Considerations of Calibration Interval of Radiation Survey Meters for Keeping the Accurate Detection Ability

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Abstract.

Many models of survey meters produced by different companies have been used at radiation-related research area and industrial facilities. It is very important procedure to calibrate survey meters regularly for keeping those accurate monitoring ability. In Korea, general '6 month rule' had been requested by the authority for a long time. Recently the periods which are warranted or assured by manufacturers are used as another decision standard. We have performed the calibration process of lab-own survey meters by officially-qualified organization last more than ten years. 21 X-ray/Gamma ion chambers, 8 neutron rem counters, 6 proportional counters and others have been calibrated every six or 12 months. The variation of calibration factor of all survey meters was investigated. The optimum calibration interval was studied. The variation levels are in 10 %, which is also in the acceptable range of qualified calibration. Based on the statistical estimation, the variation of calibration factors shows longer period than values suggested by each manufacturer. In this estimation, the statistical uncertainty of calibration is also considered. The records of more than 35 survey meters are introduced and the optimal access to determine the calibration interval is suggested.

KEYWORDS: Survey Meter; Calibration Interval; Proportional Counter; Ion chamber;

1 INTRODUCTION

Survey meters are used to ensure radiation safety in various radiological facilities. For more accurate radiation detection, the survey meter is calibrated and managed on a regular basis. In general, each country determines and manages the calibration interval through laws and guidelines. Even for the same type of survey meter, the calibration interval varies from country to country and it is shown in Table 1 [1]. In particular, recommended calibration interval of Republic of Korea is 6 months shorter than other countries. If the calibration interval is long, the cost and time used for calibration can be reduced, and more efficient facility management can be performed.

Table 1: Recommended calibration interval of IAEA and major countries

Category	Calibration Interval (month)
IAEA	≤ 36
Germany	24
United States of America, Canada, United Kingdom, Japan	12
Republic of Korea	6

In order to derive a reasonable calibration interval, the calibration history of the survey meter was checked and the change of calibration factors according to the use period of the survey meter was analyzed. The calibration history for the survey meter used in Pohang Accelerator Laboratory (PAL) was analyzed, and the information of the survey meter used is shown in Table 2. The three types of survey meters (ion chamber, proportional counter and neutron) is used for analysis. Some of these survey meters have a calibration history of 20 years, and statistical analysis was performed based on the calibration history of more than several years.

Table 2: Survey meters in Pohang Accelerator Laboratory

Detector type	Model	Manufacturer	Recommended Calibration Interval
Ion chamber	451B	FLUKE Biomedical / USA	12 months
	451P		
Proportional counter	FH40 G	Thermo Scientific / Germany	24 months
Neutron	LB6411	BERTHOLD / Germany	12 months
	NSN3	Fuji / Japan	-
	RadEye PX/NRD	Thermo Scientific / Germany	24 months

2 METHODS

The calibration history of the three types of survey meters (ion, proportional, detection for neutron) was checked. Changes in the calibration factor according to the use period were confirmed. The average and standard deviation of the total calibration factor were checked to confirm the change of the calibration factor on the time.

2.1 Ion chamber

The ion chamber is a kind of gas-filled radiation detectors, and is widely used for the detection and measurement of X-rays, gamma rays, and beta particles. A total of 21 survey meters of 451B and 451P models of the manufacturer FLUKE Biomedical were used. The appearance is as shown in Fig.1, and detailed specifications are as in Table 3 [2, 3]. The survey meter has been used for a minimum of 4 years and a maximum of 12 years, and the change in calibration factors according to the period of use was confirmed by checking the calibration history.

Figure 1: 451P (left) and 451B (right) Ion chamber of FLUKE Biomedical

Table 3: Specifications of ion chamber survey meters

Model	451B	451P
Product	Fluke Biomedical / USA	
Type	Ion chamber	
Chamber volume	349 cc	230 cc
Measuring range	0 ~ 500 mSv/h	0 ~ 50 mSv/h
Energy Range	Alpha > 7.5 MeV, Beta > 100 MeV, Gamma > 7 keV	Beta > 1 MeV, Gamma > 25 keV

2.2 Survey meters for neutron detection

The gas-filled proportional counter is generally used for neutron detection. The types of survey meters used in this study are BF_3, ^3He, and organic gas filled proportional counter. The appearance, each model name and manufacturer can be checked in Fig.2. The specifications of the survey meters can be checked in Table 4 [4, 5, 6]. LB6411 has been used for more than 5 years and less than 20 years, and RadEye PX/NRD and NSN3 have been used for 7 years, and calibration factors over time were confirmed by analysing calibration history.

