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Main Control Room Safety in the Condition of Main Steam Line Break with Containment Temperature

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1. INTRODUCTION

One of the most severe secondary side DBA (Design Basic Accident) is MSLB (Main Steam Line Break). Some fission products are released from the pipe of the main steam line. FSAR (Final Safety Analysis Report) includes radiation dose results at EAB and LPZ. In this study, sensitivity analysis is carried out in the condition of containment temperature. Main item of analysis is the MCR safety evaluation in MSLB inside containment. This case is not DBA in the scope of the radiological estimation.

At any rate, in this case, the radiological sequence would be simulated in the study level. The focus of this study understands the radiological phenomena effects in the condition of containment temperature.

The radiological consequence is affected by the condition of various thermal hydraulic phenomena.

To check the MCR safety, the sensitivity analysis carried out using the unfiltered air flow rate of MCR intake. The unfiltered air flow rate of MCR intake is the key parameter. The parameter can be used as the margin of in-leakage test and as the safety analysis assumption of FSAR.

In this paper, RADTRAD software is selected for MCR safety analysis.

And the onsite air dispersion factor is calculated by using ARCON 96 code which is the calculation tool for the onsite air dispersion factor in MCR dose [1-6].

The sensitivity analysis is carried out to find the margin of in-leakage air flow rate of MCR sealing test and the radiation dose results.

2. METHODOLOGY

2.1. Regulations and Its Applications

Regulatory Guide 1.196 and NEI 99-03 show the criteria of whole body and thyroid in dose limit. According to these documents, the criteria limits are 50mSv at whole body and 500mSv at thyroid [2-4]. The in-leakage test of MCR should be verified by experimental method using the trace gas. The trace gas leakage test should be met the unfiltered air flow rate of MCR intake written on FSAR

In this study, the maximum unfiltered air flow rate is calculated for MCR safety (Fig. 2). The maximum value will be used as the criteria of the trace gas leakage test (or in-leakage test) of MCR. The purpose of this study shows the predicted margin of the in-leakage air flow rate. The unfiltered air flow rate of in-leakage test is related to the MCR habitability for operator's safety based on Generic Letter 2003-01[4-6].

2.2. Application of MSLB Conditions

Generally speaking, MSLB is affected by Iodine spiking phenomena. Dose evaluation for MSLB inside containment is not DBA, but the radiation dose estimation is handled according to DBA method. Iodine behavior is very complex in calculating the radiation dose. Even the iodine behavior calculation is handled as like DBA MSLB. [1, 2].

Fig.1 shows the concept of MSLB dose analysis. In the case of MSLB inside containment, the pathway is strongly dependent on the containment leakage model as Fig.1.

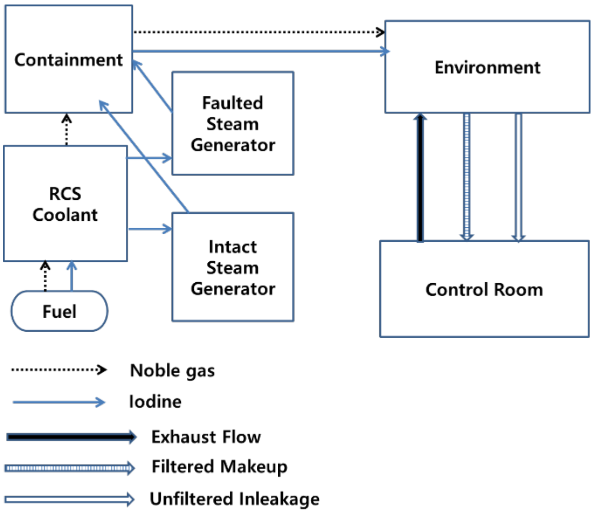

Fig. 1 Radiological Analysis Concept in Main Steam Line Break inside Containment.

In this study, energy-mass release data from MSLB into containment is calculated by LOFTRAN code. These data is calculated to generate the pressure and temperature in containment of MSLB.

LOFTRAN code is developed by Westinghouse Co. to estimate the various non-LOCA thermal hydraulic phenomena for the Westinghouse type NPP.

In duration of MSLB inside containment, the fission products release rate (the case of RCS to containment atmosphere and the case of SG to containment atmosphere) is calculated by CONTEMPT code.

CONTEMPT can calculate the temperature/pressure of containment. The calculation results are used as input data of RADTRAD code.

