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Development of Krško Severe Accident Management Database (SAMD)

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Abstract

Severe Accident Management is a framework to identify and implement the Emergency Response Capabilities that can be used to prevent or mitigate severe accidents and their consequences. Krško Severe Accident Management Database documents the severe accident management activities which are developed in the NPP Krško, based on the Krško IPE (Individual Plant Examination) insights and Generic WOG SAMGs (Westinghouse Owners Group Severe Accident Management Guidances).

Introduction

The USA NRC has indicated that the development of a licensee plant specific accident management program will be required in order to close out the severe accident regulatory issue (Ref. SECY-88-147). Generic Letter 88-20 ties the Accident management Program to IPE for each plant. The SECY-89-012 defines 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.

Purpose of Krško SAMD

Identification and documentation of those Krško plant specific severe accident management features which result from the IPE investigations are basis for future development of Severe Accident Management Guidance (SAMG) at NPP Krško. Overview of Generic WOG Severe Accident Management is presented on Figure 1. The development of the Krško plant specific Severe Accident Management Database was intended to fulfil this objective in following sub-tasks:

- assessing the identified dominant accident symptoms (Krško IPE Insights), high level and specific strategies against the generic WOG SAMG material and ensure that these accident sequences would be covered by the generic material (if not, identify when additional high level strategies would be required), and

- assessing the applicability of the Generic WOG SAMG strategies for applicability to NPP Krško identification of plant specific severe accident management strategies (equipment and lineups) that can be used.

The Krško SAMD will contain inquiry capability to sort the data base entries according to accident sequence (i.e., type of accident initiating event, status of plant systems/equipment and phase of severe accident), the plant systems/ equipment required to implement the severe accident management activity and the type of benefit to be achieved from the implementation of the severe accident management activity.

Subtask 1 - Assessing the Krško IPE Insights

IPE Level 1 Insights

The dominant core damage sequences from the Krško Level 1 IPE were grouped and assessed following the criteria set out in the NUMARC 91-04 Severe Accident Issue Closure Guidelines.
The NUMARC 91-04 defines following Functional Accident Sequences:

IA	Accident sequences involving loss of both primary and secondary heat removal in the injection phase
IB	Accident sequences involving loss of both primary and secondary heat removal in the recirculation phase
IIA	Accident sequences involving an induced LOCA with loss of primary coolant makeup or adequate heat removal in the injection phase
IIB	Accident sequences involving an induced LOCA with loss of primary coolant makeup or adequate heat removal in the recirculation phase
IIIA	Accident sequences initiated by a small LOCA with loss of primary coolant makeup or adequate heat removal in the injection phase
IIIB	Accident sequences initiated by a small LOCA with loss of primary coolant makeup or adequate heat removal in the recirculation phase
IIIC	Accident sequences initiated by a medium LOCA with loss of primary coolant makeup or adequate heat removal in the injection phase
IIID	Accident sequences initiated by a medium LOCA with loss of primary coolant makeup or adequate heat removal in the recirculation phase
IV	Accident sequences involving a failure of reactivity control
VA	System s LOCA outside containment with loss of effective coolant inventory makeup
VB	Steam generator tube rupture with loss of effective coolant inventory makeup

The insights and strategies should be read within their context when considering them for implementation in the plant specific Severe Accident Management Guidelines (SAMG).

Beyond 24 hours Insights

During the evaluation of the accident sequences in the Level 1 Krško IPE, it was found that a number of these would not lead to core damage within 24 hours of the initiating events. The MAAP (Modular Accident Analysis Program) program has been used in the Krško IPE to determine the success criteria for the accident sequences. A best estimate definition of core damage is used. Based on these analyses core damage for a number of sequences does not occur before 24 hours. Such sequences were identified following the Loss of Essential Service Water, Loss of Component Cooling Water and Station Blackout initiating events. These accidents were not further considered in either the Level 1 or Level 2 IPE of Krško. The closure of these issues from a regulatory point of view is via the implementation of Severe Accident Management.

