンドを測定する。

2.照射を実施する。

指示値が安定したら指示値を読み取る（10回）

（3）校正定数の計算

1.校正定数は次式で与えられる。

校正定数=基準１cm線量当量率（De）／（測定値の平均値ーバックグラウンド）

（4）距離1.5m、2mについても同様に繰り返す。［Appendix4参照］

（5）レンジの校正定数

レンジの校正定数は３つの校正定数の平均値とする。
しかし、実際の校正作業においては各レンジの校正定数は最小２乗法により求める。

5.あとがき

今回の発表あるいは動燃での実習を通じて、動燃基準校正場（東海事業所計測機器校正施設）における基準場の設定方法、サーベイメータ類の校正方法を紹介し、動燃各事業所の標準校正場が適切な精度で維持されていることを各国からの参加者にアピールできたことと思う。

なお、動燃各事業所標準校正場の相互比較については日本保健物理学会第３０回研究発表会においても発表した。

資料1.

発表

標準校正場の品質保証
-ガラス線量計による校正場の比較方法の提案-

発表要旨

Quality assurance of reference calibration field

Proposal of Reference Dose Value Intercomparison using RPL Glass Dosemeter

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319-11, JAPAN

Abstract

The method for a reference dose value intercomparison of calibration field using radiophotoluminescence (RPL) glass dosemeters was provided. This method was applied to the intercomparison of the reference exposure value of gamma irradiation fields among the 5 calibration facilities of Power Reactor and Nuclear Fuel Development Corporation (PNC). The results showed a good agreement by as much as 4% of deviation. These prove that reference exposure values of each calibration facility have been maintained in a good accuracy. It was shown also that the RPL glass dosemeters could be applied to a check of exposure value of a calibration field. This method will be available for the intercomparison programme among the Regional Cooperative Agreement(RCA) member states.

Introduction

To assure a quality of dose evaluation for radiation protection, a calibration of dosemeters and monitoring equipments is very important. The reference dose value of calibration fields should be evaluated by using a standard ionization chamber which is calibrated on a traceability system to a primary standard.

National primary standards of radiation dose value have been established at the Electro-Technical Laboratory (ETL) in Japan. Five sites in PNC (Tokai Works, O-arai Engineering Center, Monju Construction Office, Fugen Nuclear Power Station, and Ningyo Toge Works) have each calibration facility. The reference dose of the calibration fields are measured by their standard ionization chamber at each site. Tokai Works and Fugen Power Station request the ETL to calibrate the standard ionization chambers (Victoreen 500 for detector, 550-3 for electrometer). The standard ionization chambers of other 3 sites (O-arai, Monju and Ningyo Toge Works) were calibrated at the calibration field of Tokai Works (Figure 1).

In 1992 the intercomparison for the reference exposure values of the calibration fields was made with 5 calibration facilities by means of the ionization chambers. And all results show a good agreement by as much as 3%.

It was found that an intercomparison was a very effective method to check the accuracy of irradiation. So it is desirable to carry out the same kind of intercomparison periodically. However, the intercomparison using a standard ionization chambers is not convenient, because an ionization chamber is very sensitive to mechanical shocks and humidity, and also this method needs much man power and time. Then, the intercomparison of reference dose value using RPL glass dosemeter was proposed.

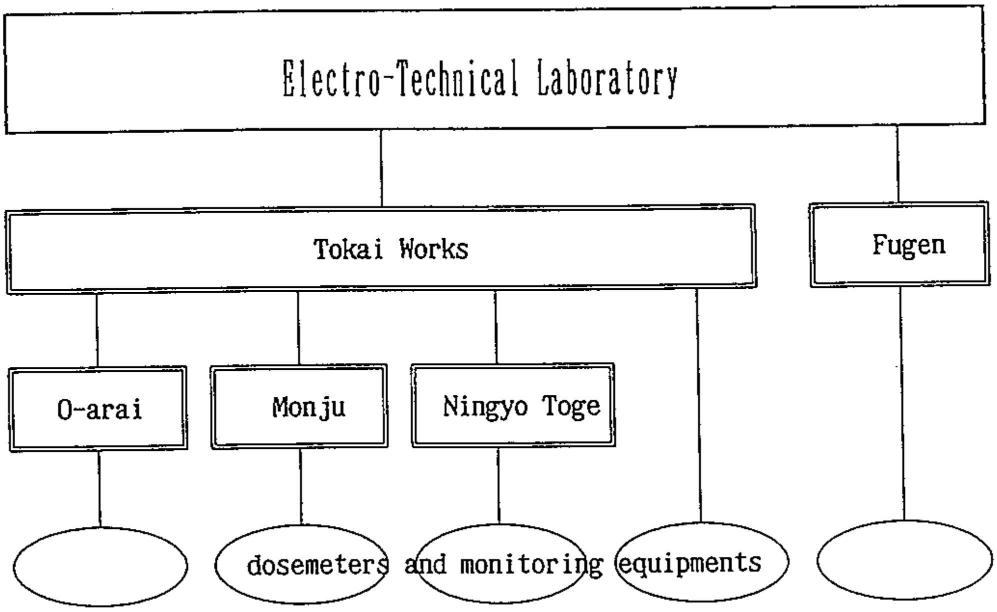


Figure 1. The traceability system of gamma calibration field in PNC

RPL glass dosemeter

The Toshiba Type SC-1 RPL glass dosemeters were used for the reference dose value intercomparison of the calibration fields because of its excellent characteristics. The dosemeters are readout by means of a pulsed UV laser excitation. The structure and the external view of the dosemeter are shown in Figure 2 and Figure 3.

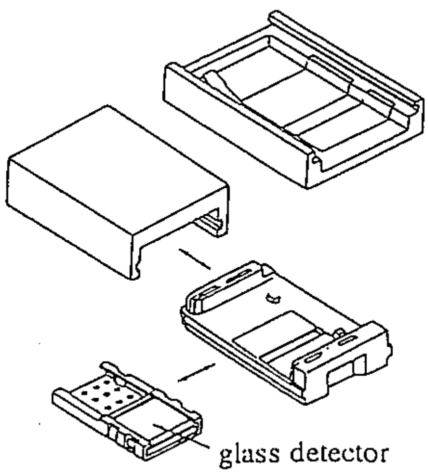


Figure 2. The structure of the dosemeter

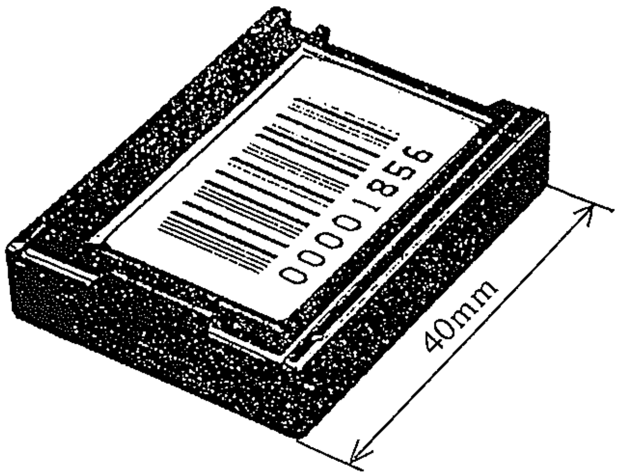


Figure 3.The external view of the dosimeter

The typical features of the RPL glass dosemeter are as follows. (1) Readingout can be done repeatedly. (2) Dispersion of sensitivity among the dosemeters is small. (3) Fading is small. (4) Fluorescence come from predose is subtracted automatically. (5) Dose imformation stored inside glass dosemeter can be erased by annealing, etc.

In our experience, some special techniques,such as the sensitivity correction for each dosemeter, were also considered to get the good performance of dose measurements of RPL glass dosemeter.

The main characteristics of the RPL glass dosemeter are shown in Table 1.

