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Sensitivity Analysis of Control Room Habitability with Unfiltered Air Flow Rate

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1. Introduction

The unfiltered air flow to the control room is the important factor for control room habitability during design basis and beyond design basis accidents. Control room habitability of APR 1400 during DBA LOCA is evaluated with the considering dose contribution of the unfiltered air flow. Sensitivity analysis is performed with changing of unfiltered air flow rate for the investigation of allowable unfiltered air flow rates. This paper describes the control room dose calculation method, sensitivity analysis results and estimation of the maximum allowable unfiltered flow rate. Control room data is based on the APR 1400 design data from Shin-Kori 3&4 FSAR [1].

2. Evaluation Model and Results

In this section, regulations, control room HVAC system, dose calculation models, sensitivity analysis method and results are described.

2.1 Regulations

Enforcement decree of the nuclear safety act specifies radiation workers dose limit. Annual dose limit of radiation workers is 50 mSv effective dose and shall not be exceeded 100 mSv effective dose during 5 years. Safety Review Guideline for Light Water Reactors(SRG)[2] chapter 6.4, control room operators shall not be exposed 50 mSv whole body dose and 300 mSv thyroid dose during accidents.

USNRC GDC(General Design Criterion) 19 control room states that radiation protection shall be provided for the occupancy of the control room under accident conditions without personnel receiving radiation exposure in excess of 5 rem whole body. Standard Review Plan(SRP)[3] states that dose limits of personnel who works at operating power plants are whole body gamma 50 mSv and thyroid 300 mSv.

In this paper, 50 mSv annual effective dose limit of enforcement decree of the nuclear safety act is used for sensitivity analysis.

2.2 Control room HVAC System

The HVAC system for the control Room has function that the radiation exposure of control room personnel does not exceed the radiation worker dose limits. APR 1400 control room HVAC system is furnished with dual air inlet duct and each inlet duct is furnished Class 1E radiation monitoring devices[1]. When the SIAS(safety injection actuation signal) or CREVAS(control room emergency ventilation actuation signal) is generated, the normal makeup air is isolated, the emergency makeup ACU is automatically started. Additionally, one of two outside air intakes automatically is isolated to select the lower radioactivity air supply from outside air intake. In principle, airborne radioactive materials in the outside air are filtered through control room emergency ACU. But unfiltered flow exists because the opening and closing of doors, leakage from control room openings and leakages from HVAC ducts etc. Design Data of APR 1400 control room HVAC system are shown in Table I.

Table I: Design data of APR 1400 control room HVAC system

Item	Value
Post accident filtered air intake rate, cfm	3,200
Post accident in-filtered air flow rate, cfm	25
Post accident filtered recirculation rate, cfm	4,800
Control room free volume, ft^3	2.6E+05
Filter efficiency, %	99

2.3 Control room dose calculation method

The Shin-Kori 3&4 FSAR uses US regulatory guide 1.195[4] as accident source terms. There are five exposure pathways to the control room operators during DBA LOCA. Pathways are as follows.

1. Contamination of control room air by intake or infiltration of radioactive material from the radioactive plume due to containment building leak
2. Contamination of control room air by intake or infiltration of radioactive material from the radioactive plume due to containment purge before containment isolation
3. Contamination of control room air by intake or infiltration of radioactive material from the radioactive plume due to ESF system leakage
4. Direct shine from containment building

5. Direct shine from radioactive plume outside of control room

Among those five pathways, direct shine pathways are irrelevant to this analysis. Containment purge and ESF leakage pathways are very small contribution to dose results compared than the containment leakage pathways. Therefore only containment leakage pathway is considered in this analysis.

Control room dose due to containment leakage is considered following assumptions based on US NRC regulatory guide 1.195.

1. Removal of radioactive iodine in the containment by containment spray system is credited.
2. Effect of radiological decay of radionuclides during holdup in the containment is taken into account.
3. Containment leak rate is the design basis leak rate specified in the Technical Specification in the APR 1400.
4. Breathing rate for CR operators is 3.5E-04 m^3/sec for the duration of accident.
5. The mixing rate between sprayed and unsprayed region in the containment is assumed 2 turnovers of the unsprayed region per hour.

The RADTRAD computer code[5] is used for control room dose calculation and sensitivity analysis. Dose calculation model of RADTRAD code is shown on Figure 1.

