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Improvement Of Fire Human Reliability Analysis For Operator Manual Action Quantification

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This paper is to describe the quantification of OMAs (Operator Manual Actions) for a fire PSA (Probabilistic Safety Assessment) with a fire HRA (Human Reliability Analysis) method developed by KAERI (Korea Atomic Energy Research Institute). The NUREG-1852 (US NRC, 2007) established the validity and reliability criteria for OMAs in the event of a fire. It defines an OMA as "operator actions conducted from outside the MCR (Main Control Room) to achieve and maintain a hot shutdown after a fire, excluding repairs." The document further distinguishes OMA into preventive actions and reactive actions, each described as follows:

- preventive actions: measures taken to mitigate potential equipment malfunctions or potential effects of a fire without additional diagnosis upon entering the fire procedure, immediately alleviating anticipated issues caused by the fire;
- reactive actions: measures taken in response to undesirable changes in plant conditions during a fire, where operators detect abnormal changes, diagnose, and execute the correct actions according to procedures, while reactive actions respond to undesired state changes caused by a fire after it has happened.

The OMA discussed in this paper falls under the category of reactive actions. It involves detecting and responding to post-fire MSOs (Multiple Spurious Operations) in accordance with procedures, making it a reactive measure, not preventive. In the analysis of MSO, OMA is considered one of the possible solutions that can be established in the event of non-compliance with the requirements for important safety-related components during a safe shutdown by NEI 00-01 (NEI, 2009). Meanwhile, we developed a guideline for performing a fire HRA required for a domestic fire PSA based on the K-HRA method which is a standard method for HRA of a domestic level 1 PSA developed by KAERI. Additionally, for the MCRA (MCR Abandonment) phase, the HEP (Human Error Probability) estimation method was established based on the NUREG-1921 supplements (US NRC, 2019, 2020). To quantify OMA with the HRA method, we previously compared the existing criteria for the feasibility and reliability of OMA in NUREG-1852 with the factors of the fire HRA we developed. This comparison allowed us to derive enhancements for Fire HRA (Choi et al., 2023):

- timeline for diagnosing HEP;
- additional considerations regarding wearing the SCBA (Self-Contained Breathing Apparatus).

In this paper, we propose solutions for the enhancements identified in our previous work. The existing fire HRA method takes into account operator action in a local area when controlling the component in the MCR is difficult. However, it does not establish a clear relationship between the decision time for MCRA, the occurrence time of MSO, and related OMA implementation time. Figure 1 shows the timelines for OMA considering MCRA. In Figure 1, MCRA-OMA #1 is for the diagnosing OMA before MCRA determination and MCRA-OMA #2 is for situations where MSOs occurred at the time of the MCRA decision or during the move to the RSP (Remote Shutdown Panel) after the MCRA decision. In the case of MCRA-OMA #2, it is assumed that MCR operators perform the movement to the RSP before diagnosing OMA. Reflecting expert opinions, situations requiring movement to the RSP due to LOH (Loss of Habitability) are considered when MCR residency becomes impossible. In such cases, it is determined that the movement to the RSP takes precedence over everything else. Table 1 shows the proposals for additional considerations regarding wearing the SCBA for OMA quantification.

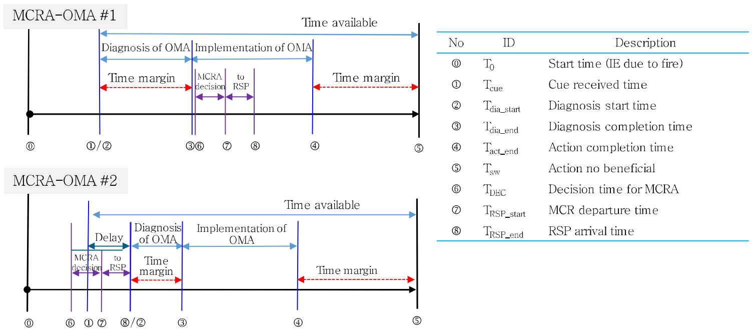

Fig. 1. Timelines for OMA considering MCRA.

Table 1. Considerations Regarding Wearing SCBA for OMA.

Factors	Existing Fire HRA	Modification for OMA Quantification
Time due to SCBA wearing for OMA	In case of an MCR fire, an additional 5 min. to the diagnosis time due to SCBA wearing	In addition to previous considerations, if SCBA is required to be worn when moving to the OMA location, an additional 5 min. to execution time
Stress due to SCBA	Increased stress level from wearing SCBA in case of MCR fire	Increased stress level from wearing SCBA for OMA execution
Communication quality due to wearing SCBA	C&C sequencing error during phase 3 after MCRA	Additional 3 min. of execution time by poor communication quality due to wearing SCBA

We are going to incorporate MSOs and OMAs into the fire PSA model. As an example of OMAs, operators stop CSPs (Containment Spray Pumps) and close their discharge valves manually in the local areas in the event of a CSP spurious start and a CSP discharge valve spurious open due to fire. The OMAs considered in Figure 1 are associated with MCRA and involve the action of controlling components locally in the event of an MCRA situation where control switches for the components necessary for safety shutdown in the RSP are not designed. To find out OMAs related to the MCRA situation, we investigated RSP design and fire protection reports of the reference plant. In the event of a fire in the MCR, the operator will maintain a safe shutdown from the RSP using the Train B ESW (Essential Service Water) pumps (and Train A pumps, if available). However, there are no control switches for the ESW discharge valves at the RSP. Therefore, if the Train B valve (and Train A valve, if available) is spuriously closed with the loss of offsite power, it will cause a complete loss of essential service water. To protect against the spurious closure of the ESW discharge valve, the operator can locally transfer the MCR control to the local mode and reopen the valve. As mentioned above, we have selected some OMAs, including those related to MCRA in Figure 1, for the case study for OMA quantification, and now we are in the process of quantifying them.

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