Table 1. Characteristics of the RPL glass dosemeter

Item	Condition	Deviation
energy dependence	200keV to ^{60}Co	<±5%
angular dependence	direction of 0° ±30° ^{137}Cs	<±1%
dose rate response	20mR/h to 1R/h	<±1%
deviation of readings	50mR<	±0.3%

Reference dose value intercomparison using RPL glass dosemeter

The convenient intercomparison method using RPL glass dosemeters was provided with the effort of Japan Atomic Energy Research Institute (JAERI). In 1993 and 1994 the trial of intercomprison was made among 5 facilities of PNC.

The sources used for the intercomparison are ^{60}Co and ^{137}Cs. The activities of the sources are from 1.85GBq to 1.11TBq for ^{137}Cs and from 370MBq to 3.7TBq for ^{60}Co. Table 2 shows the sources' data used for the intercomprison.

The JAERI Tokai Institute sent the dosemeters, which was already annealed to erase the predose of a dosemeter, to the participant facilities. Then the irradiations to the dosemeters were carried out at each facility. The distances between source and dosemeter were 1 and 2 meters. In the intercomparison, 3 pieces of glass dosemeters were used at one point. The dosemeters irradiated at each facility were returned to JAERI with the data of the irradiated exposure value. After returning to JAERI, the dosemeters were read out. And the measured values were compared to the reference exposure dose values of each facility using the following equation:

$$\text{Deviation}(\%) = \frac{\text{Exposure value - Measured value}}{\text{Exposure value}} \times 100$$

Table 2. Gamma sources used for the intercomparison

Site	Source		Distance
	nuclide	activity	source to detecter
Tokai	^{137}Cs	1.11TBq	1m,2m
		3.7GBq	1m
	^{60}Co	3.7GBq	1m
O-arai	^{137}Cs	1.11TBq	1m,2m
		3.7GBq	1m
	^{60}Co	3.7GBq	1m
Monju	^{137}Cs	1.11TBq	1m,2m
		7.4GBq	1m
	^{60}Co	370MBq	1m
Fugen	^{137}Cs	740GBq	1m,2m
	^{60}Co	37GBq	1m,2m
Ningyo Toge	^{137}Cs	2.59GBq	1m
	^{60}Co	1.85GBq	1m

Result

The results of the intercomparison among 5 sites of PNC for ^{137}Cs and ^{60}Co sources are shown in Table 3. The exposure value of each calibration facility showed the good agreement by as much as 2% of deviation, except 2 points which differed by 3.7% and 2.7%. For these 2 points, investigations of a cause why they differed more than 2 % are required.

Conclusion

It was found that reference exposure dose value of a calibration field could be checked easily and quickly by the intercomparison using RPL glass dosemeter. The total accuracy for the measurment of exposure dose value is 1.5%. The method using RPL glass dosemeters will be useful for the intercomprison among the RCA member states.

Table 3. Result of the reference exposure value check

Site	Nuclide	Activity	Distance (m)	Exposure[1] (mR/h)	Measured Value of glass dosemeter (mR/h)	Measured / Exposure
Tokai	^{137}Cs	1.11TBq	1.0	8100	8077	0.997
			2.0	2025	2025	1.000
		3.7GBq	1.0	25.43	25.64	1.008
	^{60}Co	3.7GBq	1.0	15.62	15.71	1.006
O-arai	^{137}Cs	1.11TBq	1.0	6602	6612	1.002
			2.0	1638	1577	0.963
		3.7GBq	1.0	28.5	28.25	0.991
	^{60}Co	3.7GBq	1.0	45.2	45.3	1.002
Monju	^{137}Cs	1.11TBq	1.0	9647	9450	0.980
			2.0	2344	2317	0.988
		7.4GBq	1.0	65.89	66.16	1.004
	^{60}Co	370MBq	1.0	9.86	10.05	1.019
Fugen	^{137}Cs	740GBq	1.0	4882	4859	0.995
			2.0	1220	1205	0.988
	^{60}Co	37GBq	1.0	654.8	661.9	1.011
			2.0	163.1	164.4	1.008
Ningyo Toge	^{137}Cs	2.59GBq	1.0	21.15	21.72	1.027
	^{60}Co	1.85GBq	1.0	22.50	22.32	0.992

1) Reference Exposure dose value measured by ionization chamber at each facility

発表原稿

Quality assurance of reference calibration field

-Proposal of reference dose value intercomparison using RPL glass dosemeter-

1.Title

To assure a quality of dose evaluation for radiation protection, a calibration of dosemeters and monitoring equipments is very important.

For quality assurance on calibration of radiation monitoring instruments, the intercomparison using ionization chamber was carried out among the 5 calibration facilities of Power Reactor and Nuclear Fuel Development Corporation (PNC) in 1992 to 1993.

And in 1993 the convenient intercomparison method using Radiophotoluminescence (RPL) glass dosemeters was provided with the effort of Japan Atomic Energy Research Institute (JAERI).

Then we tried to apply this method to the intercomparison of reference exposure value of gamma irradiation fields among 5 facilities of PNC.

The results showed a good agreement within 4% among 5 facilities.

These prove that reference exposure values of each calibration facility have been maintained in a good accuracy, and also RPL glass dosemeter can be applied to this kind of intercomparison.

2.Contents of presentation

now, for the first thing,I am going to present the intercomparison in PNC using ionization chamber, and second,the intercomparison using RPL glass dosemeter.

-Intercomparison using ionization chamber-

3.Traceability system of gamma calibration field in PNC

I'll show you the traceability system of gamma calibration fields in PNC.

Japanese national primery standards of radiation dose value have been established at Electro-Technical Laboratory (ETL).

And PNC Tokai Works and Fugen Power Station ask the ETL. to calibrate their standard ionization chambers.

And PNC Tokai Works calibrate the standard ionization chambers of O-arai Engineering Center, Monju Construction Office,and Ningyo-Toge Works.

So, all monitoring equipments and dosemeters being used in PNC are keeping traceability to national standard of ETL.

4.Introduction of standard ionization chamber

This is the standard ionization chamber possessed in PNC. This is a model of Victoreen 550-3 for detector, and Victoreen 500 for electrometer.

And mercury thermometer and foltan-type mercury barometer are used for measuring ambient air condition in irradiation room.

A true exposure value is given by this equation.

5.Gamma sources used for the intercomparison

For intercomparison,we used 2 kinds of gamma source,Cs-137 and Co-60.

And maximum of activity of the source is 1.11TBq,and minimum is a 1.85GBq.

6.Method of intercomparison and measurement

This shows the exposure values at each facility was measured by Tokai's standard ionization chamber.

And these exposure values measured by Tokai's standard chamber are compared to the values which were evaluated at each facility by itself.

The comparison was quantified as a deviation, by using this equation.

-Result of Intercomparison (summary)-

I'll show you some of the results.

I can say that the reference exposure values of every calibration facility in PNC have been maintained in a good accuracy within 3% of deviation.

7.Result of intercomparison (Cs high)

This is for the Cs source that have relatively high dose rate.

8.Result of intercomparison (Cs low)

This is for the Cs source that have relatively low dose rate.

9.Result of intercomparison (Co)

This is for the Co source.

10.Result of Intercomparison using ionization chamber (include Probrems)

The reference exposure values of each calibration facility in PNC have been maintained in a good accuracy within 3% of deviation.

And an intercomparison is a very effective method to check the accuracy of irradiation.

But at the same time, we came to know that it is not convenient to make a use of ionization chamber for an intercomparison.

Because an ionization chamber is very sensitive to mechanical shocks and humidity, so it is not suitable to send the ionization chamber in a distance,by trains or car.

And also this method needs much man power and time.

So more convenient method was required for making this kind of intercomparison continuously.
Then, we tried to make a use of the RPL glass dosemeter for an intercomparison.

-Intercomparison using RPL glass dosemeter-

11.Introduction of RPL glass dosimetry system

We used the Tosiba Type SC-1 RPL glass dosemeter for the reference dose value intercomparison of the calibration fields.
The RPL glass dosemeters are readout by means of a pulsed Ultraviolet radiation's laser excitation.
The reason why we select the RPL glass dosemeter is because RPL glass dosemeter have excellent features and characteristics.
The typical features are to read out can be done repeatedly, dispersion of sensitivity among the dosemeters is small,the fading is negligible, and so on.
And the total accuracy for the measurement of exposure value is 1.5 %.