MCR safety estimation method is similar to LOCA methodology. MCR methodology concept is introduced in Fig.2 in next section.

2.3. Basic Concept for MCR Safety

In this chapter, MCR safety work frame would be explained, in conception, considering two categories.

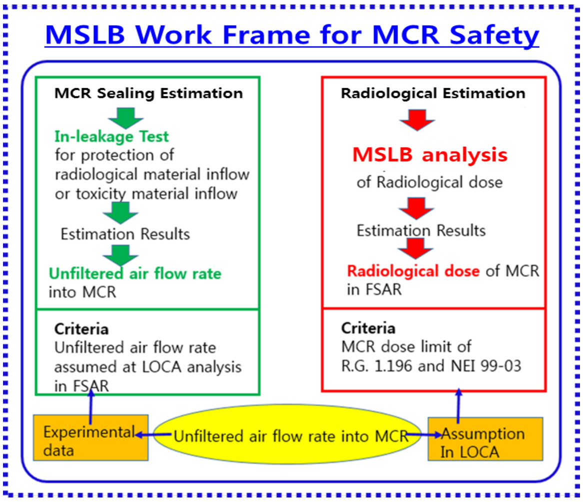

Fig.2 Basic concept of MCR Safety (MSLB inside containment)

As explained in previous section, the estimation work frame of MSLB inside containment is shown as Fig.2. MCR safety consists of two scopes which are the radiation dose of MSLB and the in-leakage test. Fig.2 shows the concept in both of them.

Otherwise, the experimental data of in-leakage test should be within the assumption of FSAR.

Fig.2 exactly shows the relation between in-leakage habitability (in-leakage test and unfiltered air flow rate) and radiological habitability (dose estimation and FSAR assumption).

2.4. Release simulation of Fission Products

For calculation of MCR dose, the source term is selected in modeling 2 pathways to MCR during accident. The pathways of fission products are below:

a. Containment air through the environment into MCR intake goes into air filter system and air unfiltered way.
b. Radioactive plume due to containment purge system before containment isolation through the environment into the intake of main control room with air filter system and air unfiltered way.

2.5. Onsite dispersion factor by ARCON 96 code.

In onsite dispersion factor, some parameters are used as below [5]:

a. Release height: Onsite dispersion factor includes a middle point between the minimum point and the maximum point of the wind instrumentation heights. If the release height point is lower than this midpoint, X/Q is calculated using the lower wind data. If not, the higher wind data is used.
b. Wind direction: North is the reference direction used as either 0 or 360 degrees.
c. Building area: Building wake factor's key point of X/Q near the building structure. This is strongly dependent on the direction and building cross-sectional area.
d. Wind speed: A wind speed group which is distributed by 13 regions and each maximum value of each wind speed group as like 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0.

2.6. Dose Calculation

MCR safety is based on the Regulatory Guide and NEI99-03. Also, MCR safety is very sensitive and is very dependent on unfiltered air flow rate.

In the previous chapter 2.3, the two pathways of the fission products behavior are shown.

Among those pathways, the containment purge model is very small contribution to dose results compared with the containment leakage model. Because of that, only containment leakage model is considered in this study.

In the analysis of containment leakage model, some assumptions are used in calculating the MCR dose. That is based on US NRC Regulatory Guide 1.195.

a. Radioactive fission product's decay is not considered, that is, it is very conservative.
b. Containment leak rate is assumed up to the specified maximum leak rate based on Technical Specification.
c. Operator's breathing rate is 3.5E-04 m^3/sec in the condition of main control room.

Additionally, MCR dose is needed to calculate onsite dispersion factors by using ARCON 96 code.

In on-site dispersion factors, some parameters are shown as below [1-6]:

a. A surface roughness length : 0.1m ~0.2m
b. An angular width : 90 degree(+/- 45)
c. A sector-averaged width is used for more than 8 hours.
d. standard deviations of a Gaussian plume are used as sector-average default.
e. Horizontal dispersion coefficient and vertical dispersion coefficient are calculated by using standard deviation of a Gaussian plume.
f. The time averaged scale is ranged from 1 hour to 720hours, in which X/Q are averaged and calculated.
g. A meteorological data set is about 50,000 data sets during one year. The data set is made by the meteorological data detected every 10 minutes during 365 days. In this study, these data sets for 4

years are prepared as the matrix of ARCON 96 and go into input file.

