Development of Radiation Dosimetry System for Gamma-ray Detection

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1. Introduction

Nowadays, various studies have been carried out for accurate dosimetry around the world[1-2]. With the purpose of disseminating radiation measurement standard, the Korean Association for Radiation Application(KARA) has been established various reference irradiation systems. For precise measurement of reference radiation field, an accurate dosimetry system capable of simultaneous measurement of radiation and environmental factor is required. And also, the measurement process must be simple and automated in order to minimize measurement uncertainty and human errors. For this purpose, the radiation dosimetry system(RDS) was developed using LabVIEW platform and various instruments. The RDS is consists of hardware and software part. Hardware part consists of electrometer, barometer, and thermometer. And all devices were combined by NI-PXIe system using USB 2.0 and IEEE 488 communication. Measurement software was developed based on LabVIEW platform. In addition, calculation program was developed based on Microsoft Excel and TRS-398 to process collected data. To evaluate the system, optimization and validation were performed in various methods. Optimization was performed in two ways according to connection methods and sampling rate. In case of validation, experiments for stability and detection method were performed to find the most efficient solution for radiation dosimetry. In this study, the development procedure will be described using RDS.

2. Methods and Results

2.1 Development of RDS

The RDS consists of hardware and software part. In case of hardware part, there are various instruments in rack mount such as electrometer, barometer and thermometer as shown in figure 1.

Fig. 1. Hardware for radiation dosimetry system.

Simultaneous measurement of measured data on a measuring device requires software to control it. In this study, we developed dosimetry software based on LabVIEW. The procedure of this software consists of 5 main steps as shown in figure 2.

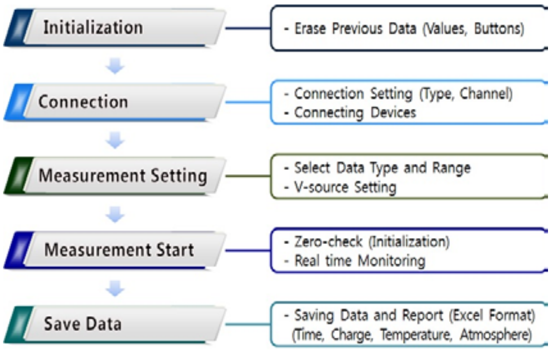
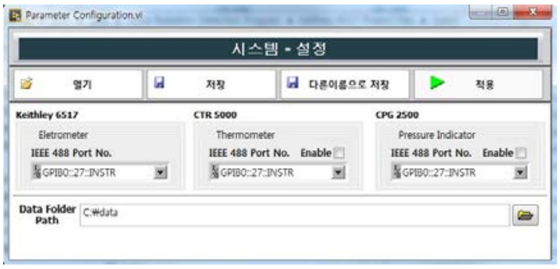


Fig. 2. Radiation dosimetry procedure using dosimetry software.

In the first step, various buttons, connection protocols and parameters that collected in previous measurement are initialized for new measurements. Secondly, each instrument has its own connection type. In this step, connection setup for each instrument is available using pop-up menu for connection setup as shown in figure 3. In addition, it is possible to create file including connection information. Using this file, connection setting is available without reset when further detection begins.



IEEE 488 Port No. GPIB0::27::INSTR
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Fig. 3. Pop-up menu for connection setup.

The measured data is monitored and stored in real time by software developed based on LabVIEW platform as shown in figure 4. This software has various advantages such as minimizing the measurement uncertainty and human error that caused by manual operation. Using this software, real time monitoring is available. In addition collected parameters are saved in Excel format automatically. Front panel of this software is user friendly and can be used by researchers who have no previous experience in theoretical radiation dosimetry.

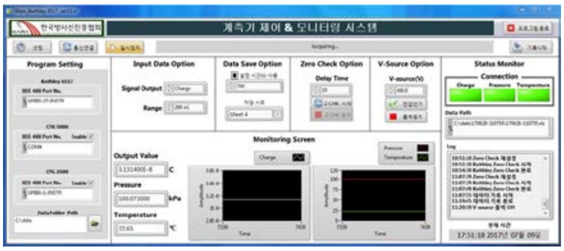


Fig. 4. Radiation dosimetry software based on LabVIEW.