IPE Level 2 Insights

The most important part of the IPE insights gathering involved the assessment of the level 2 IPE. The severe accidents considered as initiators for the Level 2 analysis are given by the plant damage states. The containment event tree considers the severe accident phenomena, their timing and their conditional probabilities. The result of the containment event tree quantification is a set of release categories and the fraction of severe accident sequences ending up in each. This task involved identifying the relevant severe accident sequences as represented by the plant damage states, identifying the symptoms of these accident sequences, evaluating the resultant severe accident phenomena and their symptoms, and assessing their impact on the fission product boundary. Accident management strategies (for mitigating the releases) based on the identified symptoms were identified and assessed toward applicable WOG SAMG generic strategies.

High priority Severe Accident Management insights obtained from sensitivity and phenomenological evaluation

Three sensitivity cases are presented which investigate the impact of various accident management measures on the Krško risk profile. These sensitivity cases were chosen after the base case results were known and investigate the impact of introducing three potential containment performance improvements:

- case 1 investigated the impact of allowing water to flood the reactor cavity for low pressure (non-dispersive) sequences;
- case 2 investigated the effect of installing a filtered vent system (assumed to operate with 100% reliability);
- case 3 investigated the effects of implementing both of above.

Although implementation of SAMG does not require the backfitting of special equipment only case 1 has been considered as reasonable improvements. High level Severe Accident Management activities which could be applicable based on wet-cavity design are presented in Table 3.5-2.

Subtask 2 - Assessing of the Applicability of the Generic WOG SAM Strategies

This tasks involved assessing the applicability of the Generic WOG SAMG strategies for applicability to NPP Krško. The WOG material provides different strategies by which each high level strategy can be implemented. Generally, a strategy is a method that can be used to recover from or mitigate a specific challenge during a core damage accident. For the SAMG development, the term strategy was further refined to include three elements: an action (or set of actions) to be taken, a challenge that is to be mitigated and the equipment that will be used. The plant specific assessment was done in the following steps:

- identification of general strategy for each WOG SAMG and conclusion of applicability to NPP Krško;
- evaluation of NPP Krško specific system for strategy implementation (system, component and its characteristics and required support systems);
- NPP Krško specific instrumentation evaluation.

The last two steps are typically done in table form. The table contains a suggested list of equipment that can be used to implement the applicable strategy. It was necessary to assess the list of equipment for applicability and define other means for achieving the high level strategy (The table supplied in the generic document gives only a very limited list since this is very plant specific). The unusual or unproceduralised lineups are also allowed (for example using mobile fire water pumps for injection into the Steamgenerators). It was only necessary to identify the means. The detailed assessment of each lineup in terms of flowrates, operating limits, special operator actions etc. will be done during the full implementation phase of the SAMG. Table 3.5-0 contains a shortly matrix of SAMG guidelines and the main actions, equipment and purposes that comprise the strategies contained in each guideline.

Conclusion

It can be concluded that almost all the strategies that came out as a result of the NEK IPE are already addressed in the generic Severe Accident Management Guidelines and they will be covered by development of Krško plant specific SAMG in near future. There are some plant specific findings - insights that have to be addressed as additional strategies during the conversion of the generic Severe Accident Management Guidelines to the plant specific. Those plant specific findings can mainly be implemented as additional Cautions or Notes during development of NPP Krško plant specific SAMG.