Figure 2: Survey meters for neutron detection (a) LB6411, Berthold, (b) RadEye PX/NRD, Thermo Scientific, (c) NSN3, Fuji

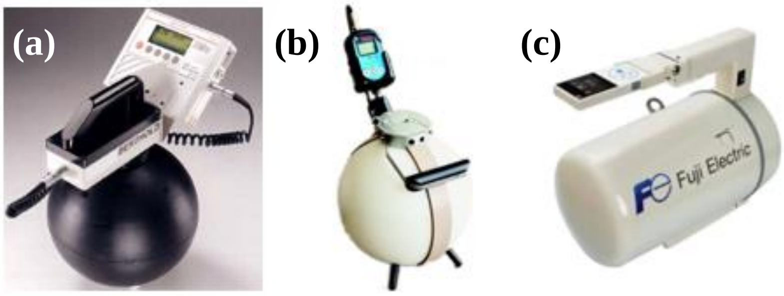


Table 4: Specifications of survey meters for neutron detection

Model	LB6411	RadEye PX/NRD	NSN3
Manufacturer	Berthold / Germany	Thermo Scientific / Germany	Fuji / Japan
Neutron Energy Range	Thermal to 20 MeV	0.025 eV ~ 10 MeV	0.025 eV ~ 15 MeV
Fluence Response	1.09 cm^2	-	-
Measuring Range	30 nSv/h to 100 mSv/h	0.1 ~ 100 mSv/h	10 nSv/h to 99.99 mSv/h
Operating Voltage	2,700 V	1,600 V ~ 2,000 V	-
Filling Volume	^3He / 60 μg	BF_3 Tube	organic gas mixture

2.3 Proportional counter

The proportional counter is a type of gaseous ionization detector used to measure ionizing radiation. In this study, FH-40G made by Thermo Fisher Scientific is used. Its appearance and specifications can be checked at Fig.3 and Table 5 [7]. Calibration records of more than 7 years were used for analysis.

Figure 3: FH-40G (Thermo Fisher Scientific) proportional counter

Table 5: Specifications of FH-40G proportional counter

Model	FH-40G
Product	Thermo Scientific / Germany
Type	Proportional counter tube
Measuring Range	10 nSv/h – 1 Sv/h
Energy Range	30 keV to 4.4 MeV

3 RESULTS AND DISCUSSIONS

The calibration history was checked for each survey meter type. The calibration factor was checked for each survey meter model. The average and standard deviation of all calibration factors were calculated to check the change in calibration factor over time.

3.1 Calibration history of Ion chamber

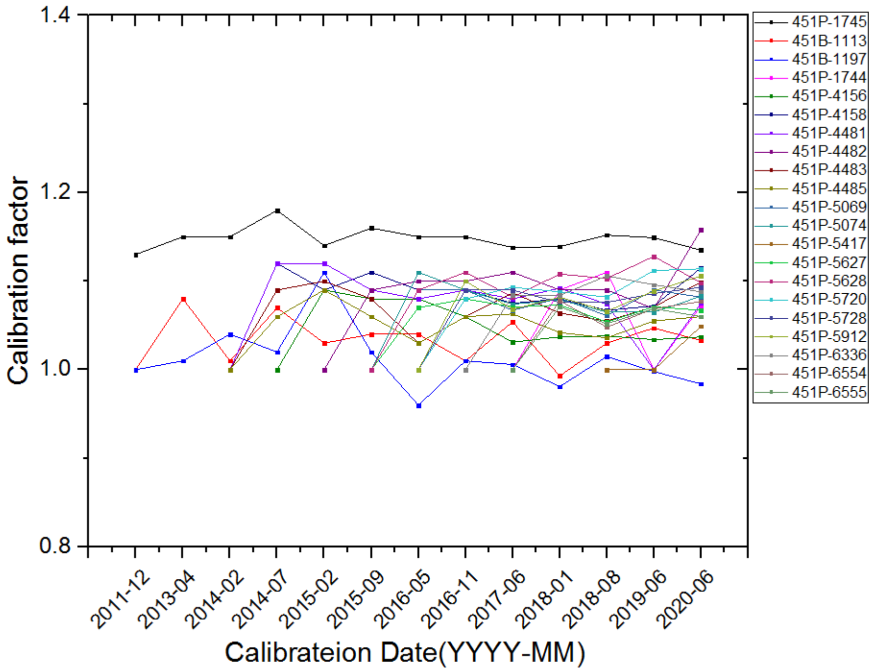
The average and standard deviation of the calibration factors for each 21 models of ion chamber is described in Table 6. Two survey meters have been use for 12 years and it is the longest period. The standard deviation of each calibration factor are 0.05 and 0.01. The shortest period of use is 4 years, and the standard deviation of the calibration factor is in the range of 0.02 to 0.04. In addition, the maximum of the standard deviation is 0.05 and the minimum is 0.01.

