Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

Canada

OECD/NEA WGAMA Project – Informing Severe Accident Management Guidance (SAMG) and Actions through Analytical Simulation

Presented by Quanmin Lei on behalf of WGAMA Task Group

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Outline

- Project objective and participants
- Major activities
- Outline of the Task Group draft report
- Examples of simulation for informing SAMG
- Key messages
- Summary and recommendations

The information provided in this presentation is based on the draft report prepared by the Task Group and has not been reviewed by WGAMA members and may be subjected to changes

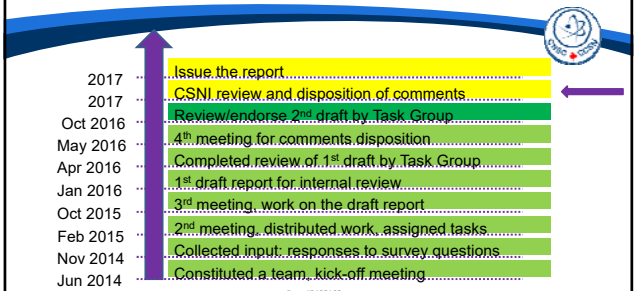
Objectives

- Discuss analytical simulations as a pragmatic means to inform severe accident management (SAM) actions and assess their effectiveness, specifically:
  - to provide basis for using concepts of “verification” and “validation” (V&V) in the context of SAMG
  - to describe existing practices aiming at assuring effectiveness of SAM
  - to describe best and recommended practices with regards to use of analytical simulations as a means to validate the SAM

Participants

Belgium, Bel V
Canada, CNSC
Czech Republic, ÚJV Řež, a.s.
Finland, VTT, Fortum, TVO
France, EDF
Germany, GRS, KIT
Italy, NINE
Japan, NRA
Mexico, CNSNS
South Korea, KAERI
Slovakia, VUJE, ENEL
Spain, CSN
Sweden, SSM, KTH
US, NRC
IAEA
European Commission, JRC
R.P. Safety Consulting
PWROG
BWROG

Major Activities



Outline of the Draft Report

- Key elements of the 2nd draft report
  - Regulatory requirements and guidance on SAM
  - Overview of concepts of V&V, assessment of effectiveness in context of SAMG, and methods of SAMG V&V
  - Current SAMG status and practices for informing SAMG, including
    - recent PWR/BWR generic SAMG updates

Outline of the Draft Report (continued)

- Guidance for informing SAMG and actions via simulation
  - review of the current severe accident analysis computer codes
  - key issues, general approach, methodologies
  - documentation and use of simulation results
- Examples of SAMG validation with analytical support

Concept of Verification, Validation and Assessment of Effectiveness

- ***Verification*** refers to technical accuracy and adequacy of the guidance. The verification process should confirm the compatibility of guidance with referenced equipment, user-aids and supplies (e.g., portable equipment, posted job aids, strategy evaluation materials, etc.)
- ***Validation*** refers to ability of personnel to follow and implement the guidance. The validation process should demonstrate that the guidance provides the instructions necessary to implement actions
- **Assessment of effectiveness** means confirmation that the accident management actions will mitigate/terminate the accident progression and minimize consequences to the public

Guidance for Informing SAMG by Simulation – Chapter 5 of the draft report (1)

- Describes roles of computer codes used to support SAM, e.g.,
  - support of Levels 2/3 PSA
  - confirmation of SAM strategies
  - supporting analysis for special topics (e.g., in-vessel retention)
  - analyses to support equipment/instrument survivability assessments
  - analyses to understand SAMG-specified actions and inform SAM effectiveness
- Provides a comprehensive review of the current severe accident computer codes

Severe Accident Computer Codes

- Integral codes
  - MELCOR, ASTEC, MAAP (MAAP4 PWR, BWR, VVER, CANDU), ECART, THALES-2
- Detailed codes
  - ATHLET-CD, COCOSYS, GOTHIC, SAMPSON, SCDAP/RELAP5, SOCRAT, TOLBIAC-ICB
- Complementary computer codes
  - SIMPROC toolset for operator actions
- Dedicated 3-d code systems
  - GASFLOW, TONUS, CFX, FLUENT, GOTHIC, CAST3M, ABAQUS, MC3D

Guidance for Informing SAMG by Simulation – Chapter 5 of the draft report (2)

- Provides guidance on how to do it
  - Important issues & general approaches
  - Methodology for assessing a SAMG-specified action one at a time
    - a step-by-step approach including a set of questions to guide an integrated evaluation
  - Methodology for assessing a set of SAMG steps or actions
    - a three-phase approach (i.e., Preparation, Assessment, and Resolution)
    - focus on assessing diagnosis capability, actions setting, and human factors
- Provides guidance on use and documentation of simulation results

