A Study on the Requisite Information for Severe Accident Management

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1. Introduction

As a part of nuclear safety research, accident management is important to understand the major parameters related to an accident. Although research on severe accidents has proceeded continuously, since the Fukushima accident, even more detailed research has been conducted.

Related this research on arranging the requisite information for severe accident management, the documents of various forms in each country as well as the domestic literature are secured and analyzed. The analyzed information is arranged up to a detailed level. For the secured documents, the issued organizations and the issued purpose are diverse. Thus, the contents of the secured documents are also diverse according to the reactor type, and the purpose and standards of the classification are also diverse. Moreover, terminologies with same meaning are not unified. These various documents are analyzed to arrange the requisite information for severe accident management. The analyzed information is described in this paper in the primary arrangement.

2. Literature Analysis and Information Analysis

In the occurrence of a severe accident, for rapid and systematic management, the related information is analyzed and arranged. To do so, the documents issued in each country as well as the domestic literature, are analyzed. The contents of these documents are arranged and attempted to be utilized as basic data to deduce the requisite information.

2.1 NRC documents

The regulatory guides issued in US NRC were secured through two documents, which were revision 3 issued in 1983 and revision 4 issued in 2006[1, 2]. Within these, in the revision 3 document, the variables of a PWR type reactor were arranged (the variables of a BWR type reactor are excluded and not applicable in a domestic NPP).

From type A to type E, 5 group variables were arranged, and the classification of the phases are not applied. The definitions of the 5 classifications are as follows.

- TYPE A Variables: those variables to be monitored that provide the primary information required to permit the control room operator to take specific manually controlled actions for which no automatic control is provided, and that are required for safety systems to accomplish their safety functions for design basis accident events.
- TYPE B Variables: those variables that provide information to indicate whether plant safety functions are being accomplished. Plant safety functions are (1) reactivity control, (2) core cooling, (3) maintaining reactor coolant system integrity, and (4) maintaining containment integrity (including radioactive effluent control).
- TYPE C Variables: those variables that provide information to indicate the potential for being breached or the actual breach of the barriers to fission product releases. The barriers are (1) fuel cladding, (2) primary coolant pressure boundary, and (3) containment.
- TYPE D Variables: those variables that provide information to indicate the operation of individual safety systems and other systems important to safety (these variables are to help the operator make appropriate decisions in using the individual systems important to safety in mitigating the consequences of an accident).
- TYPE E Variables: those variables to be monitored as required for use in determining the magnitude of the release of radioactive materials and continually assessing such releases.

2.2 FLEX documents

The FLEX documents issued in US NRC were 2 secured documents, and all documents were defined in the classification according to the 3 phases [3, 4]. In these documents, it addressed the key safety functions as follows.

- Provide reactor core cooling and heat removal
- Provide RCS inventory and reactivity control
- Ensure containment integrity
- Provide SFP cooling
- Provide indication of key parameters
- Provide reactor core cooling

Besides these key safety functions, support functions have been identified that provide support for the implementation of the FLEX strategies. These support functions are as follows.

- Providing load stripping of 125 VDC and 120 VAC vital buses to extend the battery life
- Re-powering AC and DC electrical buses

- Providing ventilation for equipment cooling and area habitability
- Providing lighting
- Providing communications capability
- Providing for fueling of portable equipment
- Providing plant and area access

Based on these functions, the definitions of the 10 classifications are decided as follows and the key parameters of each classification and phase are also decided.

- Maintain core cooling & heat removal
- Maintain RCS Inventory Control
- Maintain Containment
- Maintain Spent Fuel Pool Cooling
- Safety Functions Support (Electrical)
- Safety Functions Support (Fuel)
- Safety Functions Support (Lighting)
- Safety Functions Support (Communications)
- Safety Functions Support (Ventilation)
- Safety Functions Support (Accessibility)

2.3 EPRI documents

The documents issued in EPRI were 2 secured documents and were analyzed [5, 6]. In these documents, the methodology was provided, and 3 phases were used as a technical approach as follows.

- Phase 1: Identification of severe accident management information needs
- Phase 2: Identification of severe accident environmental and process conditions
- Phase 3: Evaluation of instruments to meet the information needs and the identification of alternative methods of measuring the needs as required

Two pilot plants (PWR and BWR) were chosen to test the methodology, and plant-specific information as follows was additionally used.