References

1. NUMARC 91-04, Severe Accident Issue Closure Guidelines, January 1992.;
2. WOG Severe Accident Management Guidance; MUHP-2310; Volume 1 -Executive Volume;
3. Krško Severe Accident Management;
   - Subtask 1: IPE Insights, September 1995. Draft;
   - Subtask 2: NEK Specific Strategies, September 1995. Draft;

Figure 1

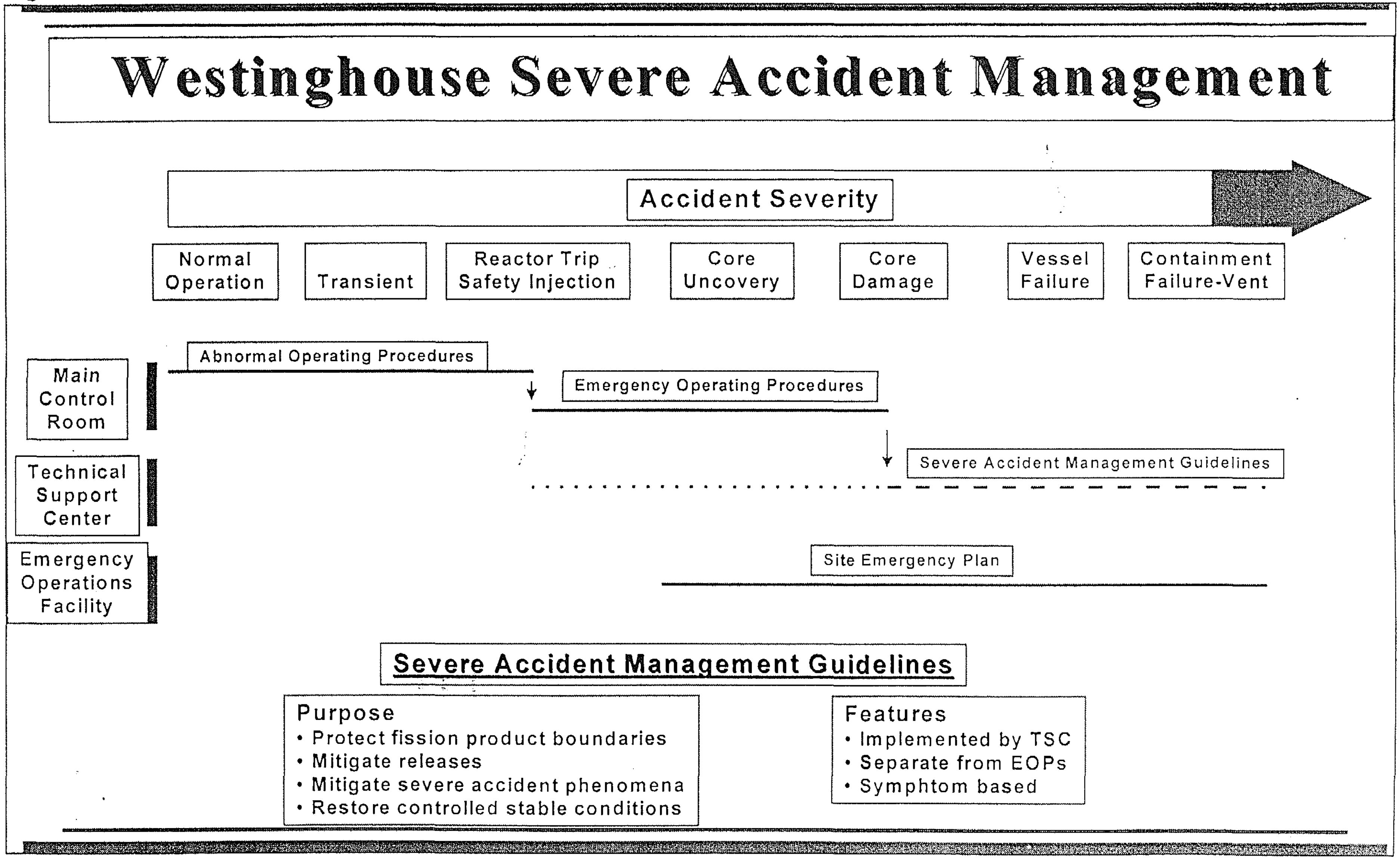
Westinghouse Severe Accident Management
Accident Severity
Normal Operation
Transient
Reactor Trip Safety Injection
Core Uncovery
Core Damage
Vessel Failure
Containment Failure-Vent
Main Control Room
Technical Support Center
Emergency Operations Facility
Abnormal Operating Procedures
Emergency Operating Procedures
Severe Accident Management Guidelines
Site Emergency Plan
Severe Accident Management Guidelines
Purpose
• Protect fission product boundaries
• Mitigate releases
• Mitigate severe accident phenomena
• Restore controlled stable conditions
Features
• Implemented by TSC
• Separate from EOPs
• Symphtom based

