

Fire Hazard Evaluation of a Simplified Cable in Research Reactor Control Room

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1. Introduction

Fire in NPPs (Nuclear Power Plants) may lead to radiation leakage accidents and subsequent environmental contaminations. Causes of the fire are categorized as electrical, oil, and others. In particular, possibility of the electrical fire was the highest cause in both USA and Korea [1].

Evaluations of fire hazard have been mainly performed for commercial NPPs. A control room in the reactor was an essential place to control safety systems under normal conditions, and there were many cables connected with various safety systems. If fire breaks out and/or affects these cables, operators may not take appropriate mitigation actions.

In this paper, fire hazard evaluation is carried out for a typical cable in research reactor control room using FDS (Fire Dynamics Simulator) [2]. Thereby, temperature and heat flux of the cable are estimated until operators' reaction time. The results are compared with damage criteria, and integrity assessment results of the cable are discussed.

2. Analysis Methods and Conditions

An electrical cabinet was assumed as ignition source and two locations in a simplified cable was set as targets. For more conservative assessments, fire protection systems and other barriers against the fire were excluded. In addition, properties of thermoplastic cables were adopted because they are more vulnerable to the fire than thermoset ones.

2.1 Fire Scenarios

Fire scenarios were classified into two circumstances depending on locations of the ignition source. The ignition source of electrical cabinet was located at the top surface in Scenario A and at the close surface with cables in Scenario B. It means that circumstances of Scenario B are more severe than those of Scenario A. Fig. 1 shows locations of the ignition source.

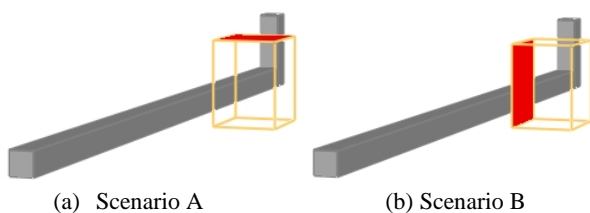


Fig. 1. Locations of ignition source

Two locations of the cable as targets were determined taking into account distances from the ignition source and characteristics of the control room; target 1 was the upper face which is the nearest to the electrical cabinet and target 2 was the upper face which is connecting from the control room to reactor room. The distance between left hand side of the electrical cabinet and right hand side of the cable is 0.4 m. Fig. 2 depicts schematic of the ignition source and targets. Through four grid sensitivity analyses, optimum size of the grid cell was determined to have a dimension of 0.1 m.

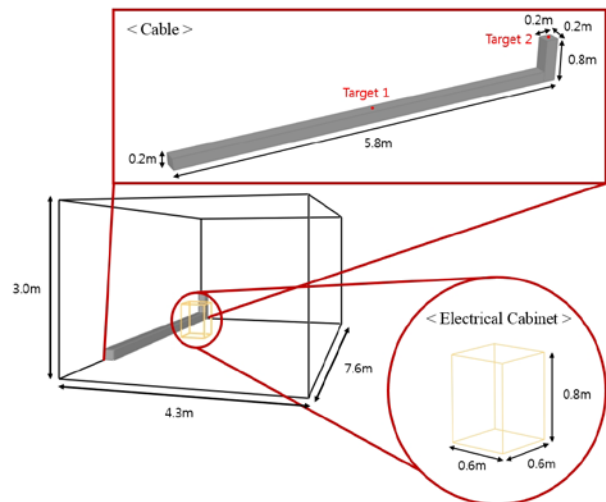


Fig. 2. Schematic of ignition source and targets

2.2 Analysis Conditions

Among thermoplastic cables, PVC material is selected because it has been commonly used in NPPs and material of electrical cabinet is steel. Their properties were referred to NUREG-1934 and summarized in Table I [3].