3. ANALYSIS INPUT

3.1. Basic Input for On-site Dispersion Factor

In basic parameters, horizontal dispersion coefficient (σ-x) is zero and vertical dispersion coefficient (σ-z) is some changed. This option can reflect the atmospheric stability class methodology of "delta T / delta Z".
And this option is more conservative than the other method. Meteorological data and condition are collected from 10m detector tower and 58m detector tower. This methodology is similar to the data collection method for offsite atmospheric dispersion factor. In source parameters, the building area is changed with the range from 30m^2 to 1000m^2.

Table1. Input parameter and conditions range of ARCON 96

Input	Values
Basic parameters	Surface roughness length : 0.15m Angular width : 360 degree Threshold wind speed : 0.3m/sec Sector-average width : 4 or 90 degree σ-x, σ-z : 0, 0~1. 5 Averaged durations : 1 hour~ 720hours
Meteorological Conditions	Wind Speed : 14 categories Stability class : 7 categories (delta T/deltaZ) Detector tower : 10m and 58m
Source parameters	Release type, Release height : Ground, 0~10 m Building area : 30 m^2 ~ 1000 m^2 Velocity, Stack radius : default
Receptor parameters	Distance to receptor : 10m ~ 1000m Intake height : 0~5m Elevation difference : 0~2m Direction to source : 180 degree or 90 degree

3.2. MCR Condition Information in LOCA

MCR conditions are referred from the final safety analysis report.
The HVAC system of MCR has the function to protect operators from the radiation dose under the dose limit criteria (whole body 50mSv, Thyroid 500mSv).
When the SIAS (Safety Injection Actuation System signal) or CREVAS (Control Room Emergency Ventilation Actuation Signal) is generated, the normal HVAC system is isolated, the emergency HVAC is automatically started. At this time, the exterior intake is automatically isolated and the external air pass through the emergency filter system go into MCR inside. This structure is to remove and to mitigate the direct radioactive material's effect. But unfiltered air flow would be existed such as control room openings and leakage from HVAC ducts.

Table 2. Input data of control room

Input parameter	Value
Filtered air intake (cfm)	4,000
Unfiltered air intake (cfm)	10
Recirculation flow rate(cfm)	8,000
Filter efficiency (%)	99
MCR free Volume (cubic feet)	5.7E+05
Breathing Rate (cubic meter/sec)	3.5E-04

4. RESULTS AND DISCUSSIONS

4.1. Base Case Analysis

Table 3 includes onsite atmospheric dispersion factor calculation results by using ARCON 96 code from this study.
Total prepared data set is about 200,000 data sets (duration of 4 years: about 50,000 data sets per year).
As previously shown, the one-year data set are made by every 10 minute's meteorological values detected from 10m high tower and 58m high tower during 365 days.
Table 4 shows the MCR dose calculation results in the condition of unfiltered air flow 10 cfm and recirculation flow 8,000cfm.

Table 3. Onsite atmospheric dispersion factors X/Q

Time (hours)	X/Q (sec / cubic meter)
0 ~ 2	1.17e-03
2 ~ 8	1.17e-03
8 ~ 24	7.11e-04
24 ~ 96	6.37e-04
96 ~ 720	6.03e-04

Table 4. Base case calculation results on control room dose (unfiltered air flow: 10 cfm)

Dose Item	Value (mSv)	Dose criteria (mSv)
Whole body	1.1	50
Thyroid	20.01	500

4.2. Containment Temperature and Dose rate

Containment temperature analysis is carried out by CONTEMPT code. The results are focused in sensitivity of re-evaporation rate from 2% to 10%.
The effect of re-evaporation rate is proportional to the rate in the duration from 24seconds to 120seconds. But even though the 10% re-evaporation, dose increase is very small. At the whole body case, the dose is 1.13 mSv, and at the thyroid case, the dose is 20.09 mSv, comparing with the base case calculation.

