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Development of RIMO for Risk Management in a Nuclear Power Plant

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Severe accident management can be defined as the use of existing and alternative resources, systems, and actions to prevent or mitigate a core-melt accident in nuclear power plants. RIMO (Risk Meter for Operators), developed for training control room staff and the technical group, is introduced in this paper. The RIMO is composed of phenomenological knowledge base (KB), accident sequence KB and accident management procedures with AM strategy control diagrams and information needs. Also, RIMO-web program supports MACCS calculation, which is a representative computer code for Level 3 PSA analysis. This RIMO might contribute to training them by providing phenomenological knowledge of severe accident, understanding plant vulnerabilities, evaluating risk and solving problems under high stress.

KEY WORDS: Severe accident management, accident phenomena, accident scenario, level 3 PSA

I. Introduction

Severe accident management can be defined as the use of existing and alternative resources, systems, and actions to prevent or mitigate a core-melt accident in nuclear power plants and it provides the extension of the defense-in-depth philosophy to severe accidents. The accident management (AM) includes the measures to (1) prevent core damage, (2) terminate the progress of core damage if it begins and retain the core within the reactor vessel, (3) failing that, maintain the containment integrity as long as possible, and finally, (4) minimize the consequences of offsite release[1]. A training program for accident management needs to be developed to enable the NPPs (Nuclear Power Plants) participants to use these measures successfully. The training program is basically required to cover several topics including: the progression of severe accidents, severe accident phenomena, the IPE (Individual Plant Examination) findings of a reference plant, and the severe accident management procedures[2]. RIMO (Risk Meter for Operators), developed for those purposes, is introduced in this paper.

The RIMO, written in html, may provide awareness training to the operators whose work may create a significant impact upon safety of NPPs (Nuclear Power Plants) during accidents. It may be basically used for fundamental training in the severe accident assessment and response strategies, instrument degradation under severe accident conditions, and alternative instrumentation to verify instrument reading necessary for the implementation of severe accident strategies.

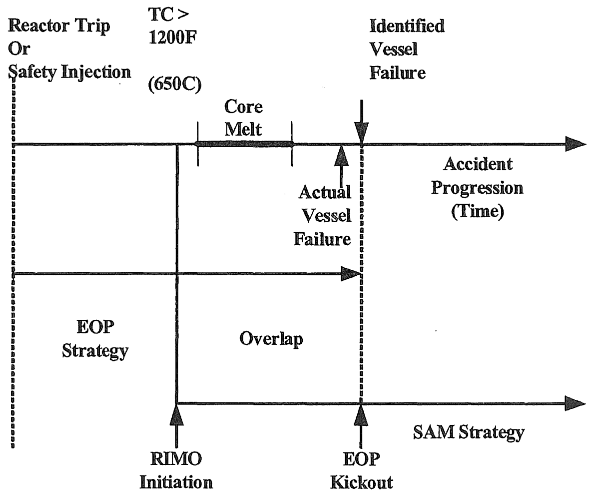

Fig 1. The Initiation Timing for RIMO Use

The initiation point for the RIMO and the scopes of EOP (Emergency Operating Procedures) and severe accident management strategy are shown in **Fig 1**. The RIMO is basically developed to help the control room operators and staffs to answer questions such as the following:

What are the possible accidents sequences under given conditions? What is the expected physical accident status after some evident symptoms? What are the minimum equipment requirements in order for accident management strategies or procedure to be effective? What are the adverse consequences if some of actions are initiated prematurely?

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II. Overall Features of RIMO

Training for accident management is especially critical in order to overcome the degradation of performance that can occur during stressful situation, to reduce the potential for human error during transition from emergency operating procedures to accident management procedures, and to promote more effective communication between the control room staff and technical support group. A well designed training program will ensure that all personnel involved in accident management have a common understanding of severe accident phenomena, (such as steam explosions, hydrogen detonation, direct containment heating, etc), the conceptual basis of the accident management procedures, and the roles and responsibilities of the various personnel during execution.

