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Westinghouse Energy Systems

Framework for AP600
Severe Accident Management Guidance

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1.0 INTRODUCTION

Prevention and mitigation of accidents has been an integral part of the design process for AP600. A significant driving force in the passive plant design is the key accident management philosophy of preventing accidents from progressing to core damage. However, in the event of a low probability core damage accident, it is prudent to have severe accident management guidance with the objective of terminating the progression of the accident and returning the plant to a controlled, stable state. Therefore, this document contains a summary of the overall philosophy and high level strategies that will form the basis of the AP600 severe accident management guidance.

The Westinghouse plan for addressing severe accident management for AP600 will be based on the Westinghouse Owners Group Severe Accident Management Guidance (WOG SAMG) for the current generation of operating plants. Since some of the AP600 design features reduce or eliminate the potential for some severe accident phenomena and fission product boundary challenges, the WOG SAMG provides an envelope of possible severe accident management considerations. Thus, the WOG SAMG has direct applications to the development of AP600 severe accident management guidance, and will be the starting point from which comparisons are made.

The scope of the AP600 severe accident management guidance is to address significant core damage accidents. Prior to core damage, the Emergency Operating Procedures (EOPs), which are based on the AP600 Emergency Response Guidelines (ERGs) will be used. [Ref. 1] Although the EOPs/ERGs for existing plants have proven to be effective in the prevention of core damage, they do not address scenarios after significant core damage has occurred.

The AP600 severe accident management guidance will be developed for use after the AP600 emergency response guidelines are no longer applicable. The AP600 severe accident management guidance will include the application of insights that are derived from the AP600 Probabilistic Risk Assessment (PRA), and elements that have been learned through severe accident management research over the past 15 years. As such, severe accident management guidance is the mechanism that brings the current level of knowledge on severe accidents to the hands of the operating and technical staff at the plant. However, the overall uncertainty of the core melt progression is still quite high, and thus the management of a severe accident can only be pre-constructed by guidance that is less prescriptive than the guidelines for design basis events and other accidents prior to core damage.

The contents of this document include a discussion of severe accident management requirements, the anticipated structure for the decision making process, the goals that must be accomplished for severe accident management, and a summary of possible strategies for AP600 severe accident management. This document provides the framework for future AP600 severe accident management guidance development and therefore does not specifically address many issues in detail.

2.0 REQUIREMENTS FOR SEVERE ACCIDENT MANAGEMENT

There are no current NRC requirements for the development of severe accident management guidance. However, NRC policy statements from the NRC Staff to the NRC Commissioners (SECY letters) identify concerns and future actions of the NRC concerning this subject. Specifically, SECY-89-012 provides the following information.

> "Accident Management encompasses those actions taken during the course of an accident by the plant operating and technical staff to: (1) prevent core damage, (2) terminate the progress of core damage if it begins and retain the core within the reactor vessel, (3) maintain containment integrity as long as possible, and (4) minimize offsite releases. Accident management, in effect, extends the defense-in-depth principle to plant operating staff by extending the operating procedures well beyond the plant design basis into severe fuel damage regimes, with the operator skills and creativity to find ways to terminate accidents beyond the design basis or to limit offsite releases.
>
> The NRC staff has concluded, based on PRAs and severe accident analyses, that the risk associated with severe core damage accidents can be further reduced through effective accident management. In this context, effective accident management would ensure that optimal and maximum safety benefits are derived from available, existing systems and plant operating staff through pre-planned strategies... Accordingly, accident management is considered to be an essential element of the severe accident closure process described in the Integration Plan for Closure of Severe Accident Issues (SECY-88-147) and the Generic Letter on the Individual Plant Examination (Generic Letter 88-20).
>
> In the IPE Generic Letter, the staff deferred the requirement to develop an accident management plan, stating that we are currently developing more specific guidance on this matter and are working with NUMARC to (1) define the scope and content of acceptable accident management programs, and (2) identify a plan of action that will ultimately result in incorporating any plant-specific actions deemed necessary, as a result of the IPE, into an overall severe accident management program."