Table I: Material properties used in fire hazard evaluation

Material	Thermal conductivity (W/m-K)	Specific heat (kJ/kg-K)	Density (kg/m ³)
Steel (Source)	54.0	0.465	7,850
PVC (Target)	0.2	1.289	1,380

In addition, the heat release rate of ignition source was referred to NUREG/CR-6850 [4]. It has grown to a maximum of 702 kW by 720 sec as time-squared form. It was applied for operators' reaction time (300 sec), which is generally considered in fire suppression [5]. According to periodic inspection report of the research reactor by KINS (Korea Institute of Nuclear Safety) in

2015, all of fire detectors activated within 60 sec. Therefore, it can be regarded that 300 sec is enough to be implemented. Also, the initial temperature was set to 20 °C since the control room is maintained at room temperature.

2.3 Damage Criteria

The damage criteria dependent on electrical cable types were set based on NUREG/CR-6850 [4]. The specific values of thermoplastic cable were 205 °C for temperature and 6 kW/m² for heat flux. If these damage criteria are violated in target surfaces, from a conservative point of view, it can be regarded as loss of cable integrity.

3. Analysis Results

3.1 Scenario A

In Scenario A, temperature and heat flux in target 1 were higher than those in target 2 due to closer distance from the ignition source as anticipated. At 300 sec, which is the operators' reaction time, temperature was 21.2 °C and heat flux was 0.48 kW/m². Fig. 3 shows temperature and heat flux histories, and Fig. 4 represents temperature distribution at 300 sec.

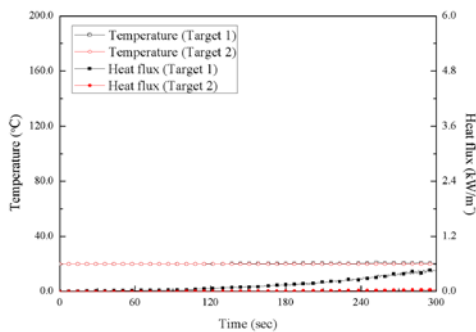


Fig. 3. Temperature and heat flux histories in Scenario A

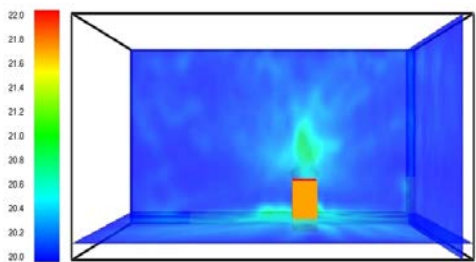


Fig. 4. Temperature distribution at 300 sec in Scenario A

3.2 Scenario B

In Scenario B, temperature was 30.6 °C and heat flux was 4.21 kW/m² at 300 sec. All of temperature and heat flux in target 2 were also remarkably less than those in target 1. Fig. 5 represents temperature and heat flux histories, and Fig. 6 depicts temperature distribution at 300 sec.

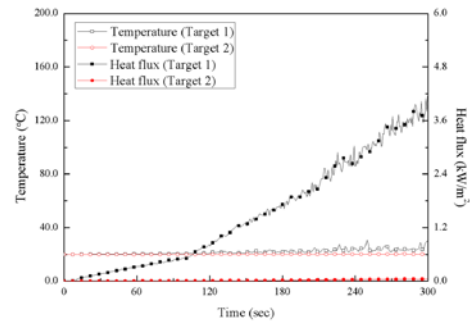


Fig. 5. Temperature and heat flux histories in Scenario B

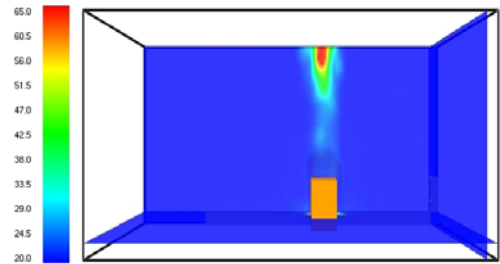


Fig. 6. Temperature distribution at 300 sec in Scenario B

4. Conclusions

In this research, fire hazard of a typical cable in research reactor control room was evaluated. Thereby, the following key findings were derived.

- (1) Until operators' reaction time (300 sec), the cable sustained integrity under both Scenarios A and B.
- (2) Detailed fire hazard evaluation is being carried out for more diverse scenarios and conditions as well as using alternative thermal-structural coupled analysis technique.
- (3) Further uncertainty analyses will be performed for more reliability.

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