Proceedings of the Korean Nuclear Society Autumn Meeting
Taegu, Korea, October 1997

A Preliminary Study for the Implementation of General Accident Management Strategies

Soo Hyung YANG, Soo Hyung KIM, Young Hoon JEONG, Soon Heung CHANG

Department of Nuclear Engineering
Korea Advanced Institute of Science and Technology

ABSTRACT

To enhance the safety of nuclear power plants, implementation of accident management has been suggested as one of most important programs. Specially, accident management strategies are suggested as one of key elements considered in development of the accident management program. In this study, generally applicable accident management strategies to domestic nuclear power plants are identified through reviewing several accident management programs for the other countries and considering domestic conditions. Identified strategies are as follows; 1) Injection into the Reactor Coolant System, 2) Depressurize the Reactor Coolant System, 3) Depressurize the Steam Generator, 4) Injection into the Steam Generator, 5) Injection into the Containment, 6) Spray into the Containment, 7) Control Hydrogen in the Containment. In addition, the systems and instrumentation necessary for the implementation of each strategy are also investigated.

1. Introduction

Based on the "Defense in Depth" concept, international regulators and industry's voluntary efforts, the safety of nuclear power plants has been maintained at higher level in comparison with that of any other power plants. However, through the accident occurred at TMI and Chernobyl, the possibility of temporal failure of safety system and induced malfunction of the protection systems, i.e. containment, are realized and the extension of the multi-barrier protection systems has been internationally pursued. According to these efforts, the accident management program (AMP) and emergency planning have been suggested in the INSAG-3, which was published by the IAEA, and the necessity of two items has been recognized. Specially, in SECY-88-147 [1] and 89-012 [2], the US NRC referred that the development of plant-specific accident management program should be required to close out the severe accident regulatory issues. Therefore, the US industry has promoted the research related to accident management and each owners groups have developed generic severe accident management guidelines. In addition, several accident management strategies have been developed and selected to enhance the nuclear power plant based on the plant-specific safety analysis throughout the world. In Korea, the implementation of the AMP for YGN 3&4 was imposed as a condition of construction permission and, considering these domestic requirement and international trends, the research works have been accomplished through industry, institute and regulatory body. Specially, the Ministry of Science and Technology announced the Nuclear Safety Policy, which point out "Further Directions for Identification of Severe Accident Phenomena and Development of Regulatory Guides for the Prevention and Mitigation of Severe Accident", in September 1994 [3]. Although these necessities and conditions, the implementation of the AMP is not suitably accomplished for nuclear power plants and, in addition, clear positions for AMP cannot be clarified till now. Moreover, as the constructions for new and next generation nuclear power plants are actively progressing in Korea, it is urgent to clarify clear and consistent position for the AMP.

In this work, the descriptions related to accident management are simply provided and general accident management strategies are identified considering the accident management strategies used in

foreign countries and the condition of domestic nuclear power plant. Moreover, the necessary systems and instrumentation to implement the accident management strategies are also reviewed.

2. Descriptions of the Accident Management

Definition of the Accident Management

The definitions of the accident management are described in the documents of IAEA, OECD/NEA and US NRC, etc [1, 2, 4, 5 & 6]. The definition is generally summarized as follows:

"Accident management encompasses those actions taken during the course of an accident by the plant operating and technical staff to:

- prevent core damage,
- terminate progress of core damage if it begins and retain the core within the vessel,
- maintain containment integrity as long as possible, and
- minimize off-site releases

In addition, prerequisites, i.e. accident management strategy, development of an accident management procedure/guidance, identification of hardware, severe accident training, are included in accident management."

Development Methodology and Key Elements for the Accident Management

IAEA suggested that the process to develop accident management program should be consist of following attributes and the development process for the accident management program mainly consisting three steps, as shown in Fig. 1.

- Planning and Familiarization
- Development and Implementation of Framework Elements
- Validation and Improvement

NRC have also performed various kinds of research related to accident management and suggested detail steps for the development of the accident management program, as shown in Fig. 2, considering 9 attributes. Though those configurations (IAEA and NRC) are different, the detail contents are very similar. The main difference is only numbers of main attributes and step (9 steps to realize 3 attributes versus 8 steps to realize the 9 attributes in IAEA and NRC methodologies, respectively) in the AMP. The suggested attributes are shown in Table 1. Through reviewing the document related to accident management suggested by IAEA, NRC and other countries, consideration for at least accident management strategies, accident management procedure and guidance, instrumentation identification, training in severe accident, organization and decision-making responsibility should be included in the AMP. Therefore, above items can be suggested as key elements for the AMP. In domestic regulatory body's suggestion, they issued that above 3 attributes and key elements should be considered in AMP [3].