12.Characteristics of RPL glass dosemeter

[Read OHP]

13.Gamma sources used for the intercomparison

The same sources were used in this intercomparison as using ionization chamber.

14.Method of Intercomparison and evaluation of doses

I'll show you the method of intercomparison,
First, as the preparing of the test, RPL glass dosemeters were annealed to erase the predose at JAERI.
Then, dosemeters were sent to each facility. and next, they were exposed to gamma rays at each facility.
When irradiations were done, the distances between source and dosemeter were 1 and 2 meters, and 3 pieces of glass dosemeters were used at one point.
And, after irradiation, each facility sent the dosemeters back to JAERI with data of the irradiated exposure value.
After returning to JAERI, the exposed dose values were readout from dosemeters. and the measured values were compared to the reference exposure dose values of each facility.

15.Method of dose evaluation

The comparison of these 2 values was quantified,by this equation.

-Result of intercomparison (summary)-

I'll show some of the results.

The result of the intercomparison among 5 facilities of PNC was that the exposure values of the calibration facilities showed the good agreement by as much as 2% except 2 points of irradiation.

16.Result of intercomparison (Cs high)

This is for the Cs source that have relatively high dose rate.

17.Result of intercomparison (Cs low)

This is for the Cs source that have relatively low dose rate.

18.Result of intercomparison (Co)

This is for the Co source.

19.Result of intercomparison using RPL glass dosemeter

By the intercomparison using RPL glass dosemeters, the exposure value of each calibration facility showed the good agreement within 2% of deviation.

And it was found that reference exposure dose value of a calibration fields can be checked easily and quickly,by the RPL glass dosemeters.

At last, I think this convenient method of intercomparison using RPL glass dosemeter will be very usefull, and a result of an intercomparison must contribute to a quality assurance and a tec PNC TN8410 95−319 of calibration, among the RCA member states.

Thank you.

発表ＯＨＰ

Quality Assurance of Reference Calibration Field

Proposal of Reference Dose Value Intercomparison using RPL Glass Dosemeter

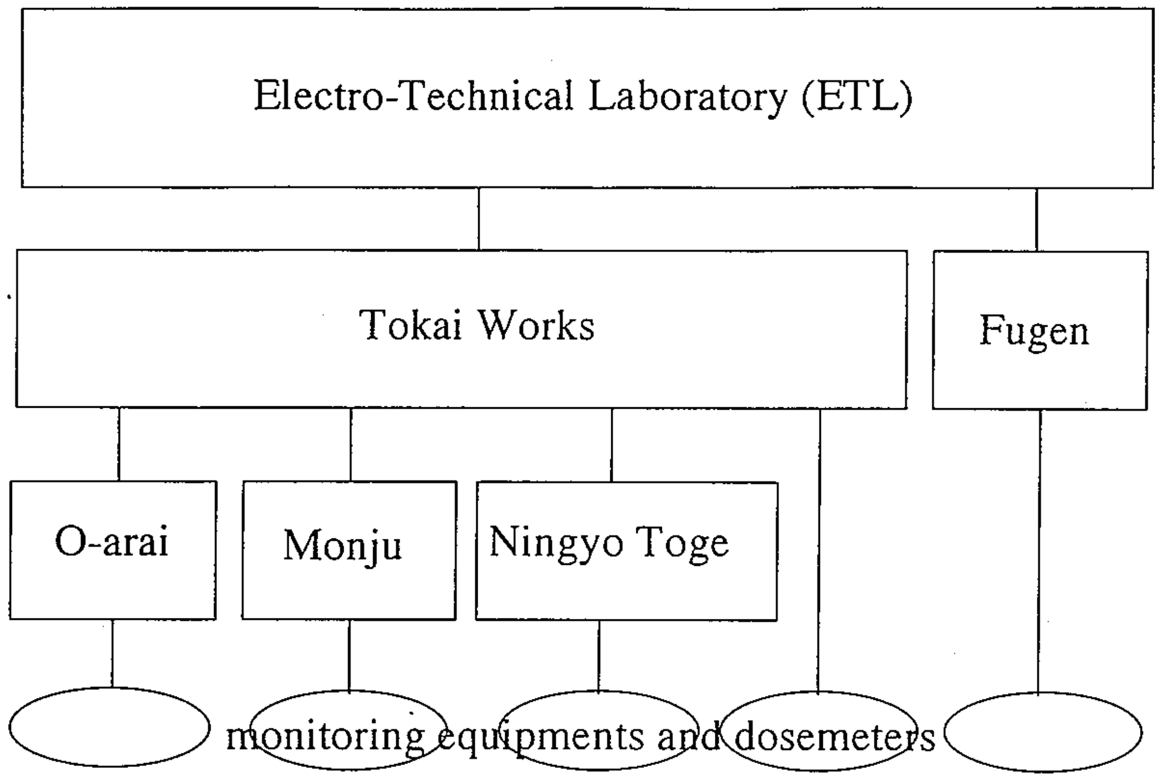
S.Mikami, T.Momose

Health and Safety Division
Tokai Works
Power Reactor and Nuclear Fuel Development Corporation

Contents

1. Intercomparison using Standard Ionization Chambers

2. Intercomparison using RPL glass Dosemeters



Traceability system of gamma calibration fields in PNC

Standard Ionization Chamber

photos of standard chamber

Standard Ionization chamber
detector : Victoreen 550-3 (330cc)
electrometer :Victoreen 500
calibrated on 20 , july,1990

Thermometer
mercury thermometer

Barometer
foltan-type mercury barometer

exposure value

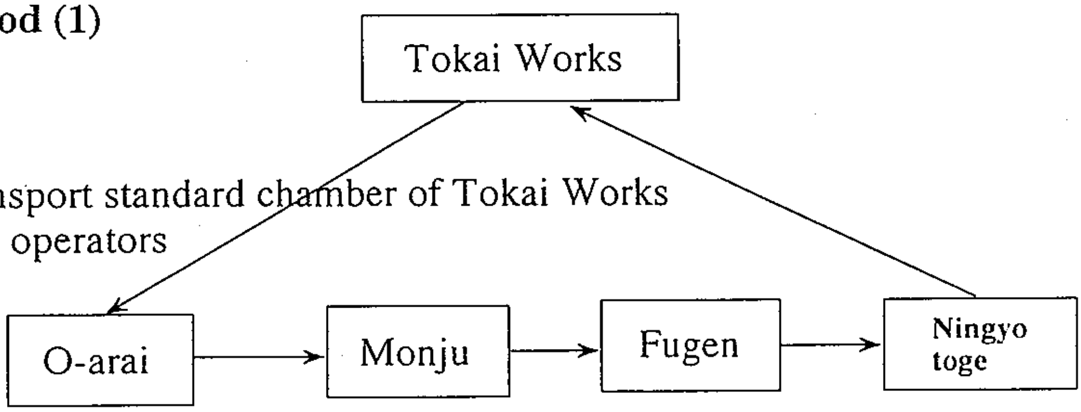
exposure value [R] = mean value of measurement [R] x F_{tp} x CF

Ftp : correction factor for temperature and air pressure
CF : calibration factor given by ETL

Gamma sources used for the intercomparison

Site	Source nuclide	Source activity
Tokai	^{137}Cs	1.11TBq
		3.7GBq
	^{60}Co	3.7GBq
O-arai	^{137}Cs	1.11TBq
		3.7GBq
	^{60}Co	3.7GBq
Monju	^{137}Cs	1.11TBq
		7.4GBq
	^{60}Co	370MBq
Fugen	^{137}Cs	740GBq
	^{60}Co	37GBq
Ningyo Toge	^{137}Cs	2.59GBq
	^{60}Co	1.85GBq

Method (1)