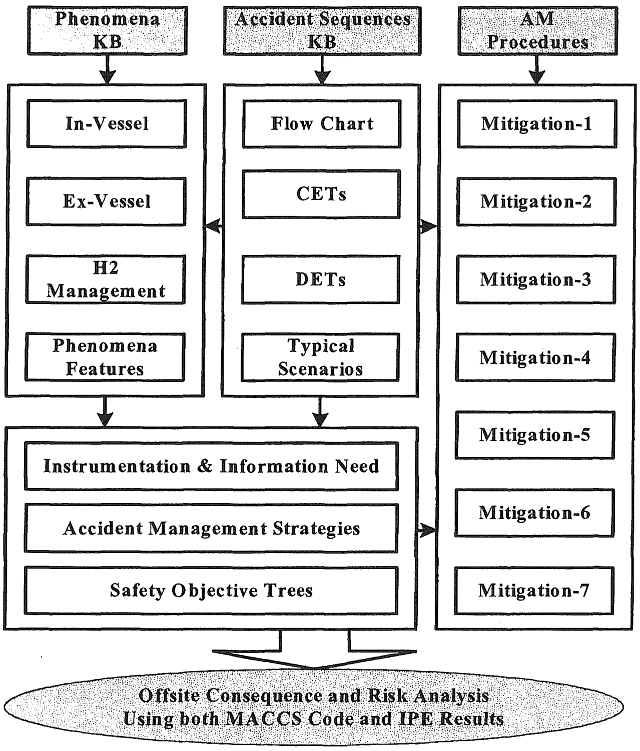

Fig 2. The Structure of RIMO

The RIMO was developed for use as a part of this training program. It was focused on achieving a fundamental understanding of "what's happening?" during a severe accident. The RIMO composed of phenomenological knowledge base (KB), accident sequence KB and accident management procedures and information needs, as shown in **Fig 2**. The KB is a collection of facts regarding severe accidents and rules for decision-making associated with problem solving. The more detailed functions of RIMO includes the definition of accident management, severe accident sequences, probable severe accident phenomena with respect to each progression step, severe accident management strategies, accident management procedures, and frequent occurring human errors. These contents include on how severe accident progress as well as how the accident management procedures should be presented to be easily understood and to be readable, especially under conditions expected during stressful conditions.

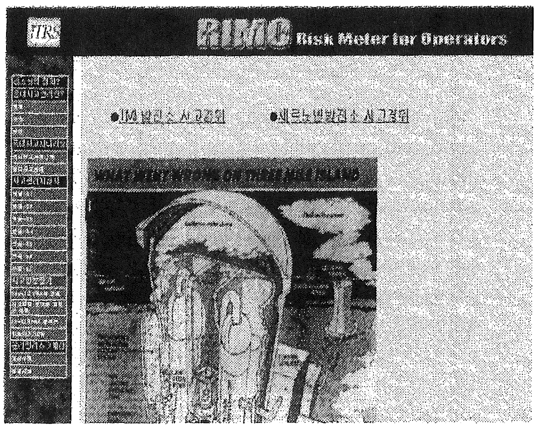

Fig 3. The MENU for RIMO

III. Description of RIMO

The UCN 3&4 plants, which are light water reactors in Korea, are used as a reference plant[3]. Based on the configurations, severe accidents scenarios of the reference plant, the severe accident phenomena knowledge base, and information / instrumentation KB was established in "RIMO". The accident phenomena KB element in RIMO includes: core melt progression, in-vessel steam explosion, ex-vessel steam explosion, hydrogen burns, direct containment heating, missiles, and molten core concrete interaction. The **Fig 3** represents the screen, which displays important elements of the severe accident assessment and main menu for training operators and staffs. Each elements compose of both schematic diagrams and explanations on how the accident phenomena happen?, and what's happening? The same structures for the other elements of accident sequence KB, accident management procedures, and information / instrument KB has been constructed in the RIMO. The RIMO is on the whole comprised of five modules, which have the following functions:

1. Phenomena

The phenomena contents in RIMO are: core melt progression, in-vessel steam explosion, ex-vessel steam explosion, hydrogen burns, direct containment heating, missiles, molten core concrete interaction, etc. For the phenomena of steam explosions, the explanations with important governing equations associated with heat transfer theory (conduction, convection, and radiation) are described in the left column of each display. Energetic steam explosions inside the reactor vessel due to core relocation pose two different kinds of threats to the vessel integrity. The alpha-failure is a mechanism where a steam explosion in the lower plenum accelerates a coolant slug towards the vessel head, which breaks off, becomes a missile and penetrates the containment roof. When the molten material discharges from the reactor vessel, the step-by-step progression diagrams coming into contact with water in the reactor cavity is also incorporated in this RIMO. In the same manner, other important severe accident phenomena are explained with the supplementary diagrams.

