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A Proposal on EOG based on a Symptom-based approach for a Research Reactor

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1. Introduction

Following the Three Mile Island Unit 2 (TMI-2) accident, the United States Nuclear Regulatory Commission (NRC) established the sets of requirements addressing their objective to improve the quality of operational information for dealing with emergency events in nuclear power plants. [1][2][3][4]

The Emergency Operating Guidelines (EOG) should be presented to provide technical information to prepare reactor-specific Emergency Operating Procedures (EOP) which cover operation during emergency events.

Applicants for operating license and licensees of reactors under construction are required to:

- Perform analyses of transients and accidents including multiple failures
- Prepare emergency operating guidelines
- Upgrade emergency procedures, including procedures for operating with natural circulation conditions
- Conduct operator retraining

The Procedure Generation Package (PGP) should be submitted to the regulatory body in Korea for the reactor licensing at the same time with Final Safety Analysis Report (FSAR), where PGP includes:

- Reactor-Specific Technical Guidelines (RSTGs),
- EOP Writer's Guide,
- EOP Verification Procedure
- EOP Validation Procedure
- EOP Training Program
- EOP Implementation Program

The information should comply with those requirements associated with the development of EOG according to the Korean atomic law [5][6][7][8]. All assumptions made in the EOP, which relate to safety analysis, must be verified to be true and appropriate for each user by each user.

Furthermore, a set of EOP are required as one of operating procedures that shall be developed for all safety related operations that may be conducted over the lifetime of the facility in research reactors by international standards, Safety of Research Reactors (IAEA NS-R-4) [9][10]: 7.51 (g) the reactor operator’s response to anticipated operational occurrences and DBAs and, to the extent feasible, to BDBAs.

In Korea, the regulation on codes and standards for nuclear facilities such as research reactors recommends the nuclear facilities operating organization to prepare EOP.

Hence a set of EOG is proposed for helping to develop the EOP in a simplified manner for a research reactor.

In this paper, it is described about a development and a revision of a set of EOG for a research reactor.

2. Development of EOG

2.1 Requirements on EOG systems

A goal of the EOG is to provide the best available technical information to be used for developing reactor-specific EOP. Each reactor has an extensive network of procedures. EOP must be coordinated with the existing procedures. The content and scope of the EOP developed from EOG should be designed to interface with, but neither overlap nor duplicate, reactor procedures.

The EOG are designed to be used independently and cross referencing is minimized. Cross referencing is appropriate only when the other guideline entry conditions are achieved during the course of operation.

2.2 Interfaces and Structures of EOG systems

An understanding of what constitutes an emergency is a prerequisite to deciding what information is to be collected and in which format that information is to be arranged. For the purpose of the EOG, an emergency event is distinguished from other off-normal reactor operations by virtue of its severity; it is sufficiently severe that a reactor trip is either activated automatically or required to be manually initiated to mitigate the event. FIG. 1 depicts the distinction between emergency operating procedures based on these guidelines and other off-normal procedures.

Emergency events can be divided into two classes:

1) the operators can ascertain the general type of the event by recognizing its correlated symptom set from control board indications and their knowledge of the reactor and recent operating history. For these events where an accurate diagnosis can be made, it is highly desirable to provide mitigating guidance which is selected and sequenced to strategically address that symptom set. Since these types of events have been well analyzed and understood (e.g., Loss of Coolant Accident (LOCA), Loss of normal Electric Power (LOEP), and etc.), it is possible to write the event-based recovery emergency operating procedure guidelines to optimize the recovery (i.e., minimize release of

radiation, minimize system leakage, reduce risk of core damage, etc.). For ease of use, these events have been grouped;

2) the operators are unable to identify a unique symptom set for the disturbance. This may be due to errors in symptom assessment by the operators; multiple, simultaneous failures in the reactor (e.g., combined LOCA and LOEP, and etc.); the occurrence of a heretofore unanalyzed event (e.g., loss of flow capability, and etc.); or instrumentation failures which distort the symptom picture.