- Dominant IPE plant damage status (PDS)
- MAAP runs for selected dominant PDSs
- Plant-specific EOPs and other applicable procedures
- Plant design information (P&IDs, Instrument Loop Drawings, Layout Drawings, etc.)
- Selected instrument technical manuals
- Pant instrument data

In the first step (Phase 1), three primary inputs are considered as follows.

- Emergency operating procedures
- Severe accident management strategy options
- Core and containment state assessment

Related to the 3rd inputs, the description of various stages of the core and containment states for a severe accident is presented. The core states are defined as follows.

- OX : rapid oxidation
- BD : Badly damaged
- EX : ex-vessel

The containment states are defined as follows.

- CC : Closed, cooled containment
- CH : Closed, challenged containment
- I : Impaired containment
- B : Bypassed containment

Based on this methodology, trial application results are provided as follows.

- Information needs
- Parameters and environmental ranges
- Instruments and survivability

For the PWR type reactor, the trial application results can be summarized as follows.

- 23 information needs identified.
- 46 parameters identified to provide information needs
- 6 instruments did not fully satisfy the initial assessment of suitability or survivability for the selected scenarios:
  + Containment hydrogen monitors
  + Containment temperature
  + Containment sump level
  + Containment high range radiation monitors
  + Hot leg temperature
  + Steam generator level

Between these 6 instruments, alternatives for final four of six are available for obtaining the information needs. The detailed alternatives are also described within the documents.

2.4 Other documents

KEPIC guidance was secured and analyzed [7]. KEPIC guidance applied the documents issued in 2005, and in this guidance five types of variable are used related to accident monitoring.

The general SAMG document for an OPR1000 type reactor was secured and analyzed. In these documents, the 23 variables for the severe accident management were defined accompanied with each setup value.

In addition, the severe accident document for the SMART reactor control room was secured and analyzed [8]. In these document, the monitoring variables of the essential function, the instrumental variables related to a severe accident, and the monitoring variables related to a severe accident are the objects of analysis. Among these, the monitoring variables of the essential function in detail are as follows.

- Variables of core reactivity control
- Variables of core heat removal
- Variables of RCS inventory control
- Variables of RCS pressure control
- Variables of RCS heat removal

- Variables of containment pressure and temperature control
- Variables related containment isolation
- Variables of radioactive emissions control
- Variables related the maintenance of vital Auxiliaries

2.5 Deduction of the requisite information

Through the analysis of various documents, the major requisite information were deduced, and a few of them are described in table I.

Table I: Requisite Information

Parameter	Information category	Detail information
Containment Pressure	Maintain Containment	Containment pressure indication is available in the MCR throughout the event.
Containment Temperature	Safety Functions Support (Electrical)	Containment temperature indication is available in the MCR throughout the event.
DC bus voltage	Safety Functions Support	DC bus voltage is required to be monitored in order to ensure that the DC bus voltage remains above the minimum voltage.
Demineralized water storage tank level	Water resources Maintain Core Cooling & Heat Removal	DWST water level indication is available from the MCR and locally at the tank throughout the event.
Pressurizer Level	Maintain RCS Inventory Control Safety Functions Support (Electrical)	Pressurizer level indication is available from the MCR and C-10. Pressurizer level indication is available throughout the event.
RCS Cold Leg Temperature	Maintain RCS Inventory Control Safety Functions Support (Electrical)	RCS cold-leg temperature indication is available from the MCR and C-10. Cold leg temperature indication is available throughout the event.
RCS Hot Leg Temperature	Maintain RCS Inventory Control Safety Functions Support (Electrical)	RCS hot-leg temperature indication is available from the MCR and the auxiliary shutdown panel. Hot leg temperature indication is available throughout the event.
RCS Wide Range Pressure	Maintain RCS Inventory Control Safety Functions Support (Electrical)	RCS Wide Range Pressure indication is available from the MCR and C-10 throughout the event.
SFP water level	Maintain SFP Cooling	Water level indication will be provided in accordance with the requirements of NRC Order EA-12-051. Water level indication will be available throughout the event.
Spent Fuel Pool Level	Maintain Spent Fuel Pool Cooling	Spent Fuel Pool Level

3. Results and Conclusions

Based on the documents of a related severe accident, the major information was analyzed. The information is different according to the reactor type, classification standard, and classification standard of the safety function. Thus the information is classified variously.

In this study, based on the analysis results of the documents described these information, the major information and parameters are examined as safety function. And the results of parameters and information including the safety function and the detail information are induced. These results will be applied in severe accident management.

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