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Integrity Assessment of Cables in Zero-power Reactor Room under Postulated Design-based Electrical Fire

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1. Introduction

Recently, hazard analyses become gradually important to manage Nuclear Power Plants (NPPs) and take measures against various accidents based on strengthened legislative regulations and standards [1, 2]. Especially, among various hazard causes, the number of fire accidents is increasing. For this reason, investigation of fire accidents is required for educational and research reactors as well as huge commercial reactors.

The causes of fire are categorized as electrical, oil, batteries, and others. Among diverse causes of fire, the electrical fire occurs most frequently in NPPs. In zero-power reactor room, there are safety related cables connecting operating console. It is necessary to evaluate the cables with electrical fire conditions.

The objective of this research is to introduce the hazard assessment for the cables under design-based fire conditions in a zero-power reactor room. After setting representative postulated scenarios, numerical analyses were carried out for two types of cables using Computational Fluid Dynamics (CFD) with Smagorinsky turbulence model. As results, temperature and heat flux profiles were calculated and their maximum values were compared with corresponding damage criteria.

2. Analysis methods and conditions

2.1 Fire scenarios

The zero-power reactor is operated with a licensed power of 10 W. The reactor is located in an independent structure and divided into several spaces such as reactor room, control room, administration room, corridor, and so on [3]. Figure 1 depicts a part of zero-power reactor room. The dimension of the room is 10.0 m x 9.7 m x 10.0 m. There are many cables such as safety related cables and cable connecting electrical cabinet.

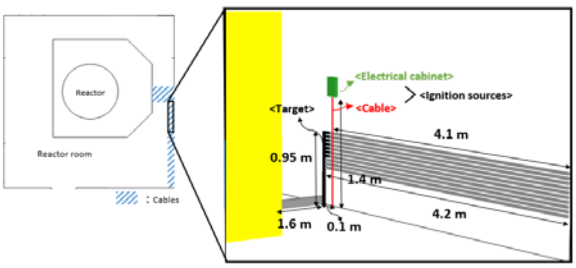


Fig. 1. Schematic of zero-power reactor room

Table I summarizes the postulated fire scenarios with ignition sources and targets. The ignition source was an electrical cabinet in Scenarios A and B, while both electrical cabinet and connecting cable were ignition sources in Scenarios C and D. And also, targets were safety related cables. As targets, Polyvinyl Chloride (PVC) and Cross-linked Polyethylene (XLPE) were each selected as the representatives of thermoplastic and thermoset cables. The minimum distance between ignition sources and targets was 0.04 m.

Table I: Postulated fire scenarios

Scenario	Ignition source	Target
A	Electrical cabinet	PVC
B	Electrical cabinet	XLPE
C	Electrical cabinet & Connecting cable	PVC
D	Electrical cabinet & Connecting cable	XLPE

2.2 Analysis conditions and model

The heat release rate of electrical cabinet was referred to NUREG/CR-6850 [4]. In Figure 2, the fire has grown to 211 kW as time-squared form, endures with maximum point, and attenuates linearly to zero. For cables linked with electrical cabinet, the maximum heat release rate was 271 kW [5]. In this study, design-based fire conditions were implemented, including the time for fire to grow with maximum value.

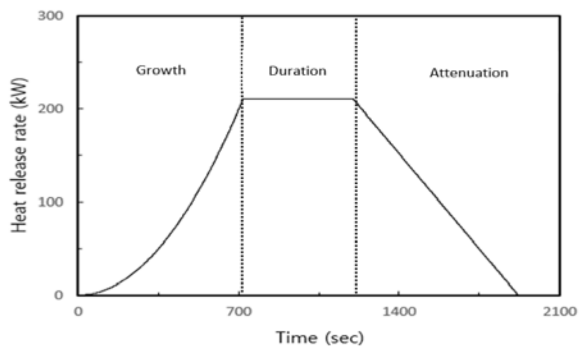


Fig. 2. Heat release rate of electrical cabinet

The material properties of cables were used in NUREG-1934 [6]. The initial temperature was set to room temperature. The flexible conduit surrounding cables and other fire protection systems were excluded.