Also within SECY-89-012, the first objective for an accident management plan developed by licensees for each plant is:

> "Developing technically sound strategies for maximizing the effectiveness of personnel and equipment in preventing and mitigating potential severe accidents. This includes ensuring that guidance and procedures to implement these strategies are in place at all plants."

In a June 3, 1993 meeting between the NRC and NUMARC, the NRC endorsed a NUMARC industry initiative on accident management as an alternative to an NRC Generic Letter. [Ref. 2] Currently in draft

form, the industry initiative does not contain specific regulatory criteria. Rather, industry has defined its goals and objectives by its actions relative to severe accident management. These include, but are not limited to, performance and submittal of an Individual Plant Examination (IPE) and an Individual Plant Examination of External Events (IPEEE), development of generic (Owners Group) severe accident management material, and numerous interactions at various levels among industry, the NRC, and vendors. It is anticipated that the NUMARC initiative will be issued in March 1994 as a revision to NUMARC 91-04, "Severe Accident Issue Closure Guidelines." The NRC has expressed the view that the industry initiative is acceptable as an alternative to the accident management generic letter provided that the NRC could conclude that "the initiative meets the objectives for accident management established at the time the severe accident program was initiated." [Ref. 2]

The previous information is in regards to general positions of the NRC on severe accident management, and it does not distinguish between current operating plants and new, advanced plant designs. However, the NRC has indicated their interest in AP600 severe accident management through several of the Requests for Additional Information (RAIs) over the past year. Specifically, RAI 720.55 asks how Westinghouse plans to use the AP600 Probabilistic Risk Assessment to identify and assess accident management measures. Furthermore, in RAI 720.56, the NRC asked how Westinghouse plans to address the five elements of accident management as defined in SECY-89-012. These elements are: 1) accident management procedures, 2) training for severe accidents, 3) accident management guidance, 4) instrumentation, and 5) decision-making responsibilities.

In addition, the Advanced Light Water Reactor (ALWR) Utility Requirements Document (URD) states that the Plant Designer shall establish the technical basis for a severe accident management program that includes core damage prevention and mitigation. The Plant Designer is also to translate the plant design bases into operational limitations and responses which can then be developed into procedural guidelines and training by the Plant Owner. The Plant Designer is also responsible for confirming that the plant design is compatible with the EPGs and the severe accident management program based on the plant specific PRA and other relevant information. [Ref. 3] The NRC's Safety Evaluation Report for this document states: "The use of PRA for developing and confirming the severe-accident management program and EPGs is also consistent with the Commission's severe-accident policy." [Ref. 4]

3.0 DECISION-MAKING PROCESS

Severe accident management involves the implementation of actions to bring the plant to a controlled, stable state following core damage and to mitigate challenges to the containment fission product boundary. In a severe accident state, the first two fission product boundaries (the fuel rod cladding and the reactor coolant system) may be severely damaged and the focus shifts to maintaining the final fission product boundary. To effectively choose the appropriate severe accident management actions and to prioritize the implementation of the appropriate actions, assessment of the plant conditions is needed.

The nature of severe accidents and the possible responses dictate that severe accident management diagnostics be symptom-based. Several specific features of severe accidents can be cited which support the symptom-based approach:

a) Severe accident management must provide a response for a wide range of severe accident conditions. While a large number of possible scenarios have been identified in severe accident studies, it is likely that most of these scenarios do not accurately represent realistic severe accident scenarios due to modelling assumptions in these studies (such as all equipment failures are assumed to occur at time zero).

b) During a severe accident, the plant conditions are undergoing continual change. Severe accident management must relate actions to symptoms.

c) The overall goals of severe accident management involve the response to challenges to fission product boundaries, which can be diagnosed through symptoms.

