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Analysis Methodology of Clean Agent Fire Extinguishing System Discharge Test for NPP MCR Raised Floor

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1. Introduction

Since fire in the Main Control Room (MCR) can seriously affect the reactor safety shutdown actions, fire safety equipment is installed to minimize the possibility of fire generation and to suppress the fire [1]. Some of the domestic nuclear power plants have a raised floor structure in the MCR, viewing room of the MCR and the electrical equipment room. A large amount of cables are installed in the raised floor.

IG-541 clean agent fire extinguishing system is installed in the lower part of the raised floor to ensure safety in case of fire [2]. When a fire occurs in the raised floor, fire extinguishing should be possible with IG-541 clean agent. However, there is an airway between the raised floor and the Main Control Board (MCB), which may cause leakage of IG-541 clean agent.

A real-scale test facility was constructed to perform a real-scale clean agent fire extinguishing agent test on the lowered area of the raised floor. In this paper, a total of seven test methods were derived after considering the limited test methods for obtaining the optimum concentration of the agent under raised floor from each test.

2. Methods and Results

2.1 Verification testing facility

The full scale model of MCR is based on the main control room of the OPR1000 type nuclear power plant. The model room size is as shown in Fig. 1.

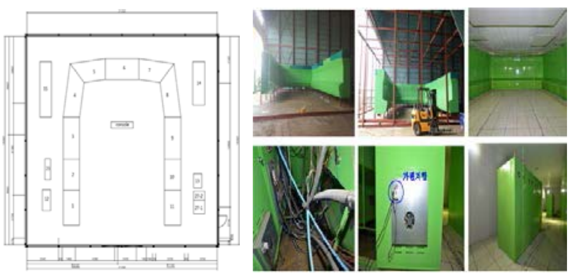

Fig. 1. Main control room and electric compartment installation

The main control board and the electric compartment installed inside are made in the same size as that installed in the actual main control room, and the internal raised floor has the same floor structure. Also, in case of fire extinguishing facilities, piping and nozzles were installed as close as possible to those installed in the target nuclear power plant. The amount of fire extinguishing agent and minimum design concentration are summarized in Table 1.

Table 1: Extinguishing agent quantity and minimum design concentration data

	Space Vol.(m^3)	Required Agent Vol.(m^3)	Cylinder Vol.(m^3)	Agent Bottle (ea)	Amount of Agent Vol.(m^3)
Initial discharge	218.04	38.7	13.393	8	147.33
Extended discharge				3	

2.2 Test method

In the case of nuclear power plants with raised floors in the main control room, the amount of agent was calculated by limiting the IG-541 clean agent fire extinguishing system to the bottom of the raised floor, and equipment is installed accordingly. Especially, as the cables, etc. are connected, the raised floor, MCB and the electric compartment are likely to be open to some extent between the raised floor and the lower floor. Since the volume of the MCB is larger than the volume of the raised floor, it is also possible that if the amount of agent is calculated taking into consideration only the volume of the raised floor and the facility is installed, it may not meet the required level of adequate extinguishing agent required by the NFPA 2001.

Table 2: Test conditions for actual scale agent discharge test cases

Test case	Fan	Opening Ratio (%)	Div.	Amount of Extinguishing Agent(ea)	Agent discharge method
1	on	100	×	Initial 8, Extended 3	After 1 minute, extended release
2		30	×	Initial 8, Extended 3	After 1 minute, extended release
3		30	×	Initial 8, Extended 3	After 2 minute, extended release
4		30	×	Initial 8	Initial release 1 min, no extended release
5		30	○a)	Initial 8	Initial release 1 min, no extended release
6		30	○b)	Initial 8	Initial release 1 min, no extended release
7		0	×	Initial 8, Extended 3	After 1 minute, extended release

a) Symmetrically divided into quadrants
b) Asymmetrically four compartment

Therefore, we constructed a test system that simulates the raised floor of the nuclear power main control room and considered the test methods to find out the predictable problems and to find ways to improve them in the target power plants in the future. Table 2 shows summary of test conditions for actual scale agent discharge test cases.

The IG-541 clean agent fire extinguishing system has a total of eleven nozzles (8 initial discharges, 3 extended discharges) at the bottom of the raised floor. During discharged, the eight initial nozzles discharge the agent for one minute, then the extended nozzle releases the agent for next one minute. The MCR of OPR1000 type nuclear power plants are blocked by about 70% between the raised floor and MCB, 100%, 30% and 0% opening as a test method means worst-case (100% open), actual conditions (30% open), and ideal conditions (0% open) respectively. Other open conditions (for example, 70%, 50%, etc.) were not considered because of the expense of the discharge agent and the difficulty of the test preparation period. To make the worst case conditions, "off" condition of the fan was not considered.