Measure exposure value at each facility by Tokai's standard chamber

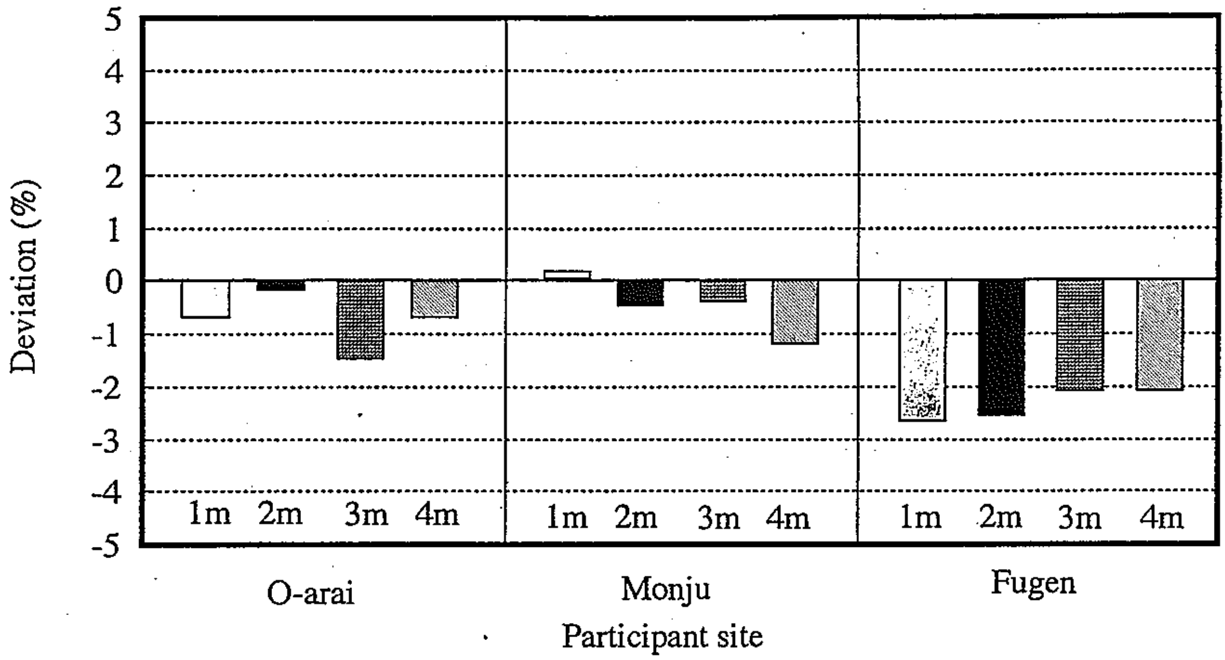
Evaluation

Measured exposure value by Tokai's standard chamber [A]

↕ compared

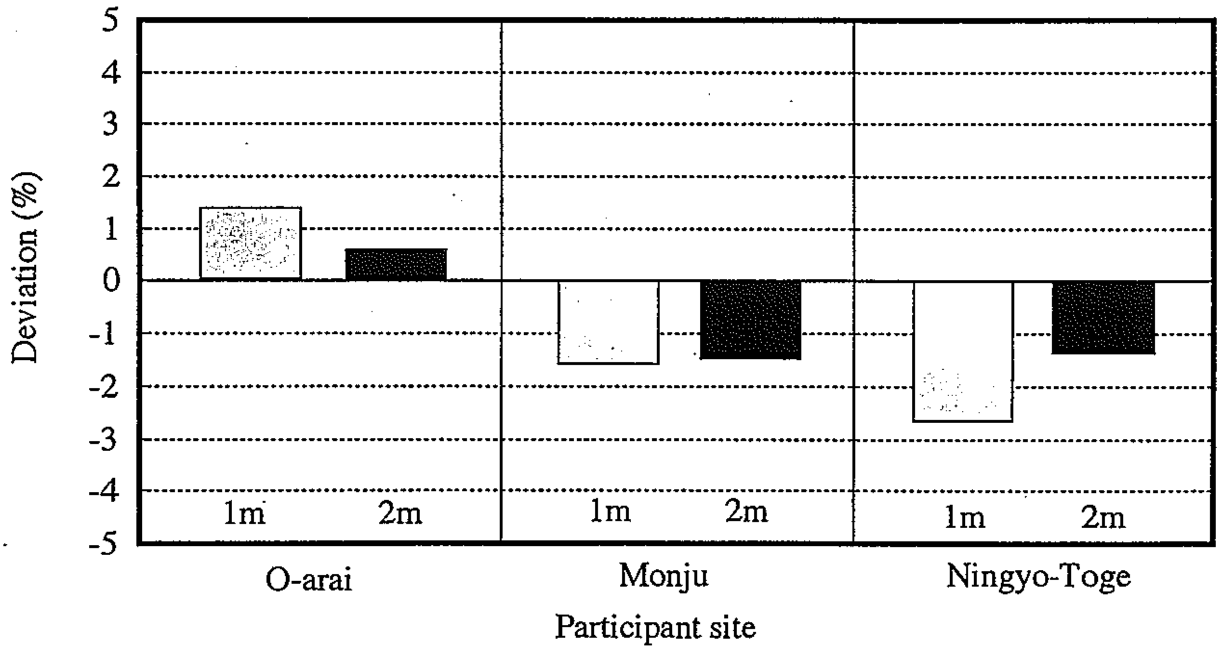
Reference exposure value evaluated at each facility [B]

$$\text{Deviation}(\%) = \frac{[B]-[A]}{[A]} \times 100$$



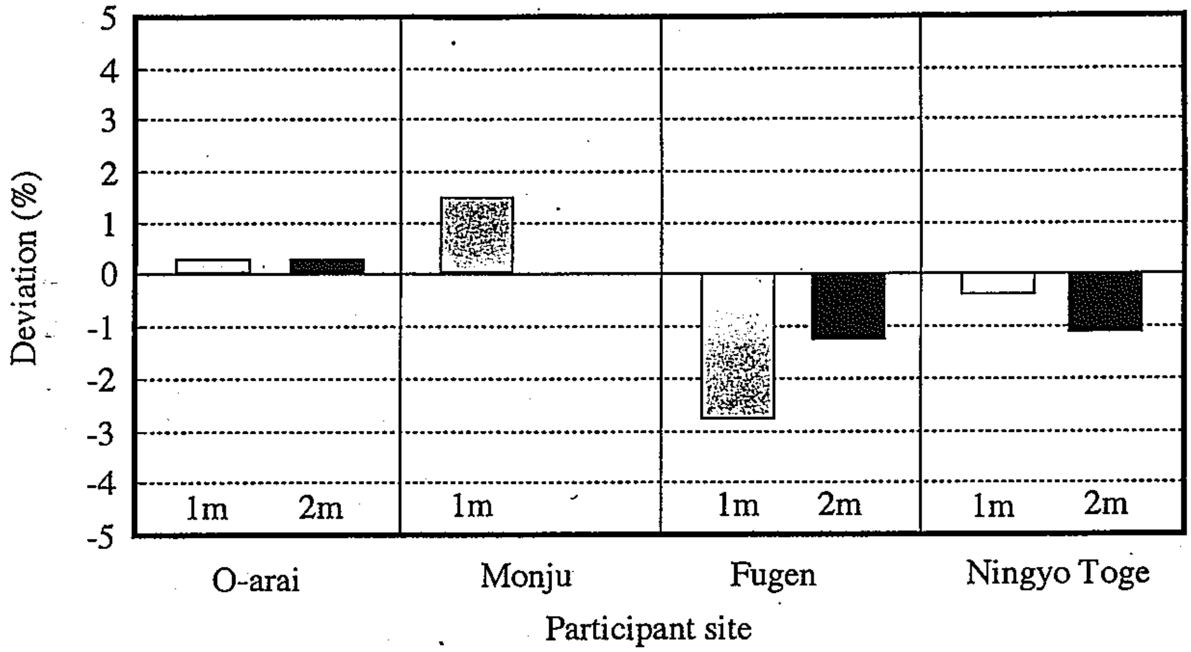
Result of intercomparison (1.11TBq and 740GBq of ^{137}Cs)

using Ionization Chamber



Result of intercomparison
(3.7GBq and 7.4GBq and 2.59GBq of ^{137}Cs)

using Ionization Chamber



Result of intercomparison

(3.7GBq and 370MBq and 37GBq and 1.85GBq of ^{60} Co)

using Ionization Chamber

Result
of
Intercomparison using Standard Ionization Chamber

1. the reference exposure values of each calibration facility have been maintained in a good accuracy (deviation is less than 3%).