Table 3.5-0 Strategies Contained within Each TSC SAMG Guideline				
Guideline	**Title**	**Strategy**		
		Action	**Equipment**	**Purpose/Function**
SAG-1	Inject into the SGs	Inject into SGs	• High pressure feed paths (MDAFW, TDAFW, MFW, or SFW) • Low pressure feed paths (condensate pumps, firewater pumps, or service water pumps)	• Maintain RCS integrity • Maintain containment integrity • Establish heat sink • Reduce fission product releases
		Depressurize SGs	• SG PORV or steam dumps	
SAG-2	Depressurize the RCS	Depressurize the RCS directly	• Pressurizer PORV or auxiliary pressurizer spray • RCS head vent or letdown	• Maintain RCS integrity • Maintain containment integrity • Establish core cooling
		Depressurize SG	• SG PORV or steam dumps	
SAG-3	Inject into RCS	Inject into RCS	• CCP, SI pumps, or RHR pumps using a variety of flow path line-ups from the RWST, containment sump, VCT, or BAT. • Recirculation • RCPs	• Establish core cooling • Reduce fission product releases • Maintain RCS integrity
SAG-4	Inject into Containment	Inject into containment	• Containment spray pumps • Gravity drain of RWST	• Maintain RCS integrity • Maintain containment integrity • Establish core cooling • Reduce fission product releases
SAG-5	Reduce Fission Product Releases	Depressurize containment	• Fan coolers • Containment sprays	• Reduce containment releases • Reduce auxiliary building releases
		Dump steam	• Steam dumps and condenser	• Reduce SG releases
		Reduce RCS injection	*(See SAG-3)*	• Reduce auxiliary building releases
		Operate auxiliary building ventilation	• Aux building ventilation	• Reduce auxiliary building releases
SAG-6	Control Containment Conditions	Operate containment heat sinks	• Fan coolers • Containment sprays	• Maintain containment integrity • Reduce fission product releases • Preserve equipment and instrumentation
SAG-7	Reduce Containment Hydrogen	Burn hydrogen	• Various sources to initiate a spark	• Maintain containment integrity
		Pressurize containment	• Stop heat sinks • Open RCS valves	
		Reduce hydrogen	• Recombiners	
SAG-8	Flood Containment	Inject into containment	• Containment spray pumps • Gravity drain of RWST	• Maintain RCS integrity • Maintain containment integrity • Establish core cooling • Reduce fission product releases
SCG-1	Mitigate Fission Product Releases	Depressurize containment	• Fan coolers • Containment sprays	• Reduce containment releases • Reduce auxiliary building releases
		Dump steam	• Steam dumps and condenser	• Reduce SG releases
		Reduce RCS injection	*(See SAG-3)*	• Reduce auxiliary building releases
		Operate auxiliary building ventilation	• Aux building ventilation	• Reduce auxiliary building releases

Table 3.5-0 Strategies Contained within Each TSC SAMG Guideline				
Guideline	**Title**	**Strategy**		
		Action	**Equipment**	**Purpose/Function**
SCG-2	Depressurize Containment	Depressurize Containment	• Containment fan coolers • Containment spray pumps	• Maintain containment integrity
		Vent Containment	• Various pathways (mini-purge system, hydrogen purge system, containment atmosphere monitor, or hydrogen control system)	
SCG-3	Control Hydrogen Flammability	Pressurize containment	• Stop containment heat sinks • Pressurizer PORVS	• Maintain containment integrity
		Isolate potential ignition sources	--	
		Vent Containment	• Various pathways (mini-purge system, hydrogen purge system, containment atmosphere monitor, or hydrogen control system)	
SCG-4	Control Containment Vacuum	Pressurize containment	• Stop containment heat sinks • Open pressurizer PORVs	• Maintain containment integrity
		Add non-condensable gases	• Instrument air • Nitrogen to accumulators	