3. Identification of General Accident Management Strategies

Accident management strategy is one of the most important elements in the accident management program. Moreover, if using suitable accident management strategy, it is possible to terminate severe accident and mitigate the consequences of severe accidents. Therefore, NRC suggested the methodology for the selection of the accident management strategies, using safety objective tree [7]. However, in this study, the general accident management strategies are identified through reviewing the literatures related to the accident management and accident management guidance [6, 8, 9, 10 & 11] and considering

domestic conditions. The details are shown in Table 2. The accident management strategies in the dashed region are selected as general accident management strategies, considering the number of selection case and the possibility of applicability for accident management strategy to domestic nuclear power plant.

4. Identification of Systems and Instrumentation for the Implementation of the Strategies

Evaluation on the applicability of the selected accident management strategies to nuclear power plants should be established, considering the availability of the system and information needed for the implementation of each accident management strategy under severe accident conditions. In this point of view, for 7 accident management strategies, necessary systems and information needed for the implementation of accident management strategies are investigated and described in Table 3. According to the investigation, there are various kinds of systems and instruments, which can provide useful information needs, for the implementation of above 7 accident management strategies. Therefore, it is possible to implement 7 accident management strategies to domestic nuclear power plants.

To develop plant-specific accident management program with adequate accident management strategies, there will be a strong need to evaluate the applicability of the accident management strategies to each plant, identifying the availability of the plant-specific systems and instruments, which provide the information need, under severe accidents conditions, as shown in Fig. 3. The severe accident conditions can be estimated by severe accident analysis code, i.e. MAAP and MELCOR, etc. However, in performing the evaluation using severe accident analysis code, the uncertainties included in the analysis code should be carefully considered. Moreover, additional works, i.e. prioritization for the selected accident management strategies, development of procedure to implement a strategy, etc., should be also considered.

5. Conclusions and Further Studies

In present study, in the viewpoint of accident management strategies, broad investigation has been performed. Identified important items are as follows:

1. 7 accident management strategies are identified considering the other countries' accident management programs and conditions of domestic nuclear power plant:
   - Injection into Reactor Coolant System
   - Depressurize Reactor Coolant System
   - Depressurize Steam Generator
   - Injection into Steam Generator
   - Injection into Containment
   - Spray into Containment
   - Control Hydrogen in Containment

2. There are many kinds of systems and instrumentation necessary for the implementation of 7 accident management strategies. Therefore, it is possible to implement above accident management strategies in domestic nuclear power plants.

3. The detail investigations to evaluate the applicability of the accident management strategies to domestic nuclear power plants will be strongly needed. Specially, the availability of the system and instruments under severe accident conditions should be evaluated using the severe accident analysis code. In performing the evaluation with severe accident analysis code, the uncertainties included in the analysis code should be considered. Moreover, additional works, i.e. prioritization for the selected accident management strategies, development of procedure to implement a strategy, etc., should be also established.

Acknowledgment
This work was supported by Korea Electric Power Research Institute (KEPRI).

Reference

1. SECY-88-147, Integration Plan for Closure of Severe Accident Issues, US NRC, 1988.
2. SECY-89-012, Staff Plans for Accident Management Regulatory and Research Program, US NRC, 1989.
3. J.I. Lee, I.G. Kim & C.J. Lee, KINS Severe Accident Management Overview, International Conference on Probabilistic Safety Assessment Methodology and Application, pp. 1176-1180, Nov. 26-30, Seoul, Korea, 1995.
4. Accident Management Programmes in Nuclear Power Plant; A Guidebook, Technical Report Series No. 368, IAEA, 1994.
5. Proceedings of the Specialist Meeting on Severe Accident Management Implementation, NEA/CSNI/R(95)5, Niantic, Connecticut, USA, June 12-14, 1995.
6. Implementing Severe Accident Management in Nuclear Power Plant, OECD/NEA, 1996.
7. Accident Management Information Needs, NUREG/CR-5513, US NRC, 1990.
8. Severe Accident Management Guidance Technical Basis Report Vol. 1 & 2, EPRI/TR-101869, 1992.
9. Westinghouse Owners Group Severe Accident Management Guidance, Vol. 1, 2 & 3, 1994.
10. Identification and Evaluation of PWR In-Vessel Severe Accident Management Strategies, NUREG/CR-5856, USNRC, 1992.
11. Preliminary Study for Development of Accident Management in Nuclear Power Plants, TR.96NJ11.97.77-1, KEPRI, 1997.