2. An intercomparison is a very effective method to check the accuracy of irradiation.

3.Intercomparison using Standard Ionization Chamber is not convenient.

Because

* Ionization chamber is very sensitive to mechanical shocks and humidity.

* This method needs much man power and time.

RPL glass dosimetry system

photos of glass dosimetry system

detector
Toshiba Glass Co. Ltd.
Type SC-1 (phosphate glass)

Reader
Type FGD-20 (UV laser excitation)

Typical features

Reading out can be done repeatedly
Small dispersion of sensitivity among dosemeters
Negligible fading and so on.

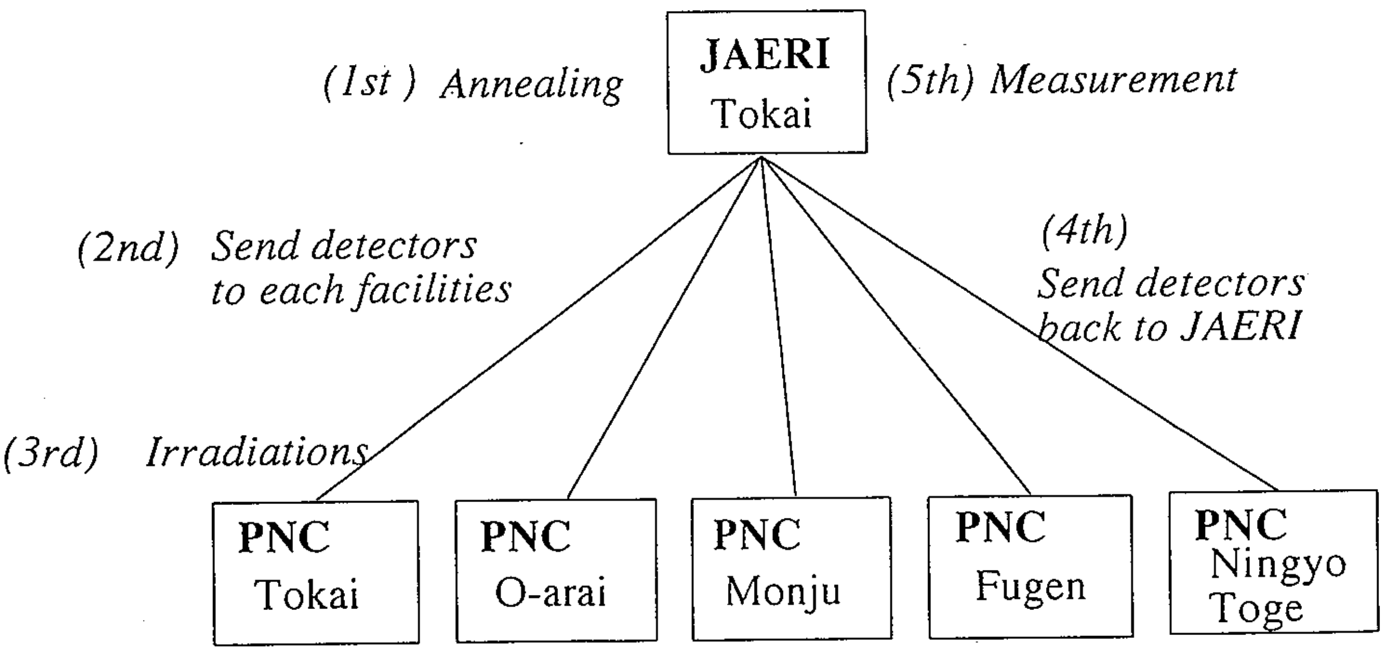
Characteristics of the RPL glass dosemeter

Item	Condition	Deviation
energy dependence	200keV to ^{60}Co	< 5%
angular dependence	direction of 0° ±30° ^{137}Cs	<1%
dose rate response	20mR/h to 1R/h	<1%
deviation of readings	50mR<	0.3%

Gamma sources used for the intercomparison

Site	Source nuclide	Source activity
Tokai	^{137}Cs	1.11TBq 3.7GBq
	^{60}Co	3.7GBq
O-arai	^{137}Cs	1.11TBq 3.7GBq
	^{60}Co	3.7GBq
Monju	^{137}Cs	1.11TBq 7.4GBq
	^{60}Co	370MBq
Fugen	^{137}Cs	740GBq
	^{60}Co	37GBq
Ningyo Toge	^{137}Cs	2.59GBq
	^{60}Co	1.85GBq

Method (2)



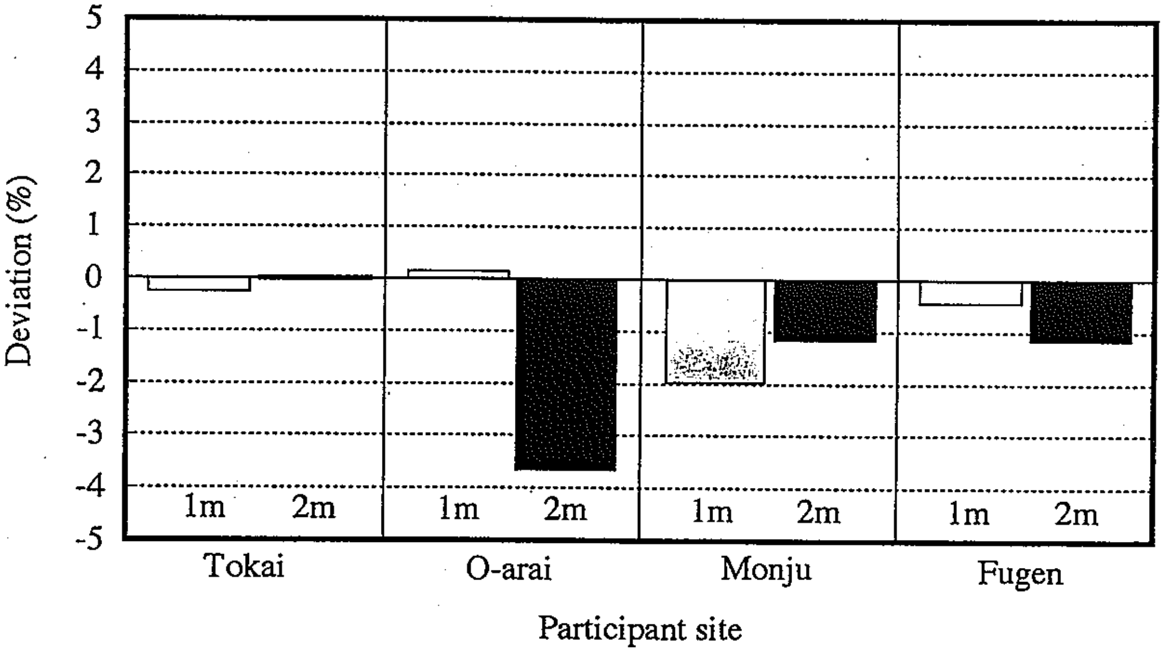
Method of evaluation

Exposure dose value at each facility [A]

