Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22-23, 2025

Accident Impact Assessments of MCR, EAB and LPZ for Recirculation Pipe Leakage Model in LOCA Condition

Seung-Chan LEE*, Kyungho Nam and Yerim Park

Korea Hydro Nuclear Power Co., KHNP Central Research Institute, Yuseong-daero 1312, Yuseong, Daejeon 34101 Korea.
**Corresponding author: eitotheflash@khnp.co.kr*

1. INTRODUCTION

The final safety analysis report includes design-based accidents dose evaluation results. In the results, LOCA (Loss Of Coolant Accident) is confined case and include complex model. Here, three models include the containment leakage model, containment purge model, and ESF (Engineering Safety Features) leakage model. In this study, ESF model is focused on the evaluation of LOCA dose evaluation [1].

This model is to calculate the fission products leakage of recirculation sump system in LOCA condition.

This study introduces the accident impact assessment of LOCA caused by recirculation sump leakage, assuming pipe leakage and considering factors such as the design value, system mass, and specific volume of the power plant. The research has been conducted on the APR1400 nuclear power plant [2]. The assessment used in this study can also be applied to evaluate MCR (Main Control Room) habitability under LOCA conditions. This paper introduce the evaluation results of accident's impact for EAB (Exclusion Area Boundary), LPZ (Low Population Zone), MCR (Main Control Room).

2. METHODOLOGY

2.1. Scenario and Considerations

In the context of recirculation piping leakage, the leakage rate should be assumed as a volume per unit of time, taking into account the volume of the primary coolant. Furthermore, it should be assumed that various coolants are mixed in the IRWST (In-Containment Refueling Water Storage Tank), and the leakage rate for each pipe should be evaluated based on these assumptions.

Therefore, the mass is calculated by considering the temperature and pressure of each system within the primary system, and the volume is estimated under conservative conditions for evaluation. At this time, the minimum coolant amount of systems such as the IRWST, where the minimum volume is determined, is assumed. These considerations can be applied based on RG 1.195 [1-2].

2.2. Modeling Concept of Recirculation Pipe Leakage Evaluation in LOCA Scenario

Figure 1 is a conceptual diagram for accident impact assessment modeling under LOCA conditions.

The paths indicated by the curved and blue arrows represent the modeling concept used in this study.

As shown in the modeling concept diagram, when operating in recirculation mode under LOCA conditions, radioactive substances in the spray and unsprayed zones are transferred to the auxiliary building atmosphere through the recirculation piping cycle and the IRWST. These substances are then released into the environment via the auxiliary building filters.

In the concept of Figure 1, dose assessment was performed using RADTRAD 3.03 code. And diffusion behavior from environment to EAB and LPZ was evaluated using PAVAN code, and diffusion behavior from the environment to MCR was evaluated using ARCON96 code.

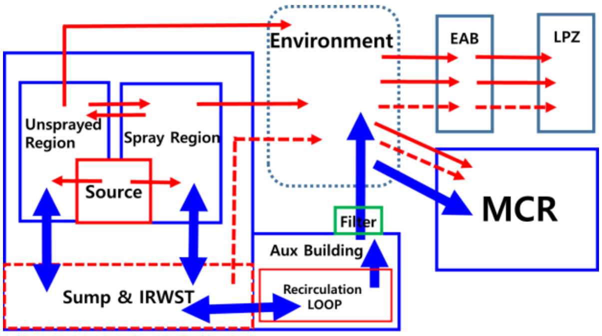

Fig. 1 Modeling Concept of Recirculation Pipe Leakage Evaluation in LOCA using RADTRAD 3.03 code.

Based on the concept in Figure 1, for dose evaluation of the recirculation piping leakage model, factors such as the IRWST (In-Containment Refueling Water Storage Tank), RCS (Reactor Coolant System), PZR (Pressurizer), SIT (Safety Injection Tank), pipe, and non-circulating volumes are considered. The volume of the recirculation leakage model, which is applied to the actual dose, is calculated and evaluated accordingly.

3. RESULTS AND DISCUSSIONS

3.1. Calculation Results of Actual Recirculation Total Volume of Reactor Coolant for Recirculation Pipe Leakage Model

Table 1 represents the calculation of the actual recirculating coolant volume for evaluating the recirculation piping leakage model.

The volume calculation results in Table1 are used as the input of RADTRAD 3.03 code.

As presented here, the recirculating coolant volume is calculated to be 86,136 cubic feet.