In other words, the symptom-based approach is a key method to develop flexibility in the AP600 severe accident management guidance. This flexibility refers primarily to the ability of plant personnel to shift priorities and implement accident management strategies based on the situation of the plant during the accident. Specific technical decisions may be knowledge-based, and will be dependent on the interpretation of the plant status. Therefore, the appropriateness of specific actions cannot be predetermined during the development of AP600 severe accident management guidance. This approach allows the guidance developed to be useful during any severe accident, even scenarios which are not currently recognized situations. As such, an AP600 severe accident management plan is the final stage in the defense-in-depth plant safety concept.

Although flexibility is a necessity, there is a need for the guidance itself to be a structured process for choosing the appropriate actions based on actual plant conditions. Human factor considerations during a high stress environment that would accompany a severe accident require that the guidance be simple to use. Thus, the AP600 severe accident management guidance must be an effective decision-making tool based on some fundamental concepts about the organization of the guidance, as detailed below.

3.1 Role of the Plant Personnel

NUMARC has developed recommendations for severe accident assessment and mitigation that divide responsibilities of personnel into categories of *evaluators, decision makers,* and *implementers.* The evaluators must assess the plant symptoms to determine the plant state, and then evaluate the potential strategies that may be used to mitigate the event. The decision makers are to assess and select the strategies to be implemented. The implementers are responsible for performing the steps necessary to accomplish the objectives of the strategies, such as hands-on control of valves, breakers, controllers and special equipment.

The plant personnel to perform each of these functions will be identified in a later phase of the development of the AP600 severe accident management plan. Factors that will be considered include:

- the structure of the organization that is needed for accidents prior to core damage, so that there would be an orderly transition to management of the accident after core damage is diagnosed,
- the instrumentation, equipment and computers necessary to fulfill each function,
- the skills, training and expertise of personnel,
- the size and location of the necessary staff, and
- the desire to address severe accident management preparation, while still maintaining a focus on the prevention of core damage.

3.2 Structure of AP600 Guidance

The AP600 guidance for severe accident management will include overall diagnostic tools that control the flow of the decision-making process, as well as detailed guidelines. The following sections provide a summary of the expected flow charts, as well as further information on the content of the detailed guidelines.

3.2.1 Diagnostic Flow Chart

As identified in Section 3.0, there is a need for severe accident management guidance to have an organized structure to facilitate effective decision-making. For AP600, the form of this structure should be based on the WOG SAMG, although some of the details may differ. The element discussed within this section is the Diagnostic Flow Chart, which is the primary decision-making tool to determine when the plant has achieved the overall goals of severe accident management.

The Diagnostic Flow Chart (DFC) is the primary tool to identify the appropriate guidelines for the key possible plant conditions that may occur following a severe accident. The flow chart is the point of entry

into severe accident management (from the ERGs), and it also serves as the exit point. The flowchart is based on setpoints for different parameters that are either necessary to define a controlled, stable state or which may prevent further challenges to fission product boundaries. The elements that determine a controlled, stable state are discussed in Section 4.0. Prevention of fission product boundary challenges refers to the prevention of severe accident phenomena, which may challenge fission product boundary integrity, such as induced steam generator tube rupture, high pressure melt ejection and reactor vessel lower head failure. Key plant conditions will be defined based on the capability to take actions to control the conditions and on the potential challenge to the containment fission product boundaries which these conditions may indicate. Based on the particular plant conditions identified in the DFC, a specific guideline is consulted to evaluate the availability and effectiveness of the various severe accident management strategies which may be used to control the conditions. If a controlled, stable state is achieved, the DFC instructs plant personnel to develop a set of limitations and cautions for the long term recovery process, based on the consideration of large quantities of fission products released from the core and other important aspects of the severe accident scenario. The parameters in the DFC will be prioritized and the setpoint values will be determined during the development of the detailed AP600 guidance.