Table 1. Attributes Suggested in the Development Methodology of the AMP

Attributes considered in IAEA methodology	Attributes considered in NRC methodology
• Planning and Familiarization	• Identification of the capabilities and possible limitation
• Development and Implementation of Framework Elements	• Accident management strategies • procedure and guidance • engineering method • information need • decision-making responsibility and authority • training
• Validation and Improvement	• Validation and Improvement

Table 2. Suggested Accident Management Strategies

Accident Management Strategies	1	2	3	4	5	Remarks
1. Inject into the Steam Generators	•	•	•			General
2. Depressurize the RCS	•	•	•	•	•	General
3. Inject into RCS	•	•	•	•	•	General
4. Depressurize Steam Generators		•	•			General
5. Inject into Containment	•	•				General
6. Reduce Fission Product Releases	•					Is possible with 9 & 20
7. Control Containment Conditions	•					Is possible with 8, 9 & 20
8. Reduce Containment hydrogen	•					General
9. Flood Containment	•		•			General
10. Mitigate Fission Product Releases	•					Is possible with 9 & 20
11. Depressurize Containment	•					Is possible with 9 & 20
12. Control Hydrogen Flammability	•					Is possible with 8
13. Control Containment Vacuum	•					Not applicable
14. Vent Containment		•	•		•	Not applicable
15. Restart RCPs		•				Is not considered
16. Restoration of AC Power and Provision of Portable Pumping Capacity				•		Is not considered
17. Operate Igniters		•	•		•	Is included in 8

Table 2. Suggested Accident Management Strategies (*cont.*)

18.	Operate Recombiners		•	•	•	Is included in 8
19.	Operate Fan Coolers		•	•		Is not considered
20.	Spray into Containment		•	•	•	General
21.	Spray Secondary Containment		•			Not applicable
22.	Flood Secondary Containment		•			Not applicable
23.	Flooding Reactor Cavity to Cover RPV Lower Head		•	•	•	Is possible with 9 & 20
24.	Steam Inerting/De-Inerting of the Containment		•		•	Not applicable
25.	Prevention and Mitigation of RCP Seal Failures				•	Is not considered
26.	Maintaining Forced Circulation through the Core				•	Is not considered
27.	Feed and Bleed			•	•	Is not considered
28.	Isolate Containment: Prevent or Mitigate Bypass				•	Is not considered
29.	Reactor Pit Flooding				•	Is possible with 9 & 20
30.	To add Additional Concrete or Refractory Concrete				•	Is not considered
31.	Spray Actuation				•	Is possible with 20
32.	Scrubbing the Fission Products by Flooding the Reactor Pit and SG Secondary Side				•	Is possible with 9 & 20
33.	Chemistry Control to Avoid the Iodine Release				•	Is not considered
34.	Limit the Radioactive Release by Filters				•	Not applicable

(1; EPRI TR, 2; OECD/NEA, 3; NUREG/CR-5856, 4; WOG SAMG, 5; Framatome owners group)

Table 3. Necessary System and Information for the Implementation of Accident Management Strategies

Accident Management Strategies	Necessary system to implement the strategies		Information need to select the strategies / identify the initiation of the strategy / identify the effects of the strategy
Injection into RCS	• High Pressure Safety Injection System • Safety Injection Tanks • Low Pressure Safety Injection System • Chemical and Volume Control System • …	1	RCS Inventory, RCS Pressure History, Inventory Availability, Pumping Capability, Alignment Capability
		2	Feedwater Flow Status, Feedwater Inventory
		3	RCS Inventory, Core Damage Status, RCS Fluid Temperature, Energy Generation Rate
Depressurize RCS	• Operate Pressurizer Spray Valve • Operate Pressurizer Aux. Spray Valve • Heat Removal from Secondary System • Safety Depressurization System • Letdown Line • Passive Safety Valve • RV Head Venting • …	1	RCS Pressure History, SG Heat Removal Capacity, Core Damage Status
		2	RCS Pressure History, Prz. Safety Valve Status, SG Pressure, SDV Status, SDV Flow Rate, Prz. Spray Flow Rate
		3	RCS Pressure, Containment Pressure
Depressurize Steam Generators	• Passive Main Steam Safety Valves • Main Steam Atmospheric Dump Valves • Turbine Bypass Condenser Dump Valves • Turbine Bypass Atmospheric Dump Valves • …	1	DP between Primary/Secondary System, SG Radioactivity, MSSV Status, MSADV Status, TBCDV Status, TBADV Status, Containment Status
		2	MSSV Status, MSADV Status, TBCDV Status, TBADV Status
		3	SG Pressure, RCS Status
Injection into Steam Generators	• Aux. Feed Water Pumps • Main Feed Water Pumps • …	1	SG Status, Inventory Availability, Pumping Capacity, Alignment Capacity
		2	Feed Water Flow Rate, Water Inventory
		3	RCS Fluid Temperature, Secondary Coolant Inventory
Spray into Containment	• Containment Spray System	1	Containment Status, Spray Water Inventory
		2	Containment Status, Spray Pumping Capacity, Spray Flow Rate
		3	Containment Status
Injection into Containment	• Injection with Fire Protection System • Injection with Gravity Water Drain from the IRWST • …	1	RCS Status, Core Damage Status, Cavity Coolant Inventory, Coolant Inventory
		2	Coolant Inventory, Spray Pumping Capability, Spray Flow Rate
		3	Coolant Inventory, Containment Status
Control Hydrogen in Containment	• Hydrogen Recombiners • Hydrogen Igniter • Hydrogen Purge Venting System • …	1	Containment Status, Hydrogen Status
		2	Recombiner Status, Hydrogen Purge Venting System Status
		3	Hydrogen Monitoring System Status, Containment Status

