Manual fire fighting tactics at Nuclear Power Plant

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1. Introduction

The general requirements of fire protection at nuclear power plant (NPP) are fire protection program, fire hazard analysis, and fire prevention features. In addition, specific fire protection requirements such as water supplies, fire detection, fire protection of safe related equipment, and safe shutdown capabilities must be provided. Particularly, manual fire fighting is required as specific requirements with the provisions to secure manual fire suppression, fire brigade and its training, and administrative controls for manual fire fighting [1].

If a fire is alarmed and confirmed to be a real fire, the fire brigade must take manual fire fighting activities as requested at fire protection program. According to the present requirements in itself, there is not any specific manual fire fighting ways or practical strategies. In general, fire zones or compartments at NPPs are built in a confined condition. In theory, the fire condition will change from a combustible-controlled fire to a ventilation-governing fire with the time duration. In case of pool fire with the abundant oxygen and flammable liquid, it can take just a few minutes for the flash-over to occur. For the well-confined fire zone, it will change from a flame fire to a smoldering state before the entrance door is opened by the fire brigade [2].

In this context, the manual fire fighting activities must be based on a quantitative analysis and a fire risk evaluation. At this paper, it was suggested that the fire zones at NPPs should be grouped on the inherent functions and fire characteristics. Based on the fire risk characteristics and the fire zone grouping, the manual fire fighting tactics are suggested as an advanced fire fighting solution.

2. Fire Hazard Analysis and Risk Management

2.1 Fire growth at a confined fire zone at NPPs

At NPPs, most of fire zones are well confined with thermal barriers including HVAC systems with fire dampers. The fire resistant rating of walls, floors, and penetrations is at least two or three hours. The figure 1 shows the patterns of fire growth curves depending on the available oxygen and combustibles. The severest condition is the curve for design basis fire that is defined as all the combustible within a fire zone is burnt out regardless of available oxygen. If the fire zone is tightly confined, then the oxygen is depleted in a few minutes until the fresh air is supplied from outside.

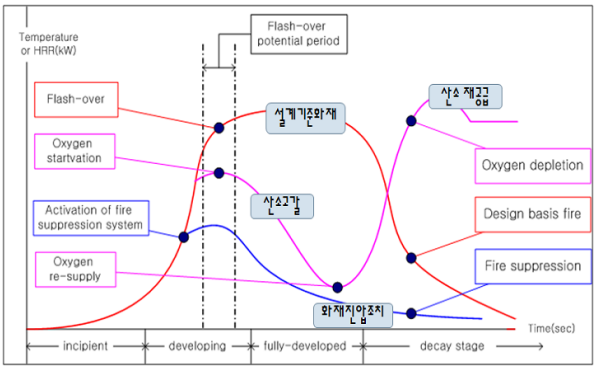

Fig. 1. Patterns of fire growth curves at a confined zone

The best condition is the fire suppression curve with the activation of fire suppression system. One of critical factors of fire risk and manual fire fighting ways is the flash-over potential period. The total heat released until the door is manually open and the available amount of oxygen are another important factors for fire risk. In this aspect, the manual fire fighting strategies must be based on the fire hazard analysis and risk evaluation against stereotyped manual fire fighting actions.

2.2 Improper manual fire fighting activities

As an example, a well-confined diesel oil tank room was selected to compare the fire risk for two scenarios. At scenario #1, the door was not opened at all and manual fire fighting action was not taken. At scenario #2, the fire brigade arrived at the scene and the door was manually opened at 60 seconds after fire ignition.

All conditions at fire scenarios are exactly same except the available oxygen. At fire scenario #1, the fire was changed to oxygen starvation at 137 seconds and the maximum temperature and heat flux to target surface were quite lower than those of fire scenario #2. At this example analysis, it showed that improper manual door opening changed the fire in a more aggravated condition.

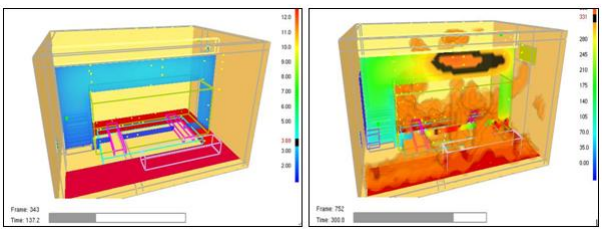

Fig. 2. (a) Fire Scenario #1 (left) (b) Fire Scenario #2 (right)

2.3 Grouping of fire zones or compartments

At the study, the fire zones are categorized into 4 groups based on their safety-related functions and possibilities to give off radioactive materials to outside boundary due to undesirable fire effects. If the fire zone has the safety-related equipment or functions with the possibility of radioactive material release, it is categorized into Special Zone. If it is related with safety functions, it is referred as Red Zone. If there is possibility to release radioactive material due to fire impact, it is designated into Yellow Zone. The other group is White Zone where it is not related with safety functions or the radioactive material release.