As shown in Table 1, considering the difference in temperature and pressure by system, the mass was calculated and this value was conservatively converted to volume. For systems such as IRWST where the minimum volume is calculated, the minimum value was applied, and for the remaining systems, the mass was reduced and applied considering a margin of 10%.

And overall, a saturation condition of 300°F was assumed.

Table 1. Volume of Recirculation Coolant for EAB, LPZ and MCR Evaluation.

System	Temperature(°F) /Pressure (psia)	Volume (ft^3)	Selection Rule
IRWST	120/14.6	83,817	Minimum value
RCS	585/2250	14,979	90% mass
PZR (water)	585/2250	1,171	90% mass
PZR (steam)	585/2250	1,260	90% mass
SIT	120/625	7,432	90% mass
Pipe	120/14.6	3,000	Minimum volume
Non-recirculation	120/14.6	24,062	Non-recirculation volume
Basic condition			Assumption of 300°F
Total Volume			86,136 ft^3

3.3. Dose Calculation Results of Recirculation Pipe Leakage Model

In dose assessment, the initial coolant volume calculated in Table1 is used as the initial condition.

Based on the assumptions made in this study regarding recirculation piping leakage, the valve leakage rate for the SI (Safety Injection)/SC (Shutdown Cooling) system was assumed to be 4,780 cc/hr, and for the CS (Containment Spray) system, 1,250 cc/hr. Additionally, considering the safety injection pump and the reactor building spray pump, a leakage rate of 2,050 cc/hr was assumed.

Therefore, the total leakage rate for a single train amounts to 8,050 cc/hr. When assuming two trains, the leakage rate becomes 16,100 cc/hr. In this study, a conservative evaluation was conducted by applying twice the calculated total leakage amount, in accordance with RG 1.195. Furthermore, a vaporization rate of 10% was applied to the environmental release, as specified by RG 1.195. Based on these regulatory guidelines, the final leakage rate was calculated to be 1.9E-03 cfm.

This leakage rate, 1.9E-03 cfm, was applied in the dose evaluation. This leakage value represents the release rate through the engineering safety features of fission products during an accident period. The dose evaluation results conducted using the calculated leakage amount are presented in Table 2 below.

Table 2 provides the evaluation results for the EAB, LPZ, and MCR.

In this evaluation, the assessment of the recirculation piping leakage model was conducted assuming an APR 1400 nuclear power plant.

Table 2. Calculation Dose Calculation Results of EAB, LPZ and MCR.

ITEM	Whole Body (mSv)	Thyroid (mSv)	TEDE (mSv)
EAB	1.9991E-02	5.5965E+00	1.9620E-01
LPZ	8.0771E-03	8.8359E+00	2.7968E-01
MCR	1.5943E-05	3.8536E-01	1.1849E-02

The evaluation results, based on the thyroid dose, were calculated as 5.5965 mSv for the EAB, 8.8359 mSv for the LPZ, and 0.38536 mSv for the MCR.

The atmospheric dispersion factors used in this evaluation were derived from meteorological data collected between 2018 and 2022.

In the case of EAB dispersion factor is 6.5540E-04 sec/m^3. In the case of LPZ dispersion factors are ranged between 8.1890E-06 sec/m^3 ~ 5.7720E-05 sec/m^3. In the case of MCR dispersion factors are ranged between 1.7250E-04 sec/m^3 ~ 7.1800E-04 sec/m^3.

4. CONCLUSIONS

Through this study, an accident impact assessment based on a recirculation piping leakage model, assuming leakage in the engineered safety features of the APR 1400 nuclear power plant, was conducted. The available recirculation piping coolant volume was estimated, and dose evaluation was performed by applying the methodology outlined in RG 1.195.

In case of thyroid dose, EAB, LPZ and Control Room are respectively 5.5965 mSv, 8.8359 mSv 0.38536 mSv.

The total coolant recirculation volume was approximately 86,136 cubic feet, and the recirculation leakage model's leakage rate was approximately 1.9E-03 cfm.

In this condition, the dose calculation results of Table 2 show very small level compared to the allowable limit of 3000 mSv (Thyroid : EAB, LPZ) and 500 mSv (Thyroid : MCR).

Therefore, the recirculation leakage model is evaluated to have no effect in LOCA.

REFERENCES

[1]R.G. 1.195, US NRC, "Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors", May (2003).

[2] Final Safety Report, SEUL units 1,2.