Figure 3 shows the analysis model in Fire Dynamics Simulator (FDS) [7]. The temperature and heat flux were calculated using Smagorinsky turbulence model. The damage criteria [4] of the PVC cable were the temperature of 205 °C and heat flux of 6 kW/m^2. Likewise, those of the XLPE cable were the higher temperature of 330 °C and heat flux of 11 kW/m^2.

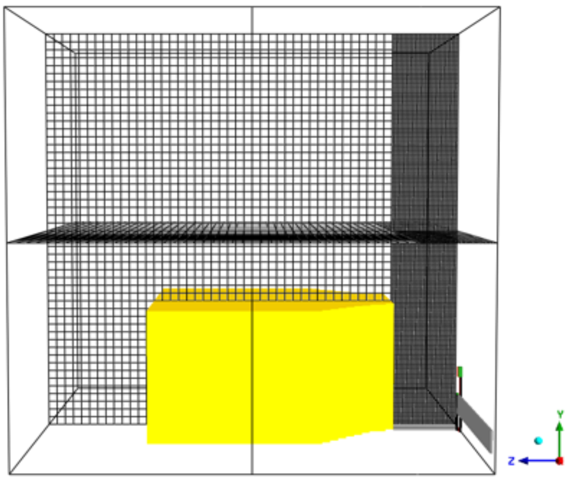
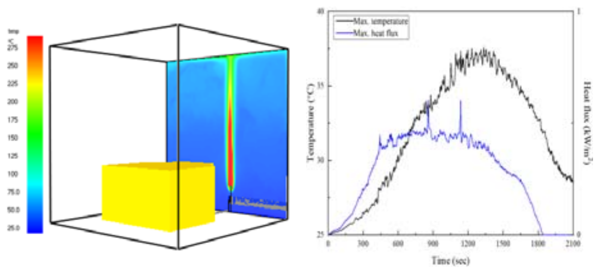


Fig. 3. Analysis model

3. Analysis results

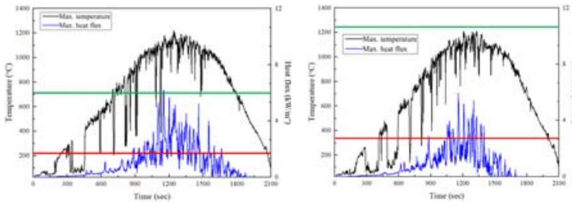
Figure 4 represents the temperature distribution and heat flux results in Scenario A. The maximum temperature was 37.6 °C and the maximum heat flux was 0.6 kW/m^2. The values in Scenario B were 0.8 % higher in view of temperature and 2.4 % higher in view of heat flux than those in Scenario A. In scenarios A and B, the safety related cables sustained integrity.



(a) Temperature distribution (b) Temperature and heat flux profiles

Fig. 4. Temperature distribution and heat flux results in Scenario A

The temperature and heat flux profiles in Scenarios C and D were evaluated in Figure 5. In case of two ignition sources, the maximum temperature of PVC cable exceeded the damage criteria in 235 sec and that of XLPE cable reached in 414 sec. In point of heat flux, the heat flux values of the PVC cable were higher than the criteria in 1,150 sec. However, the XLPE cable maintained integrity.



(a) PVC (b) XLPE

Fig. 5. Temperature and heat flux profiles in Scenarios C and D

4. Conclusions

In this study, the integrity assessment of the safety related cables under design-based fire conditions were implemented in a zero-power reactor room with postulated fire scenarios. In the subsequent, the maximum temperature and heat flux of the cables were compared with the damage criteria. The conclusions of this analyses are as follows:

(1) Because the XLPE cable have higher thermal conductivity than the PVC cable, the temperature and heat flux of XLPE cable were higher than those of PVC cable.

(2) In terms of maintaining integrity of the cables, the temperature was vulnerable than the heat flux in these scenarios.

(3) Further validation studies and more various scenarios reflecting the appropriate ignition sources and targets in zero-power reactor will be performed.

ACKNOWLEGMENTS

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