After data is stored, various analyses such as correction of measurement values and calculation of uncertainty are required. Therefore we developed analysis software using Microsoft Excel as shown in figure 4. This program process data correction and uncertainty calculation using equations based on TRS-398.

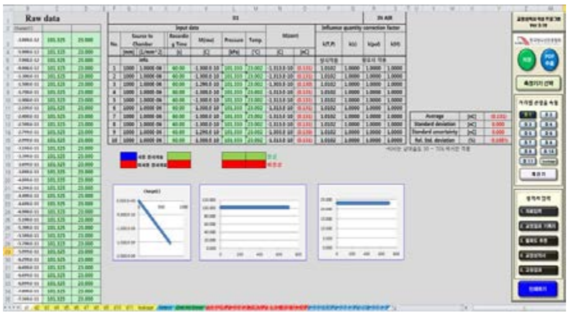


Fig. 5. Data analysis software based on Microsoft Excel.

Figure 6 shows the experimental set-up using RDS. The radiation dosimetry system consists of hardware and software part. In case of hardware part, there are various instruments in rack mount such as electrometer, barometer, thermometer, and PXIe system. And all instruments are combined by PXIe system using IEEE 488 and USB 2.0 cable. Finally, collected data is real time monitored, stored, and analyzed through software.

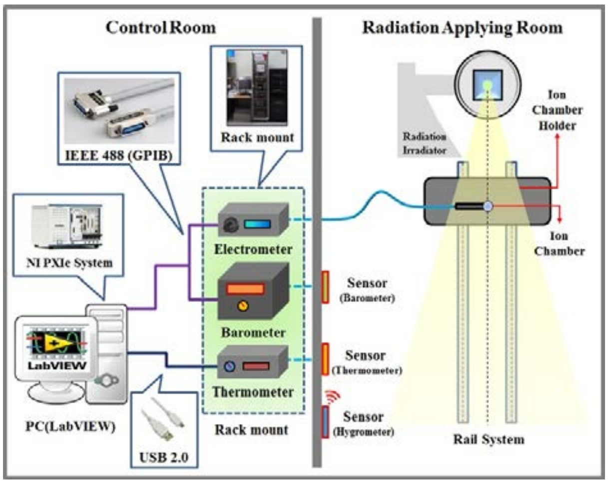


Fig. 6. Experimental Set-up using RDS.

2.2 Evaluation and validation method of the RDS

Stability of signal response is very important for accurate radiation dosimetry. Especially, data collection timing is the most important. In this study, experiments for optimization and validation were performed to evaluate radiation dosimetry system. In case of optimization, we performed experiments to find the optimized sampling rate of this system. After optimization, validation experiments were performed to find the most efficient way for radiation dosimetry. The experiments considered stability and detection methods.

2.3 Evaluation of RDS: Sampling rate

To combine devices which have different response time, optimization of sampling rate is necessary. If the sampling rate is not optimized, errors may occur during data acquisition. Especially, temperature data has a high probability of error, because of relatively long response time than other data such as charge and barometric pressure. In this experiment, two sampling methods were compared. Measurement time was set to 3,600 seconds and sampling rate was set to 500 ms and 1,000 ms using “Wait until next ms multiple” function in LabVIEW. When the sampling rate is set to 500 ms, temperature signal is unstable as shown in figure 7(a). This problem is caused by mismatch of sampling rates for connected devices. If the data transmission error is occurred, the data may not be fully transmitted. This problem is caused by mismatch of sampling rates for connected devices. If the data transmission error is occurred, the data may not be fully transmitted as shown in figure 8. In case of 1,000 ms, all signals were measured stably as shown in figure 7(b).

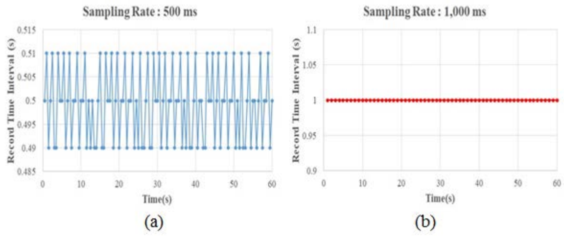
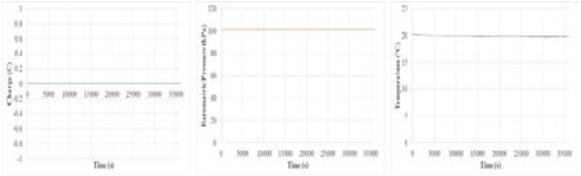


Fig. 7. Result for sampling rate(a: 500 ms, b: 1,000 ms).