↕ compared

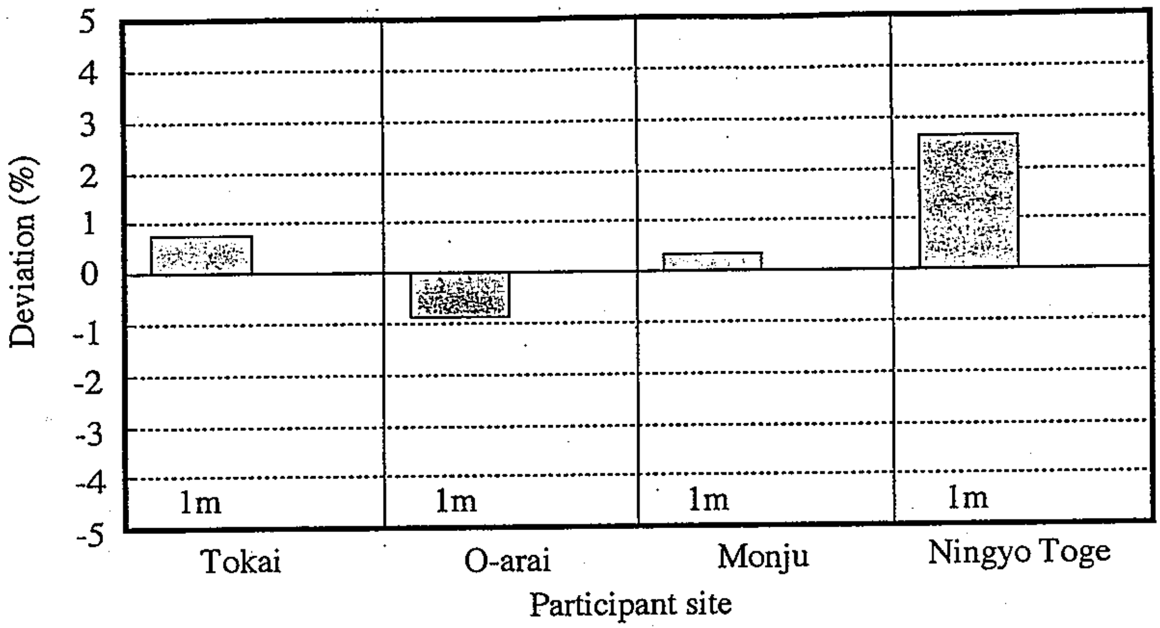
Measured exposure dose value by glass dosemeter [B]

$$\text{Deviation (\%)} = \frac{[B] - [A]}{[A]} \times 100$$



Result of intercomparison (1.11TBq and 740GBq of ^{137}Cs)

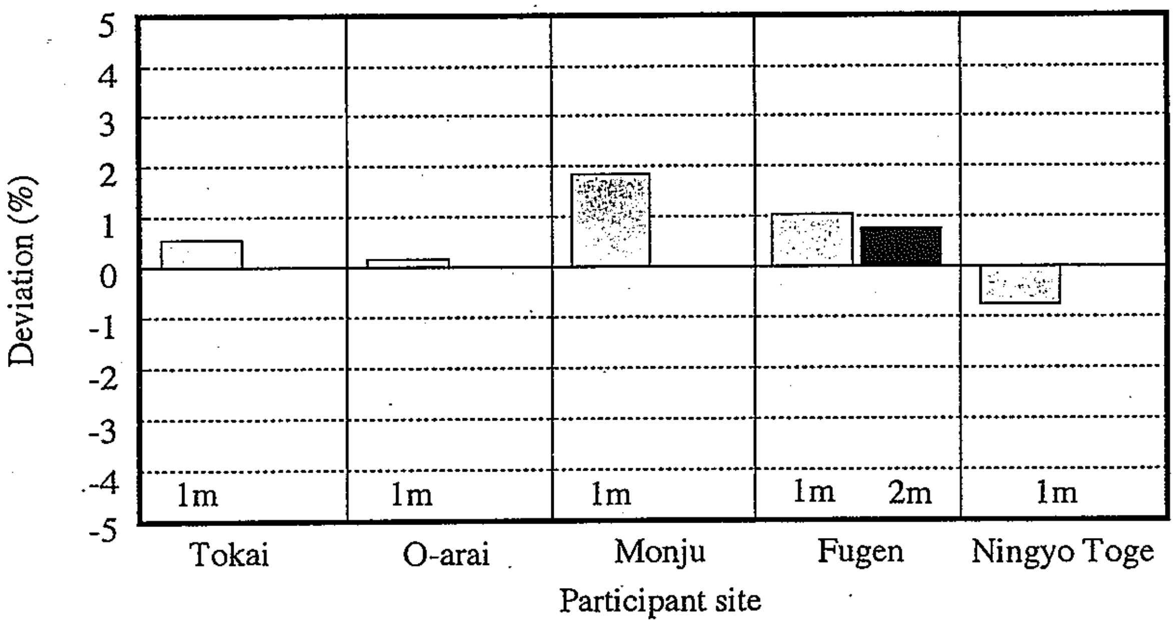
using RPL glass dosemeter



Result of intercomparison

(3.7GBq and 7.4GBq and 2.59GBq of ^{137}Cs)

using RPL glass dosemeter



Result of intercomparison

(3.7GBq and 370MBq and 37GBq and 1.85GBq of ^{60} Co)

using RPL glass dosemeter

Result
of
Intercomparison using RPL glass dosemeter

The exposure value of each calibration facility in PNC showed the good agreement by as much as 2%.

Knowledge
on
Use of RPL glass dosemeter

Reference exposure dose value of a calibration field can be checked easily and quickly.

The total accuracy for the measurement of exposure value is 1.5%.

資料2．

計測技術実習

「サーベイメータの校正」

校正実習要領

SCHEDULE

30,November,1994

PNC
Health and Safety Division

1. **Introduction of Calibration facility** (13:30-13:35)

2. **Introduction of Exercise** (13:35-13:50)

3. **Measurement of standard dose** by standard ionization chamber (13:50-14:35)

4. **Calibration of survey meter** (14:35-14:45)

5. **Discussion** (14:45-15:00)

Exercise
on
Calibration of Ionization Chamber Survey Meter

S.Mikami
Health and Safety Division
Tokai Works
Power Reactor and Nuclear Fuel Development Corporation

IAEA/RCA Workshop
on
Calibration of Dosemeters and Survey Instruments for Photons

November 28th - December 2nd , 1994

1. Introduction

To assure a quality of dose evaluation for radiation protection, a calibration of dosemeters and monitoring instruments is very important. The reference exposure value of calibration fields should be evaluated by using a standard ionization chamber which is calibrated in a traceability system to a primary standard.

In this exercise, The reference exposure value will be measured and evaluated by the standard ionization chamber. And the reference exposure value will be covert to a reference 1cm dose equivalent value by using conversion factor. Then, an ionization chamber survey meter will be calibrated by alternating method, using ^{137}Cs gamma irradiator.

2. Apparatus

1) Standard chamber : Radocon dosemeter (Victoreen Co.Ltd.)
model 500 for electrometer
model 500-3 for detector (Ionization chamber)(330cc)
calibrated by Electro-Technical Laboratory (ETL).

2)Ionization chamber type survey meter:
model 808DDE (NESCO Co.Ltd.)

3)^{137}Cs gamma irradiator :^{137}Cs (1.11TBq)
automatic calibration system

4)Barometer and Thermometer

3. Procedure

A. Evaluation of reference exposure dose value

(1) Set up the gamma irradiator and the standard chamber(Radocon dosemeter)

1. The distance between source and chamber is 1m. The ^{137}Cs (1.11TBq) source is selected.

2. Set the range of Radocon dosemeter at 2nd range.

(2) Measurement

1. Back ground value is measured by the standard chamber (Radocon dosemeter).[measuring time is 300 seconds that is set by a timer]

2. Before irradiation, The air pressure and temperature in the irradiation room are measured.

3. Irradiation is done, and reference exposure dose values are measured by the Radocon dosemeter. [measuring time is 60 seconds for 1m (120sec.for1.5m, and 180sec.for 2m) that is set by timer]

The indication of dose values are read twice, when beginning and finish of measurement. And measurement of exposure dose are given as follows;

measurement of exposure dose
= indicated value (beginning) - indicated value(finish)

The measurement is repeated 3 times.

4. The average of measured value is calculated.[(A) of Appendix 1-1]

5. After the 3rd measurement, the air pressure and temperature in the irradiation room are measured,again.

Then the correction factor of air pressure and temperature are evaluated.

(3) Correction factor of environmental conditions

1. Correction of air pressure and temperature are as follows.

Correction factor of environmental conditions (F)

$$= \frac{273.15 + T}{273.15 + 22} \times \frac{1013.3}{H}$$

where, T: Temperature(℃)
H: Air pressure (hpa)
[see *1,*2 of Appendix 1-1 and 1-2]

2. Average correction factor for environmental conditions (Fa) is calculated by two of correction factors that are evaluated before and after of irradiations to Radocon dosemeter.