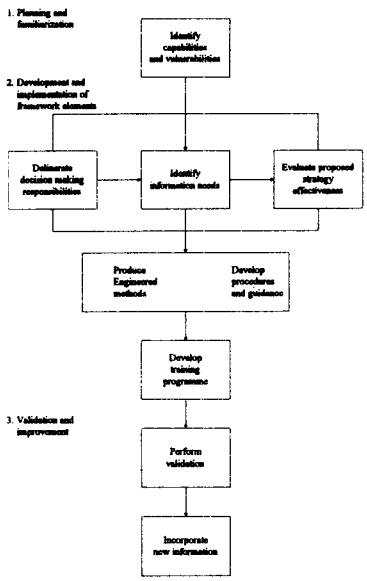

Fig. 1 IAEA Methodology

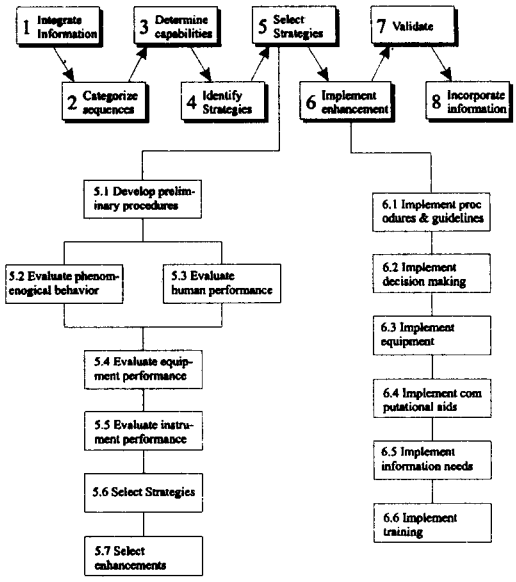

Fig. 2 NRC Methodology

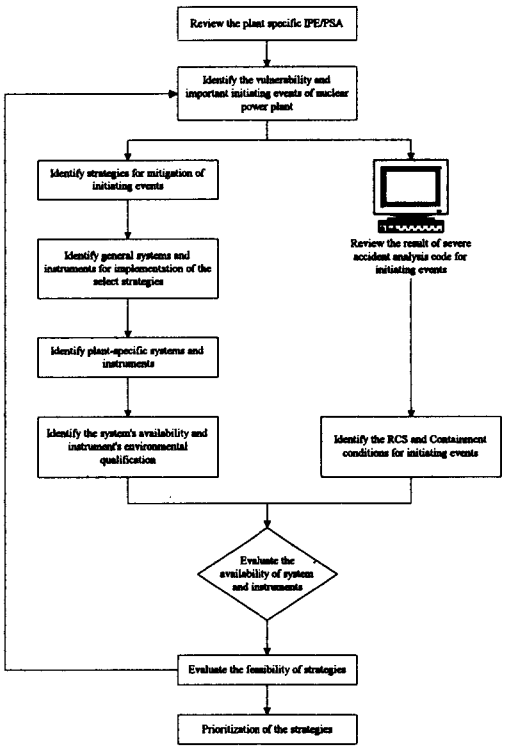

Fig. 3 Evaluation Methodology on Implementation of Accident Management Strategies