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Implementation Test of Two-dosimeter Algorithm for More Precisely Estimating Effective Dose during Maintenance Periods at Korean Nuclear Power Plants

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1. Introduction

Radiation workers can be exposed to high radiation during the maintenance of reactor coolant pumps, pressurizers, and water chambers of steam generators during maintenance periods of a NPP in spite of the short working hours since dose rate gradients are high in these areas. In general, since the radiation dose rate is high and the radiation field is inhomogeneous, if radiation workers use only one thermoluminescent dosimeter (TLD) on their chest, the amount of radiation exposure cannot be monitored exactly. Therefore, additional dosimeters are provided to workers for radiation work in an inhomogeneous radiation field in NPPs. Two additional dosimeters are usually provided and one is located on the chest and the other is on the head. In this case, the radiation dose to the whole body for radiation workers at NPPs is determined by the high deep dose between two radiation doses from these dosimeters, as a conservative method for evaluating the amount of radiation exposure.

The intent of this paper is to develop a solution of the overestimation and underestimation of the effective dose in an inhomogeneous radiation field. The application of a two-dosimeter algorithm is described, for estimating the exact deep dose to radiation workers in an inhomogeneous radiation field. In addition, the current issues of using a two-dosimeter at Korean NPPs and experimental results of adopting several algorithms for application at Korean NPPs are described in detail.

2. Current Issues of Using a Two-dosimeter

In Korean NPPs, additional dosimeters are provided to workers depending on the type of radiation work carried out, for calculation of a deep dose; however, several problems are involved. First, the provision for the conditions of use of additional dosimeters is slightly different. Although Korean NPPs apply the guidelines of the Institute of Nuclear Power Operations (INPO) for providing additional dosimeters, the guidelines for their use are not clear. In addition, the method used to implement their use, including the number of additional dosimeters to be used is slightly different among Korean NPPs. In addition, the method used to implement their use, including the number of additional dosimeters to be used is slightly different among Korean NPPs. In general, additional dosimeters (two-dosimeters) are placed on the chest and head with regard to the only top and bottom directions of the incident radiation for water chambers of steam generators. If radiation sources exist in front and back of the radiation worker, it is difficult to monitor the exact amount of radiation exposure to workers. The adoption of a maximum deep dose as the effective dose without respect to the average value of radiation doses considering the weighting factors between radiation doses from dosimeters is also conservative, thus creating an overestimation problem.

3. Experiments & Results

Several two-dosimeter algorithms were compared and analyzed from various points of view for possible application to Korean NPPs. The analyzed algorithms were 7 two-dosimeter algorithms, the algorithm of the Canadian Ontario Power Generation (OPG) used at the Pickering NPPs, the algorithm of American National Standards Institute (ANSI), the two algorithms of the National Council on Radiation Protection (NCRP (70/30) and NCRP (55/50)), the algorithm of Electric Power Research Institute (EPRI (Xu)) approved by the Nuclear Regulatory Commission (NRC), and the two algorithms of Texas A&M University (Lakshmanan and Kim) [1~5].

Three additional dosimeters (TLD) and a supplementary dosimeter (ADR) were provided to radiation workers who wore a TLD at the head, chest, and back simultaneously to analyze the two-dosimeter application to Korean NPPs during a maintenance period at the Yonggwang NPPs No. 2. The algorithms of the OPG and ANSI need TLD read-outs on the head and chest, and the other algorithms require TLD read-outs on the chest and back. The experiments were conducted at the Yonggwang NPPs No. 2 in 2004 for the installation and removal of a nozzle-dam of a steam generator, a penetration test (PT) of the reactor head, and changing the heater of the pressurizer. Additional experiments which were similar to the above experiments at a Yonggwang NPPs No. 2 were also performed at the Ulchin NPPs No. 2 during a maintenance period in 2005.

A comparison of the estimated effective dose, which showed the highest TLD read-out of two-dosimeters at Younggwang NPPs No. 2, was conducted. As a result,

the effective dose calculated by the above 7 two-dosimeter algorithms was lower than the highest TLD read-out, by approximately 10~50%. The effective dose from the experiments at Ulchin NPPs No. 2 was also calculated by the same method used at the Yonggwang NPP and it was found that the comparison results of Ulchin NPPs No. 2 were similar to those of Yonggwang NPPs No. 2.

The effective doses were calculated using each algorithm to analyze the differences among the 7 two-dosimeter algorithms. The results showed that, there were no remarkable differences among the calculated effective doses, except for Lakshmanan's algorithm and no big differences in effective doses according to the position of two-dosimeters worn on the head and chest or the chest and back. These results are illustrated in Figure 1.

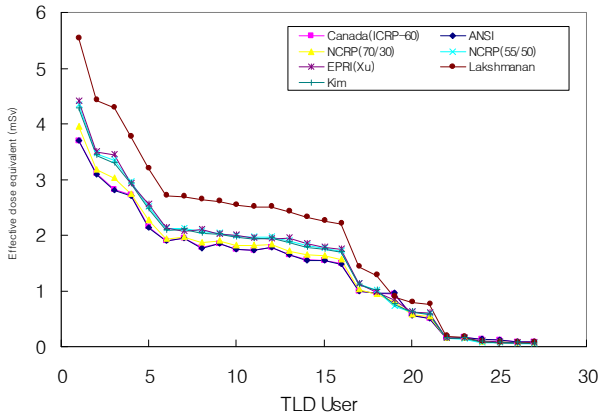

Figure 1. Application of Two-dosimeter Algorithm for the Installation of Steam Generator Nozzle Dam at Yonggwang NPPs No. 2

This paper recommends the NCRP algorithm presented by the NCRP-122 report in 1995 as an optimal two-dosimeter algorithm in consideration of the above points. In particular, since most developed algorithms show no big differences in results for practical inhomogeneous radiation fields, it was concluded that the application of the NCRP algorithm to Korean NPPs was acceptable, due to the NCRP's solid technical background. The important issue was that the NCRP suggested two two-dosimeter algorithms (NCRP (70/30) and NCRP (55/50)); however, NCRP recommended only the NCRP (55/50) algorithm for use. The final conclusion of the NCRP was that, if the algorithm of NCRP (55/50) was used as a two-dosimeter algorithm, the possibility of underestimating the effective dose would be reduced [2].

4. Conclusion

Conditions of Providing Additional Dosimeters

It is necessary to benchmark the INPO guidelines and foreign procedures of two-dosimeters and to standardize the procedures at Korean NPPs. Since, in Korean nuclear regulations, tight radiation management is performed for over 2mSv of radiation exposure, providing additional dosimeters to radiation workers who are expected to be exposed to over 2mSv of radiations is reasonable.

Positions and the Number of Additional dosimeters

After several experiments, it was found that there were no big differences in effective doses according to the position of two-dosimeters worn on the head and chest or the chest and back. In particular, the preceding research showed that wearing two-dosimeters at the chest and back rather than the chest and head reduced the overestimation or underestimation of the effective dose. Thus, it was concluded that wearing two-dosimeters at the chest and back was suitable for a radiation worker, because of the above reasons.

Selection of the Optimal Two-dosimeter Algorithm

The application of 7 two-dosimeter algorithms developed by nuclear regulatory agencies and facilities to Korean NPPs was investigated, to analyze anticipated problems that might arise. As a result, the calculated effective doses were very similar to one another, except for Lakshmanan's algorithm. Thus, it was concluded that no matter what algorithms were applied to Korean NPPs, the procedure used for estimating radiation exposure would be improved.

5. Acknowledgement

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