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Experimental and Numerical Investigation of Clean Agent Fire Extinguishing System for Main Control Room of Nuclear Power Plants

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1. Introduction

MCR (Main Control Room) is the place where takes actions to keep NPP (Nuclear Power Plant) safe. In case of a fire in MCR, major functions to achieve and maintain reactor safety shutdown can be lost. Especially, fire at raised floor of MCR could causes severe consequences since the main cables which control the NPP are routed below the raised floor. Therefore, fire extinguishing system should be installed below the raised floor and IG-541 of clean agent system has been adopted considering the habitability of MCR operators. In this paper, to verify the performance of clean agent system under raised floor, experiment and numerical analysis of the small scale module are performed, respectively. Test model is built in 1 over 3 scale down of actual MCR, and concentration of IG-541 is observed during discharge time. Analysis Results of FDS (Fire Dynamics Simulators) are compared with the experiment data and it shows good agreement in an aspects of concentration of IG-541.

2. Experiments of 1/3 module

Experiments for clean agent fire extinguishing system are performed by FILK (Fire Insurers Laboratories of Korea) using its fire detector test module composed with upper and lower areas divided by raised floor. There is a cabinet at the center of the test module and it has a large opening, which connects inside volume of the cabinet to below area of the raised floor. Opening area is about 50% of the cabinet bottom surface, and additional two holes are located on the side surface to release generated heat from the cabinet. Total amount of the IG-541 applied for the test is 93.6 kg, and 435 seconds are taken including initial and extended discharge time. Sensors are installed to measure the portion of oxygen, and concentration of IG-541 is calculated based on the measured oxygen data. Configurations and dimensions of the test module are shown in Figure 1.

3. Numerical analyses with FDS

To compare the numerical analysis results with the experimental data, FDS is adopted as a calculation tool. In this section, main assumption and techniques used for the FDS analysis are described.

3.1 Limitation of application

Since FDS solves Navier-Stokes equation with flows of low Mach number, less than 0.3, it could have some limitations to simulate the high-velocity problem [1]. When clean agent is discharged, high-velocity region near the discharge nozzle is expected. However, the purpose of this analysis is not to identify the detailed flow around the nozzle, but to check the concentration of clean agent throughout the whole area. Therefore, FDS is applied despite of the limit on solving the high-velocity problem.

3.2 Modeling of clean agent

IG-541 is an inert gas consists of 52% Nitrogen, 40% Argon and 8% Carbon Dioxide which extinguishes fire by reducing the concentration of Oxygen. Considering its composition and fire extinguishing characteristics, internal keyword of 'custom species mixture' is applied to simulate the mixing and transportation of IG-541. Additional chemical reactions are not considered in this analysis.

3.3 IG-541 discharge analysis for 1/3 Module

1 over 3 scale module of MCR shown below Figure 2 is composed of upper and lower volume of the raised floor. Inside volume and openings of the cabinet are also modeled for simulation because discharged IG-541 could get into the cabinet though the bottom opening and some portion of it will be emitted from the side holes to the upper volume of the simulation domain. Discharge nozzle is modeled with a cube, and vents are located on 5 surfaces only excluding the upper side.

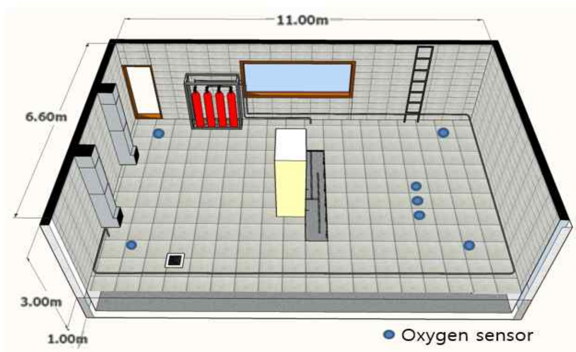

Fig. 1. Dimensions of test module and locations of major equipment for clean agent discharge test

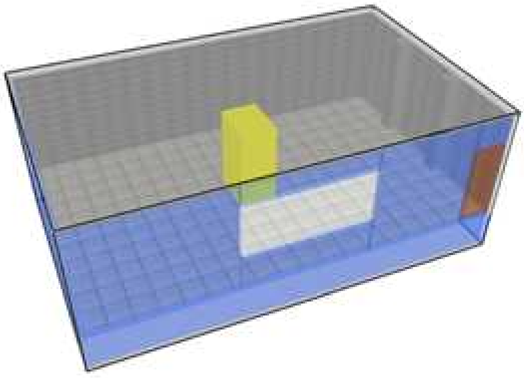

Fig. 2. Geometry model of 1/3 analysis module

Based on the minimum design concentration of 38.10% [2], total amount of required clean agent is calculated. Since the number of clean agent cylinder must be an integer, the calculated result is rounded up and total three cylinders are installed for the experiment. Due to the increased amount of discharged clean agent, design concentration is also increased to 50.86%, which is called adjusted design concentration. Analysis is performed for 1200 seconds and concentration of IG-541 is monitored to verify whether 95% and 85% of minimum design concentration at 60 seconds and 660 seconds are individually achieved or not [3]. Figure 3 shows the time histories of concentration of IG-541 measured at different locations. According to the analysis result, required concentrations of IG-541(48.31%, 43.23%) are satisfied and fairly similar tendency is observed by comparing it with the experiment results.

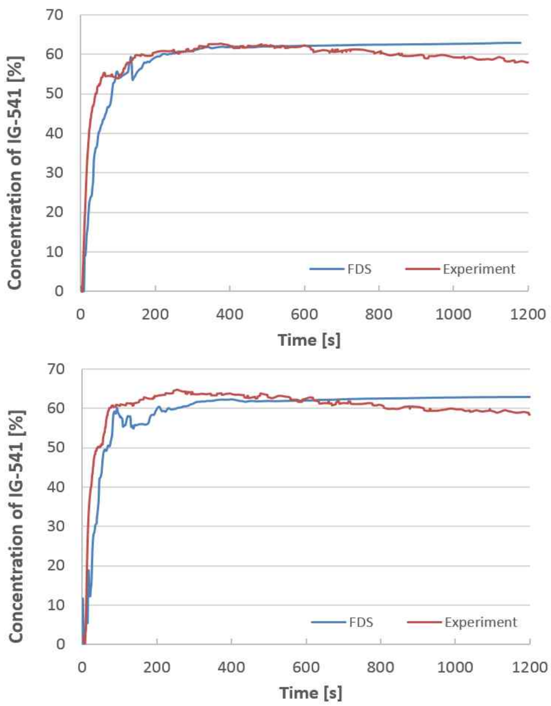

Fig. 3. Numerical and experimental result of clean agent discharge test

4. Conclusions

To verify the performance of clean agent (IG-541) fire extinguishing system for the enclosure below the raised floor of MCR, experimental and numerical studies are independently performed. 1/3 scale module of MCR is selected as a target model and time history of IG-541 concentration is measured. 95% and 85% level of minimum design concentration are satisfied in both of experiment and numerical simulation showing little difference.

REFERENCES

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[3] NFPA 2001, Standard on Clean Agent Fire Extinguishing System, 2015.