Fig. 8. Examples for data transmission errors.

2.4 Validation of RDS: Stability Test

To confirm stability of the dosimetry system, we perform the stability test using the optimized setting in the previous experiments. The measurement time was set to 36,000 seconds, which is sufficiently longer than the previous test. As a result, all signals were stable as shown in figure 9.



(a) (b) (c)

Fig. 9. Results of stability test(a: charge, b: pressure, c: temperature).

2.5 Validation of RDS: Test of Detection Type

This experiment was performed in irradiation condition using ^{60}Co irradiation system which has activity of 235.4. The radiation field used in this experiment has homogeneity of less than 0.1% at the size of 100 mm by 100 mm. In case of ion-chamber, farmer type ion-chamber Exradin A12 (Standard Imaging) was used. And source to chamber distance (SCD) was fixed at 1000 mm and water depth was set at 5 g·cm-2.

To find the most efficiency method for radiation dosimetry, we performed this experiment according to detection method as shown in figure 10. Each case was measured in flat section of irradiation region to minimize uncertainty. Also, measurement region was set to be the same. Each case has difference between data collection method. The A type is a method of measuring 10 data at a predetermined time interval, and the B type is a method of performing the data without time interval. In the case of C type, the data is measured by one data without separating the data. Finally, D type is similar to the A type, but differs in that it initializes the electrometer between each data. After measurement, average and standard deviation for the average were calculated to compare the measurement results.

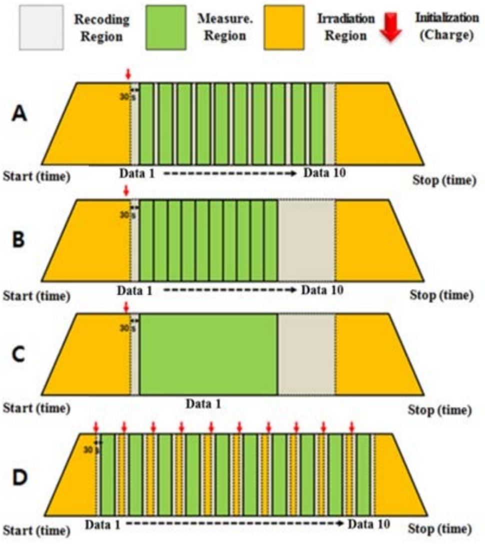


Fig. 10. Detection types for radiation detection.

Table 1 shows the results according to measurement type. As a result, all measurement values were obtained with similar values. Especially, detection type of D has the lowest uncertainty. However, in part of efficiency for measurement method, detection types of A and B have higher efficiency than D. In case of C, it is unsuitable to accurate radiation dosimetry because calculation of standard deviation is not available. Results of A and B have almost same, but B has a possibility of timing error without blank time for each measurement. Therefore, we select the measurement type of A.

Table. 1. Measurement results according to measurement type.

Type	Average (Gy/h)	Standard deviation (Gy/h)	Uncertainty (Gy/h)	Relative Uncertainty (%)
A	45.244	0.016	0.005	0.011
B	45.242	0.016	0.005	0.011
C	45.244	-	-	-
D	45.266	0.008	0.003	0.006

3. Conclusions

In this study, we developed dosimetry system for gamma-ray detection. And we performed various experiments to optimize and validate the dosimetry system. To optimize the system, we found optimal connection method and sampling rate. After optimization, we confirmed the stability of the system. And also, we found optimal detection method to minimize measurement uncertainty. The system developed in this study has various advantages such as minimizing the human error and measurement uncertainty. Also, it can shorten the measurement time by automating all measurements. Since data analysis using measured values can be performed in real time, it is expected to be applicable to various fields related to radiation measurement.

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