Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 23-24, 2019

Main Control Room Safety and Dose Estimation in OPR 1000

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1. INTRODUCTION

Since TMI accident, MCR (Main Control Room) issue has been developed by the MCR dose assessment using the LOCA source term. In current, in-leakage test problem is added by the Generic Letter 2003-01.

MCR safety includes two cases such as the radiological estimation and the in-leakage test (the MCR habitability based on unfiltered air flow experiments).

In this study, the MCR safety means the MCR habitability.

In the case of in-leakage test, MCR unfiltered air flow rate is very important.

Specially, the unfiltered air flow rate of intake of MCR is used as the assumption of LOCA MCR dose in FSAR. And the unfiltered air flow rate is used as the criteria in the case of the sealing test (or in-leakage test) of MCR. The MCR sealing test is related to the protection of operator against the toxic material release and the fission products release through HVAC. Because of that, the unfiltered air flow rate is very important to the in-leakage test for MCR habitability.

Additionally, the in-leakage test results of MCR should be within the unfiltered air flow rate of FSAR.

If the in-leakage test result (experimental unfiltered air flow rate) is beyond the unfiltered air flow rate of FSAR, the unfiltered air flow rate of FSAR should be revised by the experimental value from the in-leakage test result. And also, MCR dose re-estimation should be carried out and compared with the dose criteria. If the re-estimation result is not meet the MCR dose criteria, some action items should be carried out to solve the MCR issue.

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 MCR analysis assumption of FSAR.

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

The containment leakage of fission products in DBA LOCA is used as the source term of RADTRAD software. 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 habitability (Fig. 1). 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. Basic Concept for MCR Habitability

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

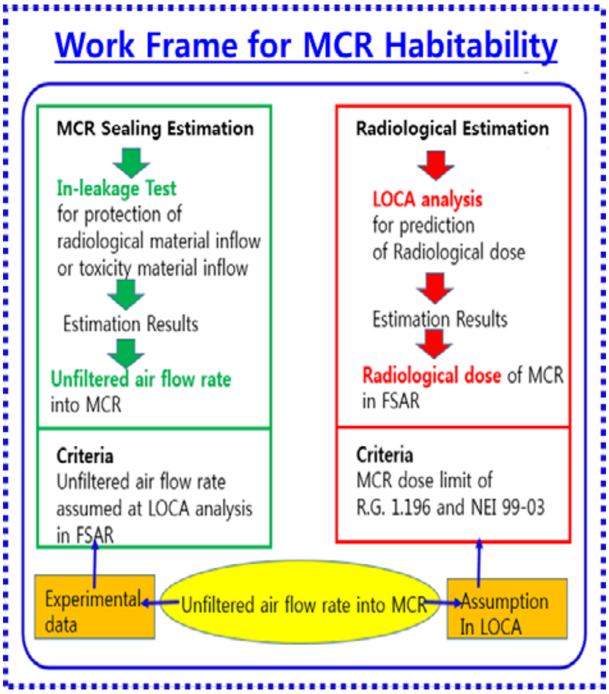

Fig.1 Basic concept of MCR Habitability

In previous section, it is explained for MCR analysis. MCR habitability consists of two scopes which are the

radiation dose of LOCA and the in-leakage test. Fig.1 shows the concept in both of them.
Otherwise, the experimental data of in-leakage test should be within the assumption of FSAR.
Fig.1 exactly shows the relation between MCR sealing estimation (in-leakage test and unfiltered air flow rate) and radiological estimation (dose estimation and FSAR assumption).

2.3. Release simulation of Fission Products

For calculation of MCR dose, the source term is selected from the FSAR chapter 15 which is based on the DBA LOCA. In the base case, the source term is referenced from HANUL 3,4 FSAR.

In OPR 1000, there are 3 pathways to the control room during DBA LOCA.

The pathways of fission products are as follows:

a. Containment air through the environment into MCR intake goes into air filter system and air unfiltered way.
b. Recirculation sump leakage through the aux building into the environment and go to the intake of main control room with air filter system and air unfiltered way.
c. 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.

2.4. 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. Calm condition: calm can be defined as hours with no wind or as very small wind speed.
d. 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.
e. 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.

2.5. Dose Calculation

MCR habitability is based on the Regulatory Guide 1.196 and NEI99-03. Also, MCR habitability is very sensitive and is very dependent on unfiltered air flow rate.

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

Among those three pathways, the containment purge and the recirculation sump leakage pathways are very small contribution to dose results compared with the containment leakage model. Because of that, only containment leakage release 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. Containment spray system function is credited about removal of radioactive iodine.
b. Radioactive fission product's decay is not considered, that is, it is very conservative.
c. Containment leak rate is assumed up to the specified maximum leak rate based on Technical Specification.
d. Operator's breathing rate is 3.5E-04 m3/sec in the condition of main control room.
e. In containment, the mixing flow rate between the sprayed region and the unsprayed region is used as 2 turnovers as containment volume per hour.