EOG must provide guidance for both classes of emergencies. Thus, when a reactor trip occurs or should occur, the operators can refer to guidance which will provide a safe response whether or not a symptom set is identified: EOG written to treat specific symptoms are called event-based recovery guidelines (ERG); the EOG which provides guidance for undiagnosed events for which a reactor trip is required is called the Symptom-based Recovery Guidelines (SRGs).

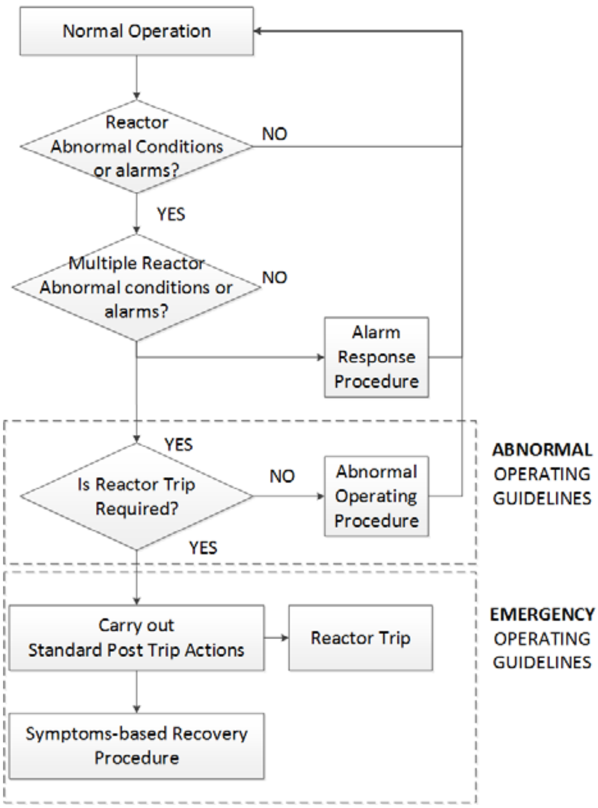

Fig. 1. Overall view of operational procedure

2.3 Safety Functions

2.3.1 The Concept of Safety Functions

The concept of safety functions introduces a systematic approach to reactor operations based on a hierarchy of protective actions. The protective actions are directed at mitigating the consequences of an event and, once fulfilled, ensure proper control of the event in progress. A safety function is defined as a condition or action that prevents core damage or minimizes radiation release to the public. A complete set of safety functions needs to be fulfilled to ensure proper operator control of the event and public safety. The actions which ensure fulfillment of a safety function may result from automatic or manual actuation of systems, from passive system performance, from natural feedback inherent in the reactor design.

All safety functions are directed at mitigating an event and containing and/or controlling radioactivity releases. These safety functions can be grouped into three major classes (Fig. 2) as follows:

1. Anti-core melt safety functions
2. Confinement isolation safety functions
3. Maintenance of vital auxiliaries needed to support the other safety functions

The anti-core melt safety function class contains three safety functions:

a. Reactivity Control (RC)
b. Pool Water Inventory Control (IC)
c. Core Heat Removal (CHR)

The purpose of the first anti-core melt safety function, reactivity control, is to shut down the reactor and to keep it shut down condition, thereby reducing the amount of heat generated in the core.

The purpose of pool water inventory control (IC) is to keep the core covered with an effective coolant medium.

The purpose of the third anti-core melt safety function, core heat removal (CHR), is to remove the decay heat generated in the core and transfer it to a location where it can be removed from the PCS.

The confinement isolation safety function class contains single safety function: confinement isolation. The primary objective of this safety function is to prevent major radioactive release from the confinement by maintaining the integrity of the confinement structure.