Table 3.5-1: Level 1 Severe Accident Strategies Based on NUMARC 91-04 Screening

Functional Accident Sequence	Severe Accident Strategy
IA	inject into the primary system
	depressurize primary system
	flood the containment to cover debris in the reactor pit and mitigate MCCI
	establish decay heat removal from the containment
	control hydrogen recombiners
IIA	inject into the primary system
	depressurize primary system
	flood the containment to cover debris in the reactor pit and mitigate MCCI
	establish decay heat removal from the containment
	control hydrogen recombiners
IIB	inject into the primary system to cover core debris in the vessel and the reactor pit using alternative sources (including replenishment of the RWST)
	flood the containment to cover debris in the reactor pit and mitigate MCCI
	establish decay heat removal from the containment
	control hydrogen recombiners
IIIB	inject into the primary system to cover core debris in the vessel and the reactor pit using alternative sources (including replenishment of the RWST)
	flood the containment to cover debris in the reactor pit and mitigate MCCI
	establish decay heat removal from the containment
	control hydrogen recombiners
IIIC	inject into the primary system
	flood the containment to cover debris in the reactor pit and mitigate MCCI
	establish decay heat removal from the containment
	control hydrogen recombiners
IIID	inject into the primary system to cover core debris in the vessel and the reactor pit using alternative sources (including replenishment of the RWST)
	flood the containment to cover debris in the reactor pit and mitigate MCCI
	establish decay heat removal from the containment
	control hydrogen recombiners
VA	mitigate fission product releases by isolating the break, flooding the break location for fission product scrubbing, or filtering the nuclear auxiliary building air before release
VB	mitigate fission product releases by injecting into the steam generator to cover the break location for fission product scrubbing, dumping steam to the condenser rather than the atmosphere
	depressurize primary system for high pressure cases
	inject into the primary system to cover core debris in the vessel and the reactor pit using alternative sources (including replenishment of the RWST)
	flood the containment to cover debris in the reactor pit and mitigate MCCI
	establish decay heat removal from the containment

Table 3.5-2: High priority SAM insights obtained from sensitivity and phenomenological evaluation

Phenomenology or Sensitivity Case	Insight	Severe Accident Strategy	Applicable SAMG
Sensitivity 1: Wet Cavity	NEK is the plant with the dry cavity design - Wet cavity would significantly reduce the releases (the percentage of the basement penetration would decrease from 12.3% to 3.9% and the percentage of no containment failure would increase from 33% to 47%)	Make the cavity wet - allow water to enter the cavity.	If the appropriate change in the design will be done then in the SAMG SAG-4 (Inject into containment) there is the consideration of the flooding of the reactor cavity as discussed in Chapter 2.2 (SAG-4).
External vessel cooling	In case of NEK vessel is not flooded from outside - due to dry cavity design - the external flooding of the reactor vessel is recommended	Make the cavity wet - allow water to enter the cavity.	If the appropriate change in the design will be done then in the SAMG SAG-4 (Inject into containment) there is the consideration of the flooding of the reactor cavity as discussed in Chapter 2.2 (SAG-4).
Debris coolability	In low pressure vessel failure cases the debris will not be cooled by overlying water (no water in the cavity due to dry cavity design) and significant MCCI in the cavity is expected	Make the cavity wet - allow water to enter the cavity.	If the appropriate change in the design will be done then in the SAMG SAG-4 (Inject into containment) there is the consideration of the flooding of the reactor cavity as discussed in Chapter 2.2 (SAG-4). SAMG SAG-3 (Control hydrogen flammability) and SAG-7 (Reduce containment hydrogen) also address this issue.