3.2.2 Severe Challenge Status Tree

The Severe Challenge Status Tree (SCST) is the primary tool used by the emergency response team to identify immediate and severe challenges to containment fission product boundaries and to select the appropriate guideline for strategies to respond to the challenge. The SCST identifies the severe challenges for all possible plant conditions that may occur following a severe accident. The plant conditions on the SCST will be defined based on the severity of the challenge and capability to take actions to control the conditions in time to mitigate the challenge to the containment fission product boundaries. Based on the particular plant conditions identified in the SCST, a specific guideline is consulted to evaluate the availability and effectiveness of the various severe accident management strategies which may be used to control the conditions.

The parameters in the SCST are regularly monitored to determine whether a severe challenge has developed. The SCST parameters are to be monitored simultaneously with the usage of the Diagnostic Flow Chart (DFC). The existence of the SCST as a monitoring tool allows for the effective use of the pre-prioritized DFC, which addresses less-immediate concerns. However, if the setpoint for a SCST parameter is reached, all activities being guided by the DFC would be put on hold until the SCST challenge has been addressed.

3.2.3 Guidelines

While a Diagnostic Flow Chart and Severe Challenge Status Tree are used to establish the organizational structure of severe accident management guidance, the details and the majority of the technical content are contained within guidelines. Guidelines are referenced directly from the DFC or SCST due to a plant parameter being outside the desired range. The structure of the guidelines will include the following major considerations:

1) **Equipment Availability** - The guidelines will contain lists of the possible equipment that may be used to implement an action. If no equipment is available, instructions will include the consideration of restoring the non-functioning equipment.

2) **Benefits vs. Potential Negative Impacts** - The potential actions will be considered in regards to their benefits weighed against the expected negative impacts. If the negative impacts are judged to be large, then methods to minimize the negative impacts will be considered when possible. If the impacts differ based on the choice of methods or equipment, this distinction will be made.

3) **Implementation** - If the decision is made to implement a strategy, implementation instructions will be provided that include any limitations that were identified during the evaluation. The implementation instructions will also identify the expected response of the plant as a basis to compare the actual response. The option to abort the action, or to implement additional actions, will also be considered.

4.0 SEVERE ACCIDENT MANAGEMENT GOALS

Before any guidance for severe accident management can be developed, the first step is to identify the overall goals that the guidance must achieve. As stated in the introduction, the overall objective of severe accident management is to terminate the core damage progression. However, the scope of severe accident management also entails maintaining the capability of the containment as long as possible, and minimizing fission product releases and their effects. These severe accident management objectives can be translated into specific goals that must be met. These three goals are: 1) to return the core to a controlled, stable state, 2) to maintain or return the containment to a controlled, stable state, and 3) to terminate any fission product releases from the plant. Secondary goals, to be achieved while focusing on the primary goals, are to i) minimize fission product releases, and ii) maximize equipment and monitoring capabilities.

Before details are provided on each of these goals, it should be noted that severe accident management does not guarantee the achievement of the goals. Severe accident management is a structured approach that best utilizes available resources at the plant based on the current understanding of severe accidents.

4.1 Controlled, Stable Core State

[a,c]

[a,c]

[a,c]

[a,c]

4.2 Controlled, Stable Containment State

[a,c]

[a,c]

4.2.1 Hydrogen Flammability

[a,c]

4.2.2 Core/Concrete Interaction

[a,c]

[a,c]

4.2.3 High Pressure Melt Ejection

[a,c]

4.2.4 Steam Explosions

[a,c]

[a,c]

4.2.5 Creep Rupture Failure

[a,c]

4.2.6 Containment Vacuum

[a,c]

[a,c]

4.3 Fission Product Release Prevention, Termination and Mitigation

[a,c]

[a,c]

[a,c]

4.4 Secondary Goals

[a,c]

[a,c]

5.0 HIGH LEVEL ACTIONS FOR AP600

Based on the severe accident management goals defined in the previous section, certain elements are necessary to meet the goals. The elements can then further be divided into actions to be taken. The relationship of severe accident management goals to potential actions are summarized in Table 5-1, which forms the basis for possible severe accident management strategies.