The third safety function class also includes only one safety function: maintenance of vital auxiliaries. The systems used to accomplish the four other safety functions addressed in this EOG are not actually supported by the maintenance of vital auxiliaries. However, in general, support systems provide service such as instrument air needed for opening and closing valves, electric power for valve operation, pump motor operation, and operating instruments and an ultimate heat sink to which PCS and core heat can be transferred. Of greatest impact to the operator actions associated with this EOG is AC and DC power.

2.3.2 Safety Function Hierarchy

The safety function concept incorporates a principle of safety function hierarchy. Some safety functions have precedence over others concerning their sequence of implementation during an event. The hierarchy of safety functions is summarized as standardized in this EOG guidance:

1. Reactivity Control
2. Maintenance of Vital Auxiliaries (AC and DC Power)
3. Reactor Pool Water Inventory Control
4. Core Heat Removal
5. Confinement Isolation

Reactivity control is the most important safety function since it responds most quickly to changes in reactor conditions. Similarly, Reactor Pool Water Inventory Control (IC) must be satisfied before core heat removal can be effected (i.e., there must be a medium to remove heat). This hierarchy concept is important in the design of systems used to fulfill each function and has also been employed in developing the EOG. All of the EOG identify each of the 5 safety functions (in the hierarchy presented previously) and the acceptance criteria which reflect accomplishment of each of the safety functions. The safety functions are provided as a complete set so that the operator can monitor and control the reactor to protect the health and safety of the public.

Application of the concept of safety functions in a restructured format is acceptable as long as: (1) the representation contains actions and acceptance criteria necessary to control and fulfill the five individual safety functions; (2) it is consistent with the safety function hierarchy of this EOG; and (3) the ultimate goal of protecting the health and safety of the public is preserved.

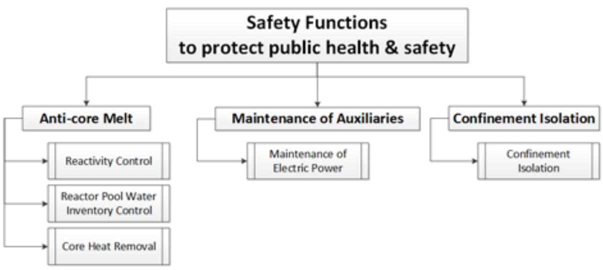

FIG. 2 Safety Functions in a Research Reactor

Each level, consisting of a rearrangement or combination of safety functions can achieve the same goal as the set which contains each safety function individually. This safety function subset or rearrangement may be enhanced by use of a particular control room operator aid, etc.

2.4. EOG

2.4.1 Original guidelines

In an original set of EOG, the Standard Post Trip Actions and Diagnostic Actions are performed prior to entry into the ERG or SRG for an event. If an ERG had been initially selected by the operator but was subsequently found to be inadequate in dealing with the event as in FIG 3, the SRG would be, then, selected.

The operator begins with the first safety function which is in jeopardy, and reviews the resource assessment tree to ascertain the availability of resources. Working from left to right on the trees the operator reviews each success path to determine its availability and whether it has been already operating or not. If it is operating, the operator checks the acceptance criteria to see if the safety function acceptance criteria are now being satisfied. If the safety function acceptance criteria are satisfied, the operator goes on to the next safety function in jeopardy.

Once all safety functions have been satisfied and appropriate operator actions for all success paths in use have been performed, the operator refers simultaneously to the Long Term Actions to attempt to evaluate reactor status, determine a diagnosis and determine an extended course of action. Concurrent with taking steps to restore jeopardized safety functions, the control room team is using the SRG SFSC to continually review the status of safety functions. As the event progresses and/or as new success paths are available, the operator may have to shift to the new acceptance criteria which correspond to these success paths. This periodic review may reveal that a safety function is in jeopardy and requires further operator action.

2.4.2 Revised guidelines

In a revised set of EOG, the Standard Post Trip Actions are only performed prior to entry into the Reactor Trip (only single event-based recovery guideline) or SRG for an event as in FIG 4.
Considering the rather simple safety functions and SSC (System, Structure, Components), the necessity to have separate sets of guidelines is very low and to have both guidelines such as event-based and symptom-based is seemingly unnecessarily bulky.
Furthermore, this proposed guideline with symptom-based approach forces to confirm every safety function's acceptance criteria in every reactor trip. The only exception is when only a simple/not complicated reactor trip such as planned one happens.