2. Accident Sequences

An accident progression flowchart is modeled with respect to time, temperature, sequence event, and likely outcomes. This module gives trainee overall accident progression pictures. For more details, containment event trees (CETs), which are the precalculated IPE results, are also incorporated in RIMO[4]. Decomposed event trees (DETs) are linked to the 9 top event headings of CETs, as shown in **Fig 4**. They might contribute to predicting the possible accident sequences by operators and staffs during accidents.

3. Accident Management Procedures

Accident management procedures consists of emergency guidance, which is a set of actions before / after TSC (Technical Support Center) actuation, strategy control diagram, mitigation guidance, which is necessary for the control of fission product release, containment integrity, reactor vessel integrity and exit guidance for TSC staff[5].

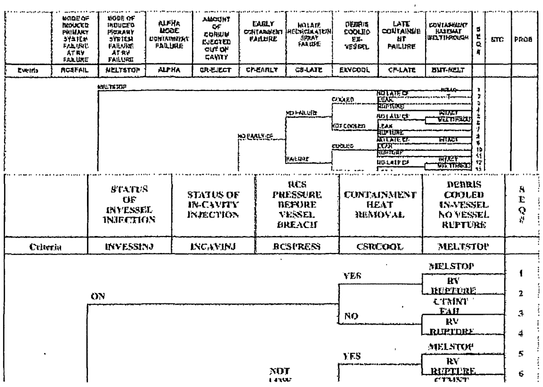

Fig 4. Accident Sequence of CETs/DETs in RIMO

4. Information and Instruments

Accident management procedures require various plant information to make decision, by which accident management procedures shall be used at the current conditions[6].

The necessary information is collected through various instrumentations. The safety objective trees and several computational aids are also incorporated in RIMO to provide necessary information[7].

5. Offsite Consequence Analysis

The level 3 PSA being termed accident consequence analysis is defined to assess effects on health and environment caused by radioisotopes released from severe accidents of nuclear power plants. The MACCS (MELCOR Accident Consequence Code System), which is incorporated in RIMO, are implemented in three modules, such as ATMOS, EARLY, and CHRONC[8]. The ATMOS module treats the atmospheric dispersion and transport of material and its deposition onto the ground. The EARLY module includes direct exposure pathways, dosimetry, mitigative actions and health effects during the emergency phase. The CHRONC module evaluates the direct and indirect exposure pathways, dosimetry, mitigative actions, and health effects during the period that follows the emergency phase: the intermediate and long-term phases. It also includes the economic costs with the mitigative actions during the emergency, intermediate, and the long-term phases. As shown in **Fig 5**, the offsite consequence analysis module as well as IPE module are loaded to assess the radiation risk for an accident nuclear power plant.

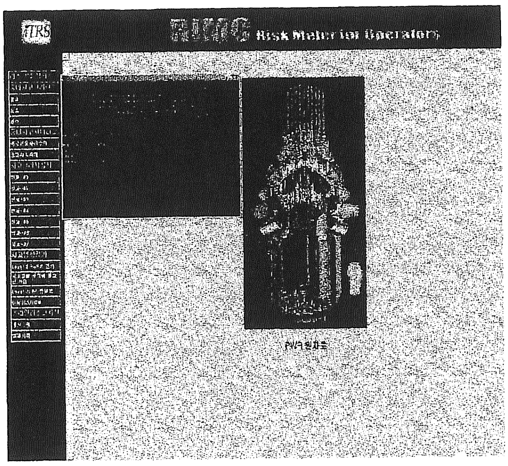

Fig 5. Realization of MACCS Code

IV. Conclusions

Accident training should be provided for control room operators and the technical support group with their responsibilities defined in the emergency plan. It is especially critical in order to overcome the degradation of performance that can occur during stressful situation. The RIMO is developed for training control room staff and the technical group. The RIMO consists of phenomenological knowledge base (KB), accident sequence KB, accident management procedures, information needs and consequence analysis using MACCS code[8]. This tool of

RIMO might be useful in training the NPP participants by obtaining phenomenological knowledge of severe accidents, understanding plant vulnerabilities, evaluating risk and solving problems under high stress.

Acknowledgement

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