The definition of a strategy for AP600 severe accident management consists of three components. A strategy is 1) an action or set of actions that 2) is taken for a specific purpose with 3) specific piece(s) of equipment. A strategy includes more than just the action, since the purposes must be well-understood for an effective evaluation, and the equipment to be used may impact the positive and negative expectations. This is the same strategy definition that was used for the WOG SAMG program, and it initially produced a list of over fifty strategies. Eventually, the strategies were combined to form a smaller number of guidelines, and they were grouped based on the potential actions. Since the AP600 severe accident management program is being developed based on the WOG SAMG program, this same process will be followed.

The information within this section is grouped according to the high level actions that may be taken during the management of a severe accident. The discussion of each high level action includes the identification of the benefits (purposes) of the action, the potential negative impacts, and the equipment possibilities. The development of the high level strategies is a preliminary step in the development of the AP600 severe accident management guidance. The information contained within this section is subject to change based on the completion and finalization of 1) Rev. 0 of the WOG SAMG, 2) the AP600 PRA, 3) AP600 accident management insights and their disposition, and 4) the AP600 function-based task analyses.

5.1 Inject into RCS

[a,c]

[a,c]

[a,c]

[a,c]

[a,c]

5.2 Inject Into Containment

[a,c]

[a,c]

5.3 Inject Into Steam Generators

[a,c]

[a,c]

5.4 Depressurize RCS

[a,c]

[a,c]

[a,c]

5.5 Depressurize Steam Generators

[a,c]

5.6 Depressurize Containment

[a,c]

[a,c]

5.7 Pressurize Containment

[a,c]

[a,c]

5.8 Burn Hydrogen

[a,c]

5.9 Vent Containment

[a,c]

[a,c]

[a,c]

[a,c]

6.0 CONCLUSION

This document has examined the overall framework for the development of the AP600 severe accident management guidance. The decision-making process, the roles of plant staff, and the high level contents of the guidelines have been examined. In addition, the goals of severe accident management have been defined, and necessary high level actions to achieve the goals have been summarized.

The conclusion of this assessment is that the AP600 high level actions for severe accident management are similar to those developed for the WOG SAMG. However, the differences between the AP600 plant and conventional plants result in some differences in accident management applications, as summarized below.

[a,c]

7.0 REFERENCES

1) DE-AC03-90SF18495, AP600 Standard Safety Analysis Report, Section 18.9.8.1, "Development of the Emergency Operating Procedures"

2) SECY-93-308, "Status of Implementation Plan for Closure of Severe Accident Issues, Status of the Individual Plant Examinations and Status of Severe Accident Research," November 15, 1993.

3) NP-6780-L, Advanced Light Water Reactor Utility Requirements Document, Volume III (ALWR Passive Plant), Chapter 1, "Overall Requirements," paragraph 2.3.3.9

4) NRC Project No. 669, "Issuance of Final Safety Evaluation Report (FSER) on the Electric Power Research Institute (EPRI) Requirements Document for Passive Plant Designs," from R. W. Borchardt, Office of Nuclear Reactor Regulation, August 31, 1993.

5) EPRI TR-101869, Severe Accident Management Guidance Technical Basis Report, Volume 2, Appendix K, "Debris Transport to the Lower Plenum."

6) EPRI TR-101869, Severe Accident Management Guidance Technical Basis Report, Volume 2, Appendix BB, "Potential for Criticality of the Core Material Under Recovery From Severe Accident Conditions."

7) WCAP-13388 (Proprietary) and WCAP-13389 (Non-Proprietary), AP600 Phenomenological Evaluation Summaries.

8) EPRI TR-101869, Severe Accident Management Guidance Technical Basis Report, Volume 2, Appendix L, "External Cooling of the RPV with Debris in the Lower Plenum."

9) EPRI TR-101869, Severe Accident Management Guidance Technical Basis Report, Volume 2, Appendix G, "Steam Explosions."

10) EPRI TR-101869, Severe Accident Management Guidance Technical Basis Report, Volume 2, Appendix U, "Water Overlying Core Debris."