The Evaluation of the Fire Protection in Hot Cell Facilities

Woo Jin Jo*, Seok-Jun Seo, Siwan Noh, Hyo Jik Lee, and Seung Nam Yu

Korea Atomic Energy Research Institute, 111, Daedeok-daero, 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea

*wjjo@kaeri.re.kr

1. Introduction

The Korea Atomic Energy Research Institute (KAERI) has been developing a pyroprocess technology to reduce the waste volume and recycle some of the elements in spent nuclear fuel. KAERI conducted the preliminary concept design of the Korea Advanced Pyroprocessing Facility (KAPF) based on the design requirements and criteria.

Hot cell facilities shall be designed in such a way that the possibilities of fire and its effects are minimized, since it involves the release of radioactive material during a fire. In addition, the facilities should prevent fire and need a rapid fire detection and extinguish. Structures, Systems, and Components of the facilities should be designed to protect the safety functions of the facilities even if they are not quickly extinguished by fire-fighting system.

In this paper, the design criteria and Codes&Standards as well as domestic and foreign regulations related to the fire protection were analyzed. In addition, anticipated fire accidents in the hot cell facilities were derived and the fire load was calculated.

2. Fire Protection for the Hot Cell Facilities

2.1 Act, Standards, Guides, Regulations, and Codes&Stndards

In Korea, article 110 of the enforcement decree of the Nuclear Safety Act requires the necessary measures for the nuclear when a fire accidents occurs with leakage of radioactive materials. In addition, documents related to Codes&Standards, planning, and safety analysis of fire protection are provided in the public notice and enforcement rule on Nuclear Safety Commission.

Unlike Korea, the United States has many experiences in facility operation, so Act and regulatory authority can provide more details. Domestic and foreign regulations related to the fire protection are listed in the table blow.

Table 1. Applicable regulations and guides on fire protection for nuclear fuel cycle facilities

Applicable regulation, guides and Codes&Standards		
Regulations	ROK	• Enforcement regulations of Nuclear Safety Act • Enforcement rule of the Radiation Safety Criteria • Act on Fire Prevention and Installation, Maintenance, and Safety Control of Fire-fighting Systems • Enforcement Act on Fire Prevention and Installation, Maintenance, and Safety Control of Fire-fighting Systems
	USA	• 10CFR Part 50 appx. A Criterion 3 • 10CFR Part 70 subpart H
Guides	ROK	• Public Notice on the establishment and implementation of fire protection plan • Public Notice on the fire risk analysis
	USA	• NUREG-0800 • DOE-STD-1066 • NFPA 80, 780, 801 • NCR BTP CMEB 9.5-1 • UL 555
Codes&Standards	NFPA 801, 12, 13, 2001 NFFSC 101, 102, 106, 107A, 109 ASTM Material standards UL 555 KEPIC FPN-801, FPC-11, 12, 13, 14, 20, 24, 2001	

3. Evaluation of the Fire Protection

3.1 Flow of the Evaluation of the Fire Protection

For the evaluation of the fire severity and required fire resistance rating, the fire load should be calculated. In order to calculate the fire load, the evaluation area must be set up first. Then the calculated fire load can be used for evaluation of fire severity and the fire resistance rating. The procedure of the fire protection evaluation for hot cell facilities is performed in the flow chart as shown in Fig. 1.

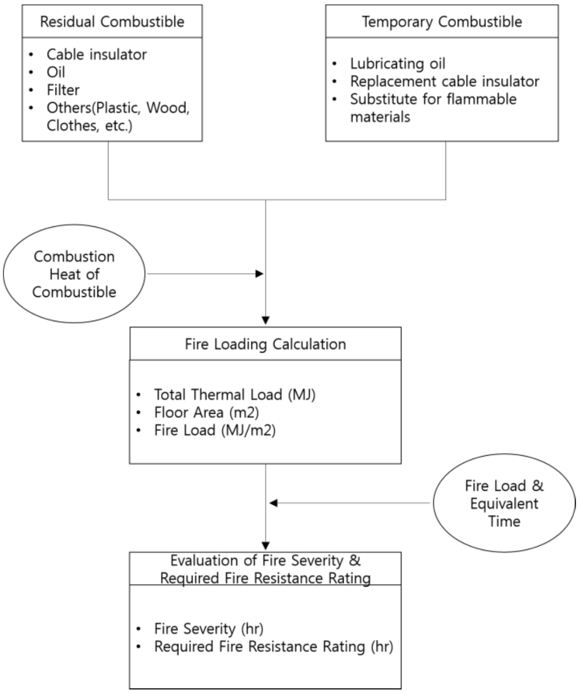

Fig. 1. Flow chart for the evaluation of fire severity and required fire resistance rating.

3.2 Evaluation of the Fire Protection

For the evaluation of fire severity and required resistance rating, it is necessary to determine the place where fire is expected from the entire facility area. Then fire hazards, that is, of the amount of combustible materials in the area of interest were identified. Using the identified the amount of combustible materials, which means the fire hazards in the area of interest, fire loads can be calculated by following equation.

$$Q = \sum m_i h_{ci} \quad (1)$$

$$Q'' = Q/A \quad (2)$$

where, Q is the total fire load (MJ), m_i is the mass of the combustible material i (kg), h_{ci} is the calorific value of the combustible materials i (MJ/kg), A is the floor area of the place of interest (m^2), and Q'' is the fire load in the area of interest (MJ/m^2).

The equivalent fire severity can be obtained by dividing the fire load per area of interest by the calorific value of the general combustible materials, W (kg/m^2), given as:

$$W = Q''/18.608 \quad (3)$$

In this paper, a part of the headend process cell derived from the KAPF preliminary concept design were analyzed. Because of the lack of design information, it is assumed that the combustible materials in the headend process cell is only cables. The calorific value of the cable and general combustible materials were assumed as 28.3 and 18.608 MJ/kg, respectively. The calculated fire load and fire severity were 11.9 MJ/m^2 and 30 mins respectively.

Headend process cell is equipped with a fire detector, a gas type extinguish system and an alarm system, and the hot cell structure it self is set to fire rating 3 hours (highest grade), so that it functions as a fire barrier. In addition, the damper installed at the confinement boundary can prevent the leakage of the radioactive material that generated by the fire. Therefore, safety can be secured even in case of the fire accident at the headend process cell.

4. Conclusion

In this paper, the regulations, standards, and guides related to the fire protection for the hot cell facilities are summarized. Based on the previous KAPF preliminary concept design, the fire protection capability of the headend process cell as evaluated using the fire load and the fire severity.

It is also important to establish the fire protection system in compliance with the laws and standards, but it is important to establish a reasonable and optimized the fire protection plan through performance-based fire protection evaluation as previously described.

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