Based on the fire zone grouping, manual fire fighting can be executed. For the Special Zone and the Red Zone, the most important concern is to protect the safety-related functions. For the Special Zone and the Yellow Zone, it must be prohibited the radioactive material release outside the fire zone. For the White Zone, the generic ways of manual fire suppression tactics can be effective. With insights for the grouped characteristics of fire zone, the manual fire fighting tactics can support to accomplish the fire defense-in-depth philosophy, that is, the prevention of fire, the protection of fire, and the mitigation of fire damage [3].

Table 1. Grouping of fire zone

Zone Grouping	Specific Function	Sample fire zone
Special Zone	Safety function and Radioactive control	Charging pump room
Red Zone	Safety function	Central chiller room
Yellow Zone	Radioactive control	Spent fuel room
White Zone	General fire zone	Turbine hall

2.4 Specific fire fighting tactics for grouped fire zone

For the Korean standard NPPs where the number of fire zones is about 150 to 200, most of the fire zones are confined with fire barriers. For example, the number of non-confined zones from total 158 fire zones is only 3 in Kori unit 3&4. The average floor area of the 98 confined fire zones is less than 33.8m^2. The other 37 fire zones have quite large fire area whose average floor area is about 223 m^2. The geometric analysis and fire defense-in-depth policy for fire zones signify that fire fighting tactics must be differentiated.

It suggests the specific fire fighting tactics at figure 3 rely on the fire growth state and fire risk situation. At the fire spot, the governing fire condition must be confirmed whether or not it is ventilation or combustible controlled fire. The major factors of fire risk and the prediction of internal condition depend on oxygen concentration, gas temperature, heat flux, internal pressure, or the existence of flammable gas ratio. The fire brigade must have the quantified procedure if it is positive to open the door or to run the movable smoke ventilator in consideration of back fire, flash-over, and other fire risk effects before manual activities.

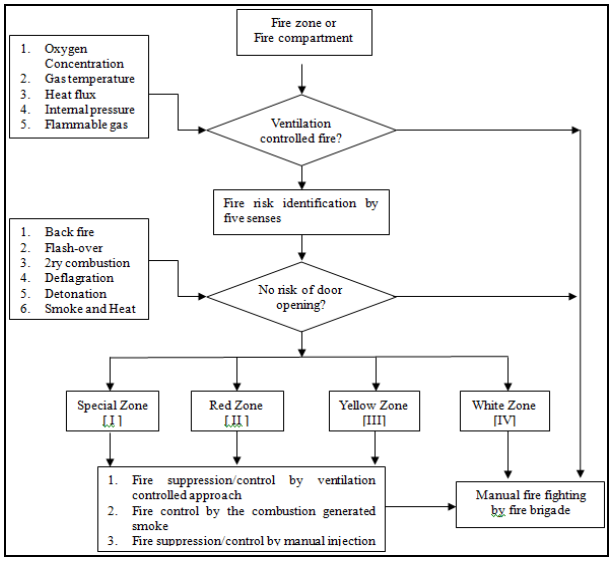

Fig. 3. Specific fire fighting tactics for fire zone or compartment

Depending on the expected fire risks and the characteristics of fire zone, the appropriate way of ventilation control can be taken. In addition, the proper smoke flow pattern or the manual fire fighting can be more effective depending on the fire zone groups and the fire growth situation as shown in figure 3 [4].

3. Conclusions

At this extended summary paper of the performance-based fire fighting strategy for confined fire zone at NPPs, the grouping of fire zones was suggested based of safety-related function and the possibility of radioactive material release. In addition, the specific fire fighting tactics were insisted based fire growth situation and fire risk evaluation.

Even if the quantitative analysis was not reported at this paper in detail, the fire modeling analysis and the quantified fire risk evaluation evidenced that the suggested manual fire fighting tactics will enhance the effectiveness of fire fighting and the protection of fire brigade members from heat and smoke environment.

REFERENCES

[1] U.S. NRC, “10CFR50 App. R, Fire Protection Program”, 1980.
[2] EPRI, “TR-100370: Appendix of FIVE, Analysis of the Transient Thermal Response of Target, FIVE”, 1992.
[3] U.S. NRC, “Standard Review Plan, 9.5.1 Fire Protection Program (CMEB)”, 1981.
[4] Moon-Hak Jee, “Performance-based fire control methods for confined fire compartments at nuclear power plant’, 2010.