Table 6: Average calibration factor and its standard deviation of ion chamber survey meters

No	Model	Year of use	Average	Standard deviation	No.	Model	Year of use	Average	Standard deviation
1	451B-1	11	1.03	0.03	12	451P-10	6	1.07	0.03
2	451B-2	11	1.01	0.04	13	451P-11	4	1.02	0.03
3	451P-1	12	1.05	0.05	14	451P-12	5	1.06	0.03
4	451P-2	12	1.15	0.01	15	451P-13	5	1.09	0.04
5	451P-3	8	1.05	0.03	16	451P-14	5	1.08	0.04
6	451P-4	8	1.08	0.03	17	451P-15	5	1.07	0.03
7	451P-5	7	1.07	0.04	18	451P-16	5	1.07	0.04
8	451P-6	4	1.09	0.04	19	451P-17	4	1.08	0.04
9	451P-7	7	1.07	0.03	20	451P-18	4	1.05	0.03
10	451P-8	4	1.05	0.02	21	451P-19	4	1.05	0.03
11	451P-9	6	1.07	0.03		Total		1.06	0.04

In order to check the change in the calibration factor of the survey meter according to period of use, a graph of the calibration factors by calibration date of each survey meter is shown in Fig.4. It can be seen that all survey meters have been calibrated with low fluctuations in calibration factors. All survey meters show a distribution within 0.05 range of calibration factor. In the case of the ion chamber, it is judged that there is small variation of the calibration factor according to the period of use. Therefore, a calibration cycle recommended by the manufacturer or higher can be applied to ion chamber for efficient management.

Figure 4: Calibration record of ion chamber (451P and 451B) survey meter



3.2 Calibration history of survey meters for neutron detection

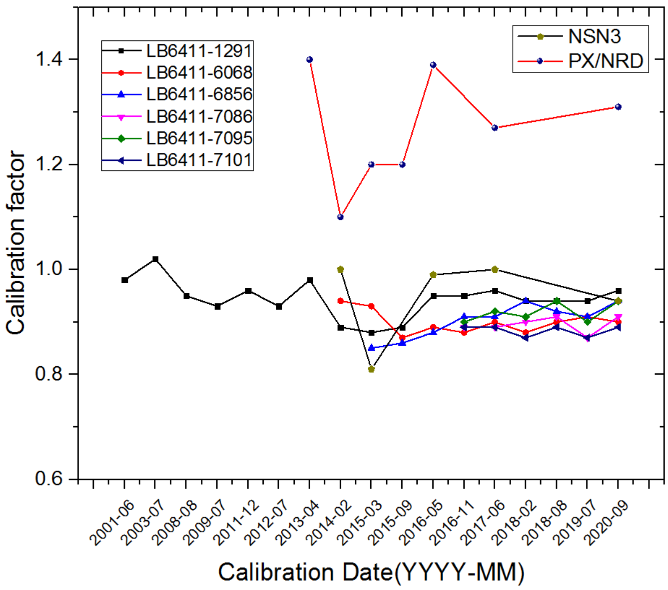
There are 6 neutron survey meters for LB6411 models, and one each of NSN3 and PX/NRD, and the calibration history for a total of 8 units was confirmed. The NSN3 and PX/NRD models have been used for 7 years, and the standard deviation of the calibration factors is 0.09, respectively. In the case of LB6411, it is confirmed that the maximum value of the calibration factor is 0.04, the minimum value is 0.01, and the standard deviation of all calibration factors is 0.02. It was confirmed that the standard deviation of the calibration factor of the LB6411 model showed a lower variation than other models. The standard deviation of the calibration factor of the survey meter, which has been used for the longest time for 20 years, is 0.04.