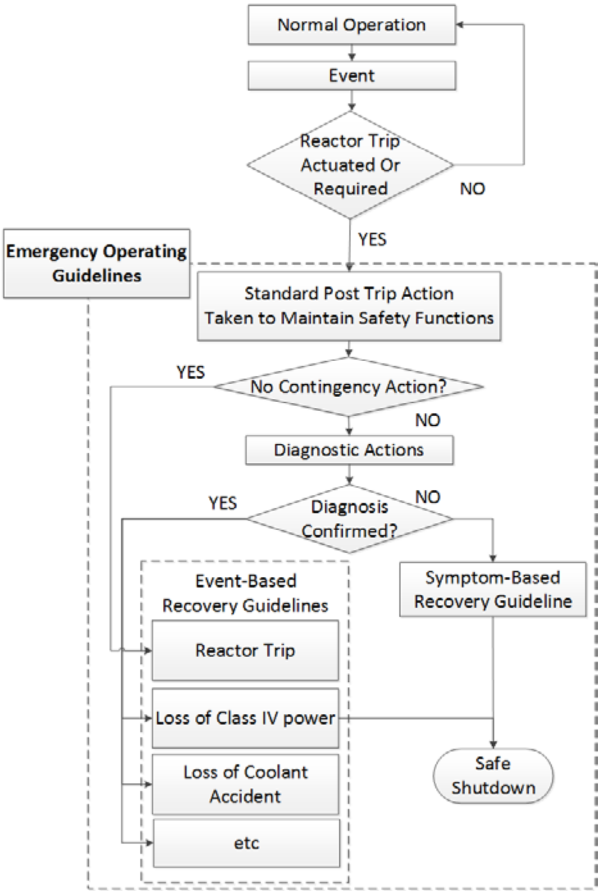

FIG. 3 Original version of EOG for a RR

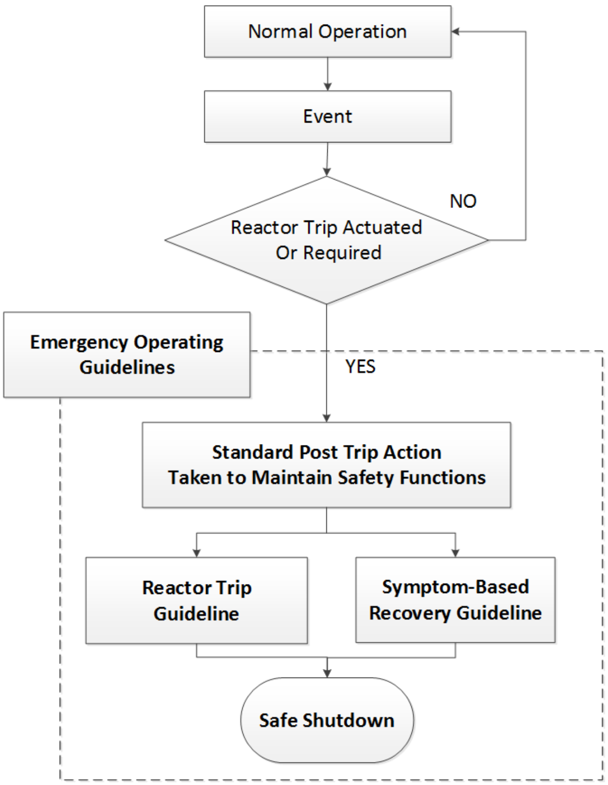

FIG. 4 Revised EOG for a RR

3. Conclusions

A set of EOG focused on a symptom-based approach was proposed for a research reactor to cover any kind of accident including beyond design basis accidents.

Acknowledgement

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