Evaluation of the Effect on the Offsite Dose with Changes in the Reuse Rate of Reactor Coolant

‡Taewook Kim and Sung Jun Maeng
*Youngjig Bae

‡Nuclear Engineering & Technology Institute, KHNP
Taewook@khnp.co.kr
*Korea Power Engineering Company

ABSTRACT

Some pressurized water reactors were designed to reuse a portion of their reactor coolant released through shim bleed, reactor and equipment drains, and clean waste. However, in some cases the coolant collected in a boric acid recovery system for processing does not meet reuse criteria, such as its level of dissolved oxygen; therefore, it needs to be released into the environment. In this study, the radioactive nuclide release and the associated offsite dose were evaluated by PWR-GALE and TEDII-60[1] for plant operational flexibility of the reuse rate of shim bleeding, reactor and equipment drains, and clean waste. The calculation carried out for Ulchin nuclear power plants units 5 and 6 shows that in the most conservative case, where no reuse is possible, the maximum organ dose and effective dose by liquid effluent were determined to decrease from 0.47 to 0.44 of the dose limit and increase from 0.14 to 0.18, respectively.

INTRODUCTION

Some pressurized water reactors were designed to reuse up to 90% of the (a)shim bleed, (b)reactor and equipment drains, and (c)clean waste.

Shim bleed and reactor and equipment drain liquids are gathered by the boric acid recovery system via a holdup tank. They are separated into concentrated water and condensation water by a boric acid concentrator. If their water quality measures meet predetermined criteria pertaining to the dissolved oxygen content, the concentrated water and condensation water are routed to a refueling water storage tank and to a reactor makeup water tank, respectively. Otherwise, they are sent to a chemical waste tank.

Chemical waste and clean waste are treated by a LRS (Liquid Radioactive Waste System) and sent to the boric acid concentrator if their water quality measures meet the criteria. Otherwise, they are discharged into the environment.

The recycle and discharge flow of the shim bleed, reactor and equipment drains, and clean waste are described in Fig. 1.

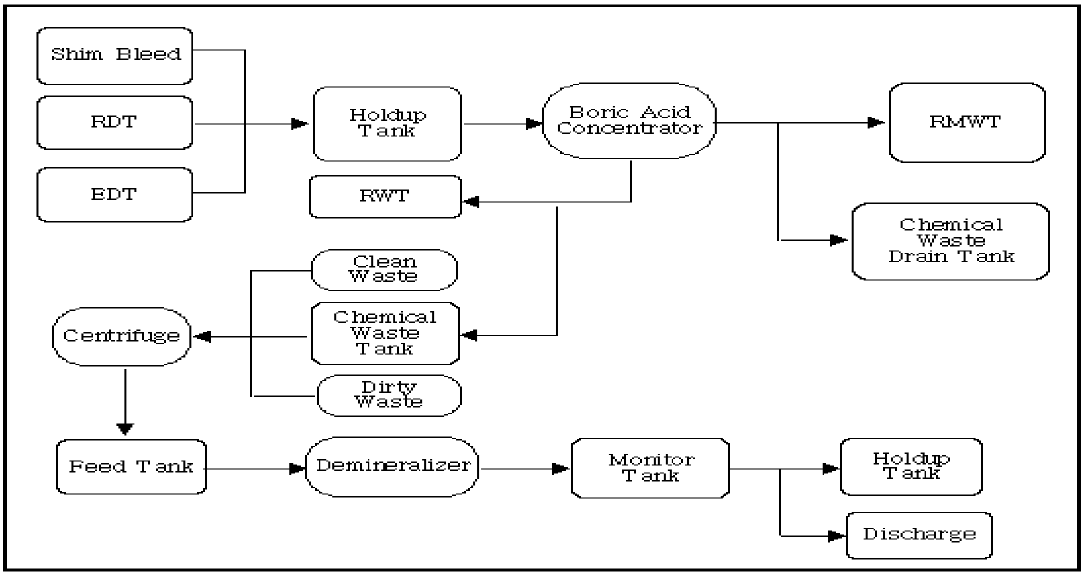

Fig. 1. Recycle and discharge flow of shim bleed, reactor and equipment drains, and clean waste

In this study, the quantities of radionuclides released into the environment and the offsite dose were estimated for the most conservative case in which all shim bleed, reactor and equipment drains, clean waste and (d)dirty waste are discharged for Ulchin nuclear power plants units 5 and 6.

RELEASE QUANTITIES OF RADIONUCLIDES

To simplify the calculations, radionuclides in PWR liquid and gaseous effluents can be classified as H-3 and other nuclides.