(4) Reference exposure dose (D) at 1m

1. Reference exposure dose (D) [see *3 of Appendix 1-1 and 1-2]
= (average value of measurements) - (back ground)
x average correction factor for environmental conditions (Fa)
x calibration factor given by ETL (CF)

2. Reference exposure dose rate (Dr) [see *4]
= (D) x {3600 / 60}

3. Reference 1cm dose equivalent rate (De) [see *5]
= (Dr) x { dose equivalent conversion factor (see table7of Appendix 5)}

(5) Same procedure as from (1) to (4) carried out for distance of 1.5m and 2m.[see Appendix 2 and 3]

B. Calibration of ionization chamber type survey meter

(1) Set up the gamma irradiator and the ionization chamber survey meter.

1. The distance between source and chamber is 1m. The ^{137}Cs (1.11TBq) source is selected.

2. Set the range of I.C.survey meter at that of x 100mSv/h.

(2) Measurement [see Appendix 4]

1. Back ground is measured, before irradiation.

2. Irradiation is carried out.
After indications got stable, readings of indication is done.(10 times)

(3) Calculation of calibration factor

1. Calibration factor is given by following equation.

$$\text{Calibration factor} = \frac{\text{Reference 1cm dose equivalent rate (De)}}{\text{Average value of measurement - Back ground}}$$

(4) Same procedure are carried out at the distance of 1.5m and 2m. [see Appendix 4]

(5) Calibration factor of the range

Calibration factor of the range is obtained as a average value of the three calibration factors.

But, in the case of actual calibration, calibration factor of the each range is obtained by the least squares fitting.

Appendix. 1−1

Table. 1 Result of measurment by Radocon dosemeter (^{137}Cs irradiator)

Back Ground value (B. G) (mR)	

Activity	Distance (m)	Correction for environmental conditions				Range	Indication (mR)		Measurment value (STOP)−(START)	Measuring time (sec)	Calibration factor (CF)	Reference dose (D) (mR)	Reference dose rate (Dr) (mR/h)
		Temperature (T) (℃)	Air pressure (H) (hPa)	Correction factor (F)	Average of Correction factor (Fa)		START	STOP					
		Before											
1.11TBq	1.0			See ＊1	$\frac{*1 + *2}{2}$ =	2				60	1.015	See ＊3	See ＊4
													Dose equivalent rate 1) (De) (mSv/h)
		After											See ＊5
				See ＊2			Average of mesurement value (A)		(A)				

1) Reference 1cm dose equivalent rate

＊1

Correction factor $(F) = \dfrac{273.15 + T}{273.15 + 22} \times \dfrac{1013.3}{H} = \dfrac{273.15 + (\qquad)}{273.15 + 22} \times \dfrac{1013.3}{(\qquad)} = (\qquad)$

＊2

Correction factor $(F) = \dfrac{273.15 + T}{273.15 + 22} \times \dfrac{1013.3}{H} = \dfrac{273.15 + (\qquad)}{273.15 + 22} \times \dfrac{1013.3}{(\qquad)} = (\qquad)$

＊3

Reference dose $(D) = [(A) - (B.G)] \times (Fa) \times (CF) = [(\qquad) - (\qquad)] \times (\qquad) \times (1.015) = (\qquad)$ [mR]

＊4

Reference dose rate $(Dr) = (D) \times \dfrac{3600}{60} = (\qquad) \times \dfrac{3600}{60} = (\qquad)$ [mR/h]

＊5

Reference 1cm dose equivalent rate $(De) = (Dr) \times$ (1cm dose equivalent conversion factor) $= (\qquad) \times (\qquad) = (\qquad)$ [mSv/h]

Table. 2 Result of measurment by Radocon dosemeter (^{137}Cs irradiator)

Back Ground value (B. G) (mR)	

Activity	Distance (m)	Correction for environmental conditions: Temperature (T) (℃)	Air pressure (H) (hPa)	Correction factor (F)	Average of Correction factor (Fa)	Range	Indication (mR) START	STOP	Measurment value (STOP)-(START)	Measuring time (sec)	Calibration factor (CF)	Reference dose (D) (mR)	Reference dose rate (D r) (mR/h)
		Before											
1.11TBq	1.5			See *1	$\frac{*1 + *2}{2}$ =	2				120	1.015	See *3	See *4
		After											Dose equivalent rate 1) (De) (mSv/h)
				See *2									See *5
							Average of mesurement value (A)		(A)				

1) Reference 1cm dose equivalent rate

Appendix 2－2

＊1

Correction factor $(F) = \dfrac{273.15 + T}{273.15 + 22} \times \dfrac{1013.3}{H} = \dfrac{273.15 + (\qquad)}{273.15 + 22} \times \dfrac{1013.3}{(\qquad)} = (\qquad)$

＊2

Correction factor $(F) = \dfrac{273.15 + T}{273.15 + 22} \times \dfrac{1013.3}{H} = \dfrac{273.15 + (\qquad)}{273.15 + 22} \times \dfrac{1013.3}{(\qquad)} = (\qquad)$

＊3

Reference dose $(D) = [(A) - (B.G)] \times (Fa) \times (CF) = [(\qquad) - (\qquad)] \times (\qquad) \times (1.015) = (\qquad)$ [mR]

＊4

Reference dose rate $(Dr) = (D) \times \dfrac{3600}{120} = (\qquad) \times \dfrac{3600}{120} = (\qquad)$ [mR/h]

＊5

Reference 1cm dose equivalent rate $(De) = (Dr) \times$ (1cm dose equivalent conversion factor) $= (\qquad) \times (\qquad) = (\qquad)$ [mSv/h]

Appendix. 3-1

Table. 3 Result of measurment by Radocon dosemeter (^{137}Cs irradiator)

Back Ground value (B. G) (mR)	

Activity	Distance (m)	Correction for environmental conditions: Temperature (T) (℃)	Air pressure (H) (hPa)	Correction factor (F)	Average of Correction factor (Fa)	Range	Indication (mR): START	Indication (mR): STOP	Measurment value (STOP)-(START)	Measuring time (sec)	Calibration factor (CF)	Reference dose (D) (mR)	Reference dose rate (D r) (mR/h)
1.11TBq	2.0	Before			$\frac{*1 + *2}{2}$ =	2				180	1.015	See *3	See *4
				See *1									
													Dose equivalent rate 1) (De) (mSv/h)
		After											See *5
				See *2			Average of mesurement value (A)		(A)				

1) Reference 1cm dose equivalent rate

Appendix 3−2

*1

Correction factor

$$(F)=\frac{273.15+T}{273.15+22}\times\frac{1013.3}{H}=\frac{273.15+(\qquad\qquad)}{273.15+22}\times\frac{1013.3}{(\qquad\qquad)}=(\qquad\qquad)$$

*2

Correction factor

$$(F)=\frac{273.15+T}{273.15+22}\times\frac{1013.3}{H}=\frac{273.15+(\qquad\qquad)}{273.15+22}\times\frac{1013.3}{(\qquad\qquad)}=(\qquad\qquad)$$

*3

Reference dose

$$(D)=[(A)-(B.\ G)]\times(Fa)\times(CF)=[(\qquad\qquad)-(\qquad\qquad)]\times(\qquad\qquad)\times(1.015)=(\qquad\qquad)\ [mR]$$

*4

Reference dose rate

$$(Dr)=(D)\times\frac{3600}{180}=(\qquad\qquad)\times\frac{3600}{180}=(\qquad\qquad)\ [mR/h]$$

*5

Reference 1cm dose equivalent rate

$$(De)=(Dr)\times(\text{1cm dose equivalent conversion factor})=(\qquad\qquad)\times(\qquad\qquad)=(\qquad\qquad)\ [mSv/h]$$

Table. 4 Result of calibration of I. C. survey meter (at1. 0m)