Table 7: Average calibration factor and its standard deviation of survey meters for neutron detection

Model	Year of use	Average	Standard deviation
LB6411-1	20	0.94	0.04
LB6411-2	15	0.90	0.02
LB6411-3	8	0.90	0.03
LB6411-4	5	0.90	0.02
LB6411-5	5	0.92	0.02
LB6411-6	5	0.88	0.01
Total (LB6411)		0.91	0.02
NSN3	7	0.93	0.09
PX/NRD	7	1.27	0.09

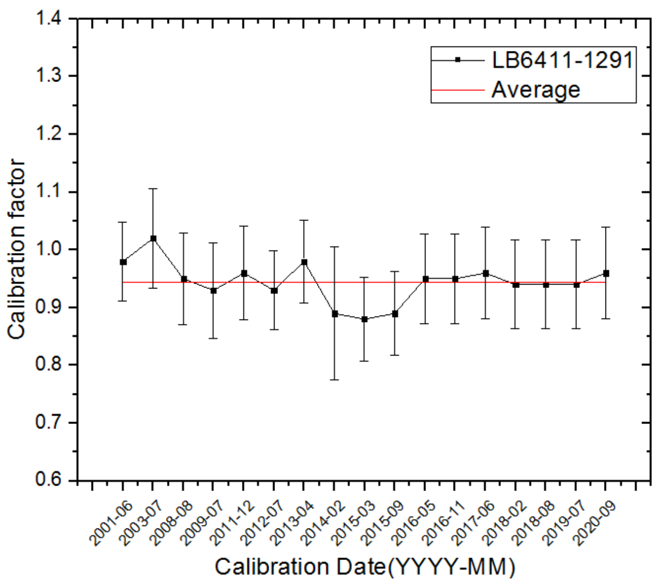
Fig.5 shows a graph of the calibration history of the survey meter for neutron detection. In the case of RadEye PX/NRD and NSN3, it is difficult to confirm the trend because there is only one case. However, in the case of LB6411, it can be confirmed that calibration is performed with a low variation range based on the average calibration factor.

Figure 5: Calibration record of survey meters for neutron detection (LB6411, RadEye PX/NRD, NSN3)



Among the LB6411 models, the standard deviation of the calibration factor of the oldest used model was the highest. Therefore, the calibration history of the model with the highest standard deviation of the calibration factor was confirmed and it is shown in Fig.6. Calibration process was performed with a low variation of calibration factor within 0.05. In particular, the standard deviation of the calibration factor for the recent 5 years is 0.01, which is very low value.

Figure 6: Calibration record of LB6411-1291



The standard deviation of the calibration factor of the model used the longest period was the highest. However, the standard deviation of the calibration factor for the last 5 years of the survey meter was very low at 0.01. Therefore, in the case of a survey meter for detecting neutrons, it can be said that the variation of the calibration factor is very small over time. Therefore, it is understood that the survey meter for neutron detection can be managed with the calibration interval by applying the manufacturer's recommendations or more.

3.3 Calibration history of proportional counter

The calibration history of a total 6 proportional counter was verified, and 2 models were used for 7 years and 4 models for 9 years. The calibration history of each survey meter is described in Table 8. The standard deviation of the calibration factor shows a value of at least 0.07 and at most 0.08. The standard deviation of the calibration factors of the survey meters used for 7 years is 0.08. Survey meters used for 9 years have a value of 0.07 with 3 units and 0.08 with one units. It is understood that it is difficult to confirm the change of the calibration factor over time with the standard deviation of the calibration factor.

Table 8: Average calibration factor and its standard deviation of proportional counter (FH-40G)

Model	Year of use	Average	Standard deviation
FH40G-1	9	1.22	0.07
FH40G-2	9	1.22	0.08
FH40G-3	9	1.13	0.07
FH40G-4	9	1.18	0.07
FH40G-5	7	1.14	0.08
FH40G-6	7	1.14	0.08
Total		1.17	0.04

Fig.7 shows the calibration factor records for each proportional counter model. It can be seen that the calibration factor is not distributed based on the average value, but a tendency to increase over time.

Figure 7: Calibration record of proportional counter (FH-40G)