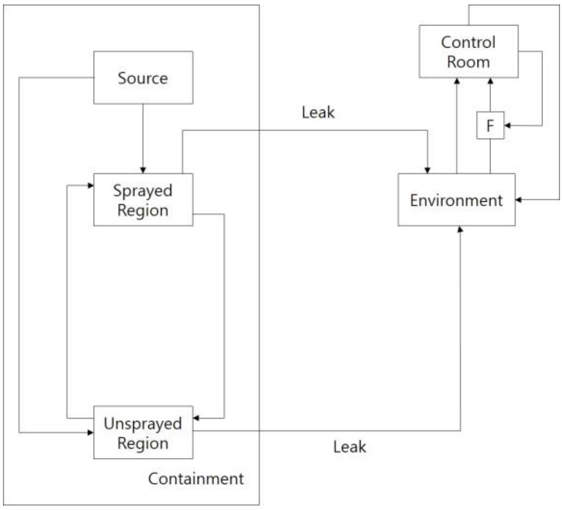

Fig. 1. Containment leak model in RADTRAD code

2.4 Base Case Analysis

The base case analysis is performed with DBA LOCA source term specified in US regulatory guide 1.195. Control room data is taken from Table I. The onsite atmospheric dispersion factors are shown in Table II. Including onsite atmospheric dispersion factors, iodine removal coefficients by containment spray and the other data such as containment leak rate are taken from Shin-Kori 3&4 FSAR.

Table II: Onsite atmospheric dispersion factors, sec/m^3

	Intake point	Infiltration point
0-2 hour	2.38E-4	2.62E-3
2-8 hour	1.93E-4	1.53E-3
8-24 hour	6.49E-5	5.77E-4
1-4 day	7.23E-5	6.04E-4
4-30 day	5.93E-5	4.68E-4

Calculation results are shown on Table III.

Table III: Control Effective dose for DBA LOCA

	Dose from the intake source	Dose from the filtration source	total
Effective dose (mSv)	1.87E+00	5.24E+00	7.11E+00
fraction	26.3%	73.7%	100%

Dose contribution of infiltration flow is higher than intake flow in spite of small flow rate(25 cfm) than intake flow(3,200 cfm). Because atmospheric dispersion factors at infiltration flow point is much higher than intake flow point and the amount of radioactive iodines to inflow from infiltration point is larger than those from intake point.

2.5 Sensitivity Analysis

Sensitivity Analysis is performed by changing infiltration flow rate. Intake and recirculation flow rate are fixed value as shown on the Table I. Infiltration flow rate is changed from 10 cfm to 100 cfm using 10 cfm interval and control room personnel dose is calculated, respectively. Same method is used for infiltration flow rate from 100 cfm to 500 cfm using 100 cfm interval. Design infiltration flow rate of base case is 25 cfm. Sensitivity analysis results are shown on Figure 2.

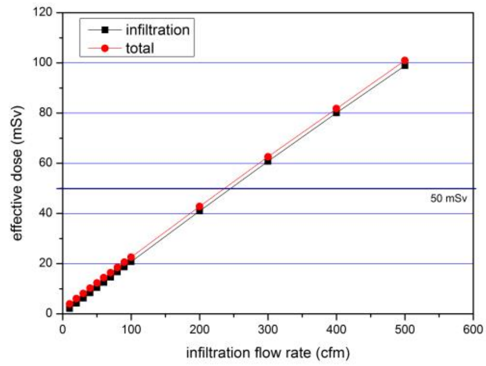

Fig. 2. Sensitivity results with the change of the infiltration flow rate

From the sensitivity analysis results, the maximum allowable infiltration flow rate is estimated based on the annual radiation worker dose limit (50 mSv). The maximum allowable infiltration flow rate is estimated to be about 200 cfm considering 10% margin of uncertainty.

3. Conclusions

Dose contribution of unfiltered flow to the control room is evaluated using APR 1400 design data. Sensitivity analysis of control room habitability with increasing infiltration flow rate is performed. The maximum allowable infiltration flow rate is estimated based on dose guideline of enforcement decree of nuclear safety act, and the calculated maximum allowable unfiltered air flow rate of 200 cfm will be used as reference data for the control room in-leakage test and control room HVAC design.

REFERENCES

[1] “Shin-Kori 3&4 Final Safety Analysis Report, rev.1”, KHNP, 2015.
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[5] NUREG/CR-6604, “RADTRAD: A Simplified Model for RADionuclide Transport and Removal And Dose Estimation” Sandia National Laboratories, 1997