(H-3)

The total release quantity of H-3 from liquid and gaseous effluents depends only on the thermal power of the plant. This has been evaluated as 1.48×10^{10} Bq/y per MWt, which is based on conservative operational experience of US PWRs from 1970 to 1980. This value continues to be used as a guideline for evaluations of the expected concentration under normal operation. It is derived from the tritium concentration of reactor coolant, which is 3.7×10^{4} Bq/g.

As the total tritium activity released via gaseous and liquid effluents is fixed according to the specifications of NUREG-0017[2], the release of tritium via gaseous effluent is assumed to decrease if the release of tritium via liquid effluent increases.

As liquid effluent is released via the (a) to (d) streams mentioned above, its tritium radioactivity can be calculated by multiplying its tritium concentration, flow rate and release fraction for all streams. As specified in NUREG, 90% of the tritium is assumed to be released through liquid effluent with the balance released through gaseous effluent, even if all of the tritium is released via liquid effluent.

Hence, the tritium release rate via liquid effluent increases by 5.6 times in comparison with the case of 90% reuse, whereas the release rate of H-3 via gaseous effluent decreases by 0.12 times.

(Other nuclides)

In case all of the streams are discharged, the total release quantities of nuclides except H-3 are calculated by the PWR-GALE code. NUREG-0017 stipulates that a total of 5.91×10^{9} Bq/y per reactor should be added to the total radioactivity of the liquid effluent in proportion to the radioactivity ratios of liquid effluent against an unplanned release at a plant.

The calculated result shows that the total release quantities of radionuclides through liquid effluent increase and that their increasing ratios differ depending on the nuclides. As the release fraction of the (a) to (c) streams increases from 0.1 to 1.0, the release quantities of the nuclides through these streams were also found to increase by 10 times. However, the ratio of all of the nuclides in these streams to the total nuclides in the liquid effluent was determined to be only 2.5%.

In case the release fraction of the clean waste increases from 0.1 to 1.0 with the same release fraction of dirty waste, the release quantities of radionuclides are calculated to increase by 5.1 times with the exception of certain nuclides, such as iodine, whose release quantity was found to increase by 1.7 times. This difference is thought to be caused by the differences in the decontamination factors for the radionuclides in the streams.

In addition, a total of 5.91×10^{9} Bq/y per reactor needs to be added in proportion to the radioactivity ratios against an unplanned release. As a result of this adjustment, the release radioactivity of certain nuclides, again such as iodine, were found to be smaller than that expected for the case of a reuse of the shim bleed, reactor and equipment drains and clean waste. However, the release radioactivity values of nuclides except tritium via gaseous effluent were found to be unchanged.

DOSE CALCULATION

The maximum effective dose at the EAB was evaluated using the TEDII-60 code, to which the US NRC Reg. Guide 1.109[3] and the effective dose concept of ICRP-60[4] were applied.

(Liquid Effluent)

The effective dose through all dose pathways of liquid effluent was determined to increase by 31%, whereas the maximum organ dose, i.e., for a thyroid of a child, was reduced by 7%.

The reduction in the thyroid dose was found to be attributed to a decrease in the released iodine.

(Gaseous Effluent)

The air dose rate of gamma and beta radiation and external doses for the entire body and the skin were calculated and found to be unchanged. The maximum organ dose by H-3, C-14 and particulates was found to be 94.6% of the value for 90% reuse. This was caused by the reduction of the H-3 concentration due to the change of the release fraction of H-3 through gaseous effluent from 0.9 to 0.1.

CONCLUSION

There may be some cases in which PWRs, even with design that allows reusing of the shim bleed, reactor and equipment drains, and clean waste cannot fully recycle them to plants. Thus, a portion of the waste will need to be released. The calculation carried out for the Ulchin nuclear power plants (units 5 and 6) shows that in the most conservative case, where no reuse is possible, the maximum organ dose and the effective dose by liquid effluent were determined to decrease from 0.47 to 0.44 of the dose limit and increase from 0.14 to 0.18, respectively. Thus, it was concluded that according to the variance of the reuse rate of reactor coolant, there is no significant difference in terms of radiation safety in these nuclear power plants.

REFERENCES

1 TEDII-60, “Totally Visualized Environmental Dose Evaluation Code Incorporating ICRP Publication 60 Recommendations”, KOPEC, 1998

2 NUREG-0017,” Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from a Pressurized Water Reactor,” PWR-GALE code, 1985.

3 USNRC, Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents from the Purpose of Evaluating Compliance with 10 CFR 50 App. I", Rev.1, 1977.

4 ICRP Publication 60, “1990 Recommendations of the International Commission on Radiological Protection”, ICRP, 1991.