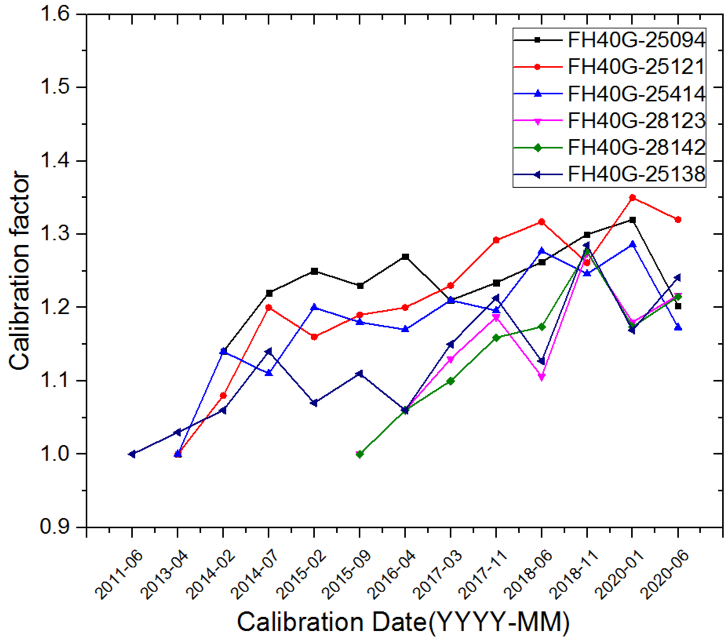
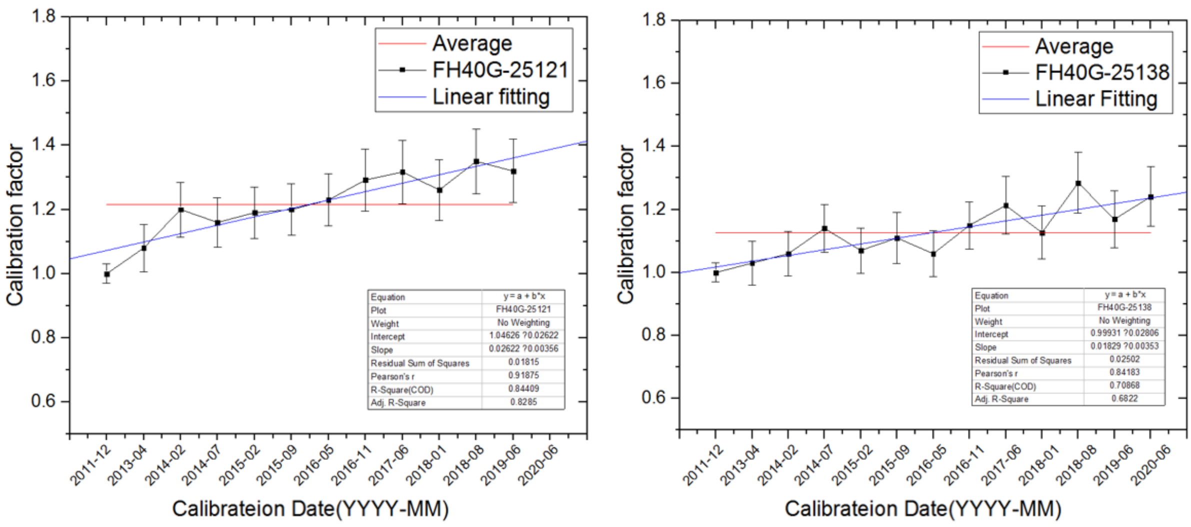


Figure 8: Linear fitting of calibration data of proportional counter (FH40G-25121, 25138)



In order to confirm a trend more accurately, linear fitting was performed for two models. The results are shown in Fig.8. It is confirmed that most of the recently calibrated results are above the average value of calibration factor, and thus the tendency of the calibration factor to increase over time is confirmed. Each R-squared value was 0.82 and 0.68. This indicates that the calibration factor tends to increase over time.

The survey meters used in this study measure radiation based on the reaction of the filling gas. Therefore, the condition of the filling gas is a very important factor in the detection. The volume of the filling gas is 349 cm^3 for 451B, 230 cm^3 for 451P, 45 cm^3 for LB6411 and 12.7 cm^3 for FH-40G. FH-40G is applied with a filling gas of more than 4 times smaller than other survey meters. Therefore, for FH-40G, it is expected that a small change in the filling gas over time immediately changes the calibration factor. The calibration factor increases with the period of use is a common phenomenon recognized by manufacturers. The calibration process with reasonable interval is needed for accurate measurement. In case of proportional counter (FH-40G), it is needed to apply calibration interval that satisfies the manufacturer's recommendation.

4 CONCLUSION

The calibration history about survey meter in PAL is checked to derive reasonable calibration interval. Ion chamber, moderated proportional counter and organic gas counter has small variation of calibration factor about period of use. Even if it is used for more than 10 years, the variation of the calibration factor is within 10%. However, in the case of the proportional counter, the calibration factor tends to increase over time because of its small volume of detection gas. This survey meters may follow the manufacturer's recommended calibration interval.

5 REFERENCES

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