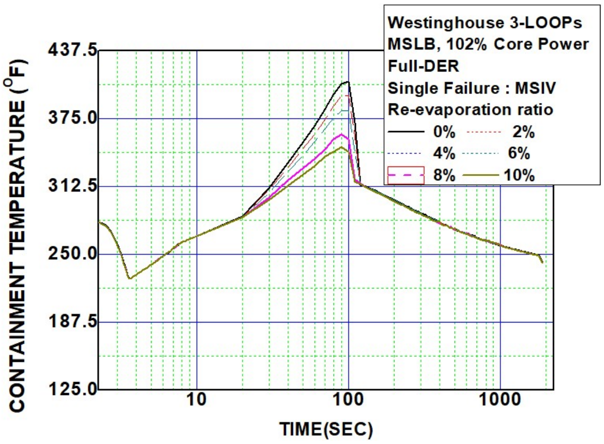

Fig. 3 Containment Temp. in each re-evaporation rate

4.3. Sensitivity Analysis

From previous section 4.2, the dose of 10% re-evaporation is maximum value. In this reason, the sensitivity analysis is always carried out in the condition of 10% re-evaporation rate.

The unfiltered air flow range is from 10 cfm to 160cfm by each increase of 10 cfm.

The filtered air flow rate and the MCR recirculation flow rate are fixed value as shown on the Table 2.

MCR safety is strongly dependent on the unfiltered air flow rate because the unfiltered value directly impacts the MCR in-leakage experiment test. Because of that, the key parameter is selected as the unfiltered air flow rate.

Fig 4 and Fig 5 show the results of MCR sensitivity analysis about thyroid dose and whole body dose.

From sensitivity results, MCR in-leakage test margin to protect the operator against fission products release is more than 150cfm.

Finally, in the case of MSLB inside containment, every case of unfiltered flow rate is not beyond dose limit.

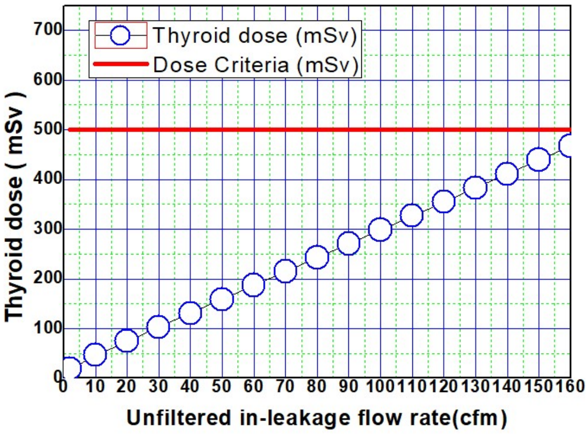

Fig. 4 Thyroid dose in unfiltered air flow rate

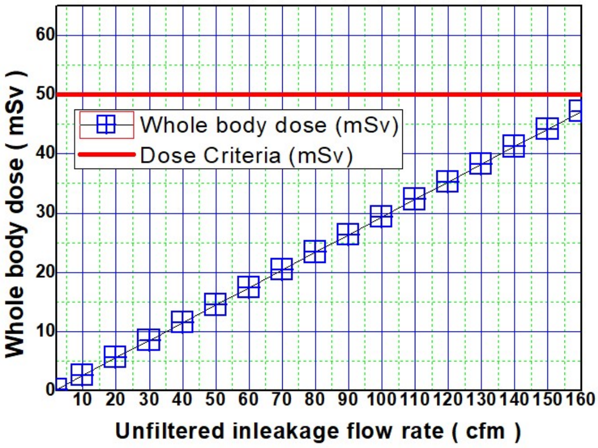

Fig. 5 Whole body dose in unfiltered air flow rate

5. CONCLUSIONS

MCR safety check for the unfiltered air flow rate of in-leakage test and dose estimation is carried out by basic case analysis and sensitivity analysis.

Onsite atmospheric dispersion factor is calculated using ARCON 96 code.

From this work, some conclusions are derived as below:

a. The base case analysis results are 1.1mSv at whole body and 20.1mSv at thyroid in 10 cfm of FSAR base assumption.
b. The increase of dose results in the condition of the re-evaporation 10% and containment temperature is very small about 0.08 mSv.
c. From sensitivity analysis results, every case is not beyond the dose limit in MSLB inside containment.
d. Onsite maximum atmospheric dispersion factor is 1.17e-03 sec/m^3 during 8 hours.
e. The meteorological data for onsite dispersion factor is prepared using 200,000 data sets for 4 years.

From some conclusions, we know that every sensitivity case is meet the dose limit of 50 mSv at whole body and 500 mSv at thyroid.

Through this conclusion, MCR safety of MSLB inside containment is good in every sensitivity case.

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