Back Ground value (B. G)										
*1 Number of measurment	1	2	3	4	5	6	7	8	9	1 0
Value of readings (mSv/h)										
Average (mSv/h)		Calibration factor= Reference 1cm dose equivalent rate [*5 of Table. 1] ( ) / Average ( ) −B. G ( ) = ( )								

＊1 Take 10 seconds between readings of indication

Table. 5 Result of calibration of I. C. survey meter (at1. 5m)

Back Ground value (B. G)										
*1 Number of measurment	1	2	3	4	5	6	7	8	9	1 0
Value of readings (mSv/h)										
Average (mSv/h)		Calibration factor= Reference 1cm dose equivalent rate [*5 of Table. 2] ( ) / Average ( ) −B. G ( ) = ( )								

＊1 Take 10 seconds between readings of indication

Table. 6 Result of calibration of I.C. survey meter (at2.0m)

Back Ground value (B. G)										
*1 Number of measurment	1	2	3	4	5	6	7	8	9	1 0
Value of readings (mSv/h)										
Average (mSv/h)		Calibration factor = Reference 1cm dose equivalent rate [*5 of Table. 3] ( ) / Average ( ) －B. G ( ) = ( )								

＊1 Take 10 seconds between readings of indication

$$\text{Average of calibration factor} = \frac{\overset{\text{at1m}}{(\quad\quad)} + \overset{\text{at1.5m}}{(\quad\quad)} + \overset{\text{at2m}}{(\quad\quad)}}{3} = (\quad\quad)$$

Table 7 1-cm dose equivalent conversion factor

Phonton energy or effective energy MeV	1-cm dose equivalent conversion factor (1) Sv/(C・kg⁻¹)	{mSv/R}	Conversion factor from the air absorbed dose (2) (reference) Sv/Gy
0.010	0.350	{0.090}	0.010
0.015	9.17	{2.37}	0.271
0.020	20.3	{5.25}	0.601
0.025	29.3	{7.56}	0.866
0.030	36.8	{9.50}	1.09
0.035	43.2	{11.2}	1.28
0.040	48.5	{12.5}	1.43
0.045	52.4	{13.5}	1.55
0.050	55.1	{14.2}	1.63
0.060	59.1	{15.2}	1.74
0.070	59.6	{15.4}	1.76
0.080	58.7	{15.1}	1.73
0.090	57.2	{14.8}	1.70
0.10	55.7	{14.4}	1.65
0.12	53.0	{13.7}	1.57
0.15	50.3	{13.0}	1.49
0.20	46.7	{12.0}	1.38
0.30	44.4	{11.5}	1.31
0.40	42.6	{11.0}	1.26
0.50	41.2	{10.6}	1.21
0.60	40.3	{10.4}	1.19
0.662	40.0	{10.3}	1.18
0.80	39.3	{10.1}	1.16
1.0	38.7	{10.0}	1.14
1.25	38.4	{9.91}	1.14
1.5	38.3	{9.88}	1.13
2.0	38.3	{9.87}	1.13
3.0	38.1	{9.82}	1.12
4.0	37.7	{9.71}	1.11
5.0	37.5	{9.67}	1.11
6.0	37.3	{9.62}	1.10
8.0	36.8	{9.50}	1.09
10	36.8	{9.50}	1.09

Notes: (1) A conversion factor from an exposure in free space.
(2) An air absorbed dose in free space with charged-particle equilibrium. The conversion factor is from attached Table 4 in a notification of the low concerning prevention from Radiation Hazards due to Radioisotopes, etc. or by the interpolation.

Remarks: When γ-ray or X-ray energies required are not available, the dose equivalent conversion factor is obtained by interpolation.

別添１．

議事日程

IAEA/RCA Workshop
on
Calibration of Dosimeters & Survey Instruments for Photons

at

Tokai Research Establishment

Japan Atomic Energy Research Institute

AGENDA

MONDAY **November 28** [Conference Room No.7]

11:30 - 12:00 **OPENING SESSION**

Chairperson: **S. Kobayashi** (NIRS: RCA National Coordinator of Japan)

1. Opening Address R.V. Griffith (IAEA)
2. Welcome Address
   1) S. Machida (MOFA)
   2) S. Yamazaki (STA)
3. Introducing of Workshop Director
   Workshop Director K. Bingo (JAERI)
   Deputy Director N. Sakurai (PNC)
4. Welcome Address by Workshop Director
   K. Bingo
5. Introducing of Participants
6. Information from Secretariat
   H. Murakami

12:00 - 13:30 **LUNCH**

SPECIAL LECTURE SESSION

13:30 - 17:15

13:30 - 14:15
Chairperson: K.Bingo

Foundations on Gamma– and X–ray Monitoring Instruments
T.Watanabe

14:15 - 15:05
Chairperson: N.Sakurai

Computation of Dosimetric Quantities in External Radiation Protection
Y.Yamaguchi

15:05 - 15:40 COFFEE BREAK

15:40 - 16:20
Chairperson: R.V.Griffith

Dissemination of Exposure Standard and the Irradiation Field on ICRU Operational Quantities (A Suggestion of Practical Calibration for Operational Quantities)
K.Minami

16:20 - 17:10
Chairperson: B.Foote

Work of the ICRU and ICRP–ICRU Joint Task Group in Specifying Operational Quantities for Radiation Protection
R.V. Griffith

17:30 Move to Akogi–club

18:00 -19:30 RECEPTION

TUESDAY November 29 [Conference Room No.7]

COUNTRY REPORT SESSION I

Chairperson: G.Ramanathan

9:25 - 9:45	BANGLADESH
9:45 - 10:05	CHINA

10:10 - 10:45 COFFEE BREAK

Chairperson: W.Wanitsuksombat

10:45 - 11:05	INDIA
11:05 - 11:35	INDONESIA
11:35 - 11:50	JAPAN

12:00 - 13:30 LUNCH

COUNTRY REPORT SESSION II

Chairperson: S.S.Ahmad

13:30 - 13:50	KOREA
13:50 - 14:10	MALAYSIA
14:10 - 14:30	MONGOLIA
14:30 - 14:50	NEW ZEALAND

14:50 - 15:20 COFFEE BREAK

Chairperson: M.Begum

15:20 - 15:40	PAKISTAN	
15:40 - 16:10	PHILIPPINES	(2 persons)
16:10 - 16:30	THAILAND	
16:30 - 17:00	VIETNAM	(2 persons)

17:00 - 17:20 DISCUSSION

WEDNESDAY **November 30** [Conference Room No.7]

DISCUSSION SESSION I : Overall Discussion for Instruments Calibration

9:15 - 10:40 Calibration of Radiation Protection Instruments in Asia & Pacific Region – Present Status and Future Subjects; What's necessary for upgrading?

Chairperson: R.V.Griffith

10:40 - 11:00 COFFEE BREAK

11:00 - 12:00 TECHNICAL DEMONSTRATION

12:00 - 13:15 LUNCH

13:15 Move to PNC

13:30 - 15:00 TECHNICAL EXERCISE

THURSDAY **December 1** [Conference Room No.8]

DISCUSSION SESSION II : Quality Assurance for Individual Monitoring

9:15 - 10:15
Chairperson: B.Foote

PROPOSAL PRESENTATION: IAEA/RCA Personal Dosimetry Intercomparison, Phase 2
R.V.Griffith

10:15 - 10:45 **COFFEE BREAK**

10:45 - 12:00 Comments from Participants & Discussion
Chairperson: R.V.Griffith

12:00 - 13:30 **LUNCH**

13:30 - 15:00 Discussion
Chairperson: R.V.Griffith

15:00 - 15:30 **COFFEE BREAK**

15:30 - 17:00 Discussion and Conclusion
Chairperson: R.V.Griffith

17:00 - 17:15 **CLOSING SESSION**
Chairperson: S.Kobayashi

1. Closing Remarks: N.Sakurai
2. Closing : R.V.Griffith

<<< PHOTOGRAPH :Conference Room No.7 >>>

17:30 Move to PNC Restaurant

17:45 - 19:30 **DINNER PARTY**

FRIDAY **December 2**

TECHNICAL TOUR

TO: Electro–Technical Laboratory (Primary Standard Laboratory of Japan)

別添２.

参加者一覧

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