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 [5]:

a. A surface roughness length : 0.1m ~0.2m
b. An angular width : 90 degree(+/- 45)
c. Minimum wind speed: 0.2m/sec, this wind is calm condition and the input hourly meteorological preparing process is checked by a calm-processing subroutine of ARCON96.
d. A sector-averaged width is used for more than 8 hours.
e. 4 standard deviations of a Gaussian plume are used as sector-average default.
f. Horizontal dispersion coefficient and vertical dispersion coefficient are calculated by using standard deviation of a Gaussian plume.
g. The time averaged scale is ranged from 1 hour to 720hours, in which X/Q are averaged and calculated.
h. A meteorological data set is about 50,000 data sets during one year. The data set is made by the meteorological elements detected every 10 minutes during 365 days. In this study, these data sets for 6 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[5]

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 shows the design data information of OPR 1000[1].

Table 2. Input data of OPR 1000 control room [1]

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

The base case analysis is carried out based on LOCA source term of FSAR and R.G. 1.195.
Table 3 includes onsite atmospheric dispersion factor calculation results by using ARCON 96 code from this study.
Total prepared data set is about 300,000 data sets (duration of 6 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	1.20e-03
2 ~ 8	1.20e-03
8 ~ 24	7.58e-04
24 ~ 96	6.96e-04
96 ~ 720	6.70e-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	4.57	50
Thyroid	93.2	500

4.2. Sensitivity Analysis

Fig 2 and Fig 3 Show the results of MCR sensitivity analysis about thyroid dose and whole body dose.
The allowable in-leakage flow rates are calculated by the sensitivity analysis using the parameter of unfiltered air flow rate.
The analysis range is from 10 cfm to 100cfm by each increase range step of 10 cfm.
The filtered air flow rate and the MCR recirculation flow rate are used as fixed value as shown on the Table 2.
MCR analysis 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.
From sensitivity results of Fig. 2 and Fig. 3, the unfiltered air flow rate margin of the in-leakage test for MCR habitability is 82 cfm at thyroid dose and 97cfm at whole body dose.

About in-leakage test, the predicted range of the unfiltered air flow rate is suggested up to 82cfm and 97 cfm.
Absolutely, the maximum allowable unfiltered flow rate is about 82 cfm considering MCR in-leakage test and dose limit criteria.

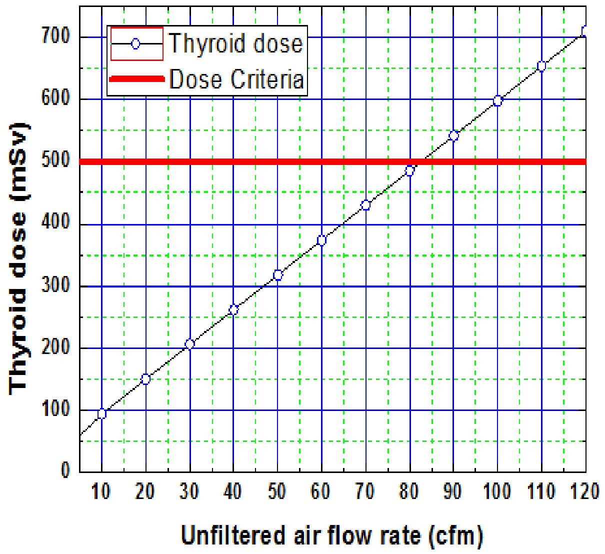

Fig. 2 Thyroid dose in unfiltered air flow rate

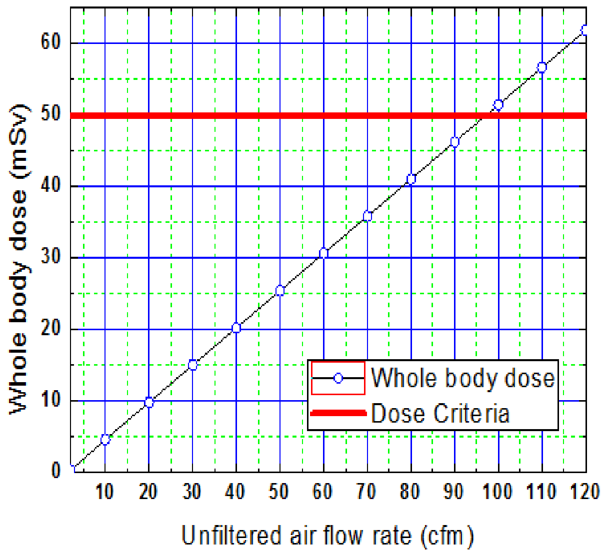

Fig. 3 Whole body dose in unfiltered air flow rate

5. CONCLUSIONS

MCR habitability margin for the unfiltered air flow rate of in-leakage test and dose estimation is estimated by base 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 4.57mSv at whole body and 93.2mSv at thyroid when 10 cfm is assumed as the unfiltered air flow rate of FSAR.
b. From sensitivity analysis results, the safety margin of in-leakage flow rate is 82cfm at thyroid and 97cfm at whole body.
c. Onsite maximum atmospheric dispersion factor is 1.20e-03 sec/m^3 during 8 hours.

From some conclusions, the maximum allowable unfiltered air flow rate for in-leakage test is 82cfm at thyroid. This value will be used as new standard value for the control room in-leakage test and control room HVAC design. This study shows the FSAR assumption 10 cfm is very conservative in the margin of the unfiltered air flow rate for the control room in-leakage test.
Finally, the unfiltered air intake flow rate of MCR would be suggested as 82cfm.

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