A. *100% open under MCB and electric compartment, extended release after 1 minute (Case 1)*

This is the most conservative test condition. The bottom of the raised floor, the MCB and the electric compartment are fully opened. In this case, it is most likely that the agent substance leaks to the upper volume of MCB from the bottom of the raised floor.

B. *30% open under MCB and electric compartment, extended release after 1 minute (Case 2)*

When the MCB and the electric compartments are fully opened, it does not correspond to the actual situation of the power plant main control room. Therefore, when 70% of the opening of the MCB and the electric compartment that are in contact with the raised floor is closed, the concentration of the oxygen under raised floor is checked when the agent is discharged.

C. *30% open under MCB and electric compartment, extended release after 2 minutes (Case 3)*

Even when the opening ratio of the MCB and the electric compartment is 30%, it is assumed that the proper agent concentration does not appear according to the agent leakage to the MCB & the electric compartment, then the initial discharge nozzle is changed to the 2 minute discharge nozzle, and launching extended release at 2 minutes after the initial release. The agent releases 8 bottles of initial release and 3 bottles of extended release, identical to the conditions set in the target nuclear plant.

D. *30% open under MCB and electric compartment, no extended release (Case 4)*

When the opening rate of the MCB & the electric compartment is 30%, the test condition for analyzing the agent concentration by the initial release is to check the concentration of the agent when only the initial release container is discharged without extended discharge. In addition, the lower part of the electric compartment where the fans speed are the fastest and have the many fans is completely closed, and the agent is discharged to check the concentration of the agent under the raised floor.

E. *30% open under MCB and electric compartment, no extended release, parcel into quadrants (Case5)*

There are many nozzles distributed in some areas as agent release nozzles are not symmetrically installed on the underside of the raised floor of the MCR. In some areas, nozzles are sparse and fire extinguishing agents are not evenly distributed. This test condition is to symmetrically divide the area of the raised floor into four quadrants to confirm the concentration distribution of each zone. The area of the raised floor is divided into 4 quadrants (Fig. 2. Left), and the concentration of agent in each floor area of the raised floor is checked by releasing only the agent in the initial discharging container with 30% opening of the lower part of the MCB & electric compartment.

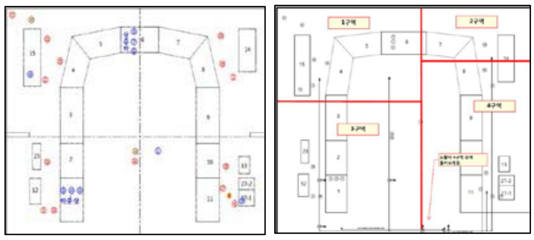

Fig. 2. Four equal split drawing of raised floor & Asymmetric compartment of raised floor

F. *30% open under MCB and electric compartment, no extended release, four compartments asymmetrically (Case 6)*

When the quadrant is symmetrically divided, a uniform distribution of the agent concentration is not formed in each zone because one nozzle is distributed in some areas and several nozzles are distributed in some areas. Therefore, in order to get uniform the concentration of the agent, the area of the compartment is divided so that the amount of the releasing agent is uniform compared with the volume of each compartment (Fig. 2. Right).

G. *100% seal under MCB and electric compartment, extended release after 1 minute (Case 7)*

When the lower parts of the MCB & electric compartments are opened, even if they have a small area, the agent will leaks to the open area. Therefore, in this test, the lower part of the MCB & electric compartments which are in contact with the raised floor are completely closed, subsequently, the agent is released to confirm the concentration of the raised floor. In the previous test, the compartment below the raised floor is completely removed and the agent is released, and an overpressure outlet with an appropriate area is installed.

3. Conclusions

In order to verify the performance of clean agent fire extinguishing system for the raised floor of MCR, seven cases were set up so that the experiment can be performed by controlling the opening ratio of the connection portion with the MCB. The selected cases were combined with 100%, 30%, 0% opening ratio of MCB, initial discharge time (1 or 2 minutes) and extended discharge, respectively.

To verify the validity of the gas system fire extinguishing system reliability of the operator habitability by conducting the tests of these seven cases in the future, continuous experiments are needed to obtain valid results and to ensure the reliability of the results. The results of this study will be applied to verify the performance of the clean agent fire extinguishing system of the real-scale test facility in the future.

REFERENCES

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