Calculation of Radiation Exposure Dose to Workers during Replacement of PWR Steam Generator by using RESRAD-BUILD Code

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1. Introduction

The steam generator in a nuclear power plant cools the high-temperature coolant passing through the nuclear reactor and generates vapor to drive the turbine engine. Approximately 3,000 or more U-tubes in the steam generator have an interior diameter of 2 cm and height of more than 10 m, so plugging is likely to occur at the time of nuclear reactor operation. The plugging phenomenon is removed during every overhaul period. However, the longer the operation time of the nuclear reactor, the greater number of plugging. This means that the efficiency of a nuclear reactor decreases. Therefore, a steam generator decreased in efficiency should be replaced at this time. From the steam generator replacement in USA's Surry unit 2 in 1979, 50 countries have changed about 150 steam generators up to the present. In Korea, there has been only the steam generator replacement in Kori Unit 1, in 1998. For the safe steam generator replacement, it is absolutely necessary to measure radioactive pollution and calculate radiation exposure dose to the workers. Various nations and institutes have used the RESRAD Code to calculate the exposure dose and get much economic benefits [1]. In this paper, the radiation exposure dose to workers is calculated at the time of replacing PWR steam generators by using the RESRAD-BUILD Code.

2. Methods and Results

2.1RESRAD-BUILD Code

The RESRAD-BUILD Code is one of 7 RESRAD Codes which Argonne National Laboratory began to extend in 1989. The code calculates the radiation exposure dose to workers from contaminants inside the building. Compared to Microsoft Excel spreadsheet and MCNP (Monte Carlo N-Particle), the RESRAD-BUILD Code has a calculation error between 0.1% and 5% to gain recognition in accuracy. Various institutes, such as the DOE (Department of Energy) and NRC (Nuclear Regulatory Commission) use this code.[2]

In this paper, the radiation exposure dose to workers is calculated at the time of replacing the PWR steam generator by using the RESRAD-BUILD Code, based on experiences of replacing Kori Unit 1 and the drawing of the steam generator in Youngkwang Units 3 & 4.

2.2 RESRAD-BUILD Code Input Factors

The factors influencing the radiation exposure dose to workers for working with radiation are deposition velocity, resuspension rate, building exchange rate, breathing rate, ingestion rate, radiation nuclides and pollution, types and thickness of shield and working hours and location, etc.

Deposition velocity represents the indoor deposition velocity of contaminant particles in the building air. Resuspension rate represents the rate at which material deposited on interior surfaces is resuspended into the indoor air per unit time. The building exchange rate is the total volume of air in the building or room replaced by outside air per unit of time. breathing/inhalation rate reflects the rate at which an individual inhales air at the receptor location. [3]

The default value of each input factor in RESRAD-BUILD Code is as the following, in Table Ⅰ:

Table Ⅰ. Default Value of Input Factor

Input Factor	Default Value
Deposition Velocity	0.01 m/s
Resuspension Rate	0.0000005 1/s
Building Exchange	0.8 1/h
Breathing Rate	18 m^3/d
Ingestion Rate	0.0001 m^2/h

Default value is used by assuming that the deposition velocity, resuspension rate, building exchange rate and breathing rate do not have a significant influence on results. Ingestion rate with little possibility in real work is also taken into account.

Thirty years after commercially operating a nuclear power plant, radioactive nuclides and radioactive contamination included in steam generator are as the following, in Table II. [4]

Table Ⅱ: Radioactive Nuclides and Radioactive Contamination

Radioactive Nuclides	Radioactive Contamination (Bq/m^2)
^{141}Ce	9.87×10^6
^{57}Co	4.41×10^5
^{58}Co	2.02×10^8
^{60}Co	8.58×10^7
^{59}Fe	5.50×10^6
^{54}Mn	4.99×10^6

^{95}Nb	3.01×10^{7}
^{103}Ru	4.38×10^{7}
^{106}Ru	2.62×10^{7}
^{113}Sn	9.06×10^{5}
^{85}Sr	2.77×10^{7}
^{65}Zn	2.86×10^{6}
^{95}Zr	1.18×10^{7}

The data of Kori unit 1 is used for the containment building volume, radioactive nuclides, radioactive contamination, work time and the number of workers. The data of Youngkwang unit 3&4 is used for the surface area of steam generators. [5] The calculation results of the surface area of the steam generator and containment building volume are 349.44 m^2 and 44345.17 m^3, respectively.

The data of radioactive contamination of surface is used by setting the steam generator as the area source. The surface area of the steam area is fixed at 174.72 m^2, by assuming that one side of the steam generator influences workers.

2.3 Calculation Results

In this paper, the radiation exposure dose to workers is calculated at the time of replacing the PWR steam generator by using the RESRAD-BUILD code. There are a total 113 procedural steps for replacing the steam generator. The radiation exposure dose to workers is calculated for each procedural step and total exposure dose by adding each exposure dose.

The radiation exposure dose to each worker by each procedural step is as the following, in Fig. 1. The total radiation exposure dose to workers is 1.44 x 10^2 mSv.

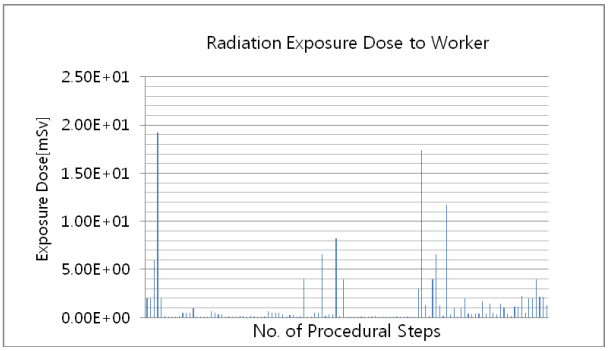

Fig. 1. The Radiation Exposure Dose to Worker by Each Procedural Steps

For grouting work, radiation exposure dose to workers has the smallest value of 1.21 x 10^{-2} mSv. For RCS (Reactor Coolant System) pipe exterior welding, it has the largest value of 1.92 x 10^{1} mSv. According to enforcement ordinances of nuclear power laws, effective dose limits should be 100 mSv for 5 years below 50 mSv per year. In other words, it should not be over 20 mSv each year for workers sent for replacing steam generators. The radiation exposure dose is 1.92 x 10^{1} mSv and 1.74 x 10^{1} mSv for RCS pipe external welding and removal and installation of steam generator heat insulation materials, respectively, with both showing values very close to dose limits each year. For the steam generator replacement in Kori unit 1, there is a total of 86 workdays. This means that each worker gets quite a bit of radiation exposure dose, so it is considered to be very dangerous for workers regarding dose limits.

3. Conclusion

The radiation exposure dose to workers is calculated at the time of replacing the PWR steam generator by using the RESRAD-BUILD code. The results show a minimum of 1.21 x 10^{-2} mSv (grouting work) and a maximum of 1.92 x 10^{1} mSv (RCS pipe external welding) for 113 procedural steps.

According to enforcement ordinances of Atomic energy laws, effective dose limits for those involved in working with radiation should not be over 20 mSv each year. In the future, the replacement of steam generators in Korea will be actively carried out. It is considered that those involved with the replacement of steam generators get radiation exposure dose close to the effective dose limit for a short period. Therefore, it is necessary to study measures for decreasing radiation exposure dose to workers at the time of replacing steam generator.

REFERENCES

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