Example of Analytical Simulations to Informing SAMG and Actions

- MAAP4-CANDU simulations (Canada)
  - Simulating SAMG actions to gain understanding of the temporal and environmental conditions while the actions being implemented
- MAAP4-VVER simulations (Czech Republic)
  - SAMG key strategies: primary circuit depressurization, containment residual heat removal, condition for in-vessel retention
- ISA - Integrated methodology for safety assessment (Spain)
  - for assessing effectiveness of SAMG actions
- SAMG validation through tabletop exercises with analytical support (Belgium)
  - General methodology with 9 severe accident scenarios exercised

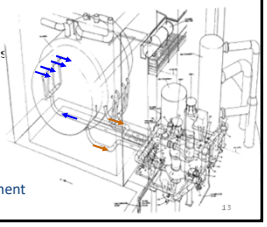
Example of Analytical Simulations to Informing SAMG and Actions (continued)

SAMG actions: provide calandria vessel (CV) water makeup and then cooling through the moderator main or pony-motor pumps via moderator HX

- Remove core decay heat, prevent further core damage, reduce H_2 and fission product releases

Potential challenges:

- Time delay to initiate the action (e.g., 1 h)
- CV bleed/relief capacity/rupture disks
- Potential damage to pumps
  - initial high temperature water in CV
  - Core debris
- Net positive suction head (NPSH) requirement

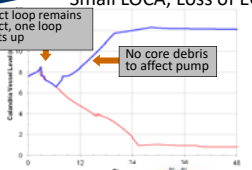


Example of Analytical Simulations to Informing SAMG and Actions (continued)

Small LOCA, Loss of ECC, Loss of moderator cooling

Intact loop remains intact, one loop heats up

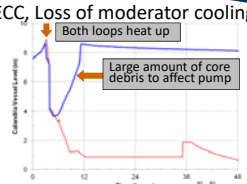
No core debris to affect pump



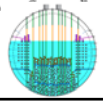
- Make-up re-submerges fuel channels
- Recirculation cools fuel channels

Both loops heat up

Large amount of core debris to affect pump



- Recirculation may not work due to core debris
- Need make-up & containment heat sink



Key Message

- Symptom based guidance provides an optimal approach to mitigate severe accidents
  - symptom based guidance requires knowledge and training to diagnose plant conditions and to identify options that implement viable countermeasures to mitigate severe accidents
  - informing SAMG and actions through analytical simulation is considered as a valid approach for accumulation of such knowledge

Key Message

- A review of current severe accident computer codes and other complementary computational toolsets indicated that they have been remarkably advanced and extensively tested in recent years
  - these codes offer capability for modeling key phenomena, physical processes, and various progressions of a severe accident with the influences of operators' actions, with reasonable confidence

Key Message

- Analytical simulation alone is not be sufficient to assess SAM effectiveness
  - in addition to the insights obtained from the simulations of SAM actions, assessing SAM effectiveness should come from an integral evaluation that takes into account all inputs such as from the review of SAMG documentation, personnel training results, and validation activities such as tabletop exercises, plant walkthroughs and drills, etc.

Key Message

- The purposes of assessment of a SAMG-specified action are
  - not only to assess whether the action will likely achieve its intended function,
  - but also to quantify the environmental conditions under which the action is being implemented, assess its positive and negative impacts over the accident duration, and
  - to provide insights for the technical support center experts, and for SAMG developers and implementers for potential SAMG updates

Key Message

- The selection of scenarios to be simulated should be made with consideration of
  - the Level 2 PSA results
  - figure-of-merit (output) parameters under examination
  - strategies for varying other modeling parameters as part of uncertainty assessment
  - existing simulations that have demonstrated the sensitivity of the output parameters to different scenarios
  - expert judgment

Key Message

- Treatment of simulation uncertainty still remains a serious challenge for assessing SAM actions
  - informing SAMG actions through analytical simulation should be performed using the best-estimate approach
  - the associated uncertainties should be recognized and, if necessary, quantified and then taken into account in the assessment
  - engineering judgement remains a part of interpretation of the simulation results and the overall evaluation of the SAMG actions

Key Message

- The time required to implement an action reflects human and organizational performance (HOP) of a SAM crew during execution of SAMG
  - the time delay is influenced by many factors
  - the time delay can be estimated based on SAMG reviews, tabletop exercises, plant walkthroughs, and plant drills
  - a range of values for action times can be simulated analytically and thus help address the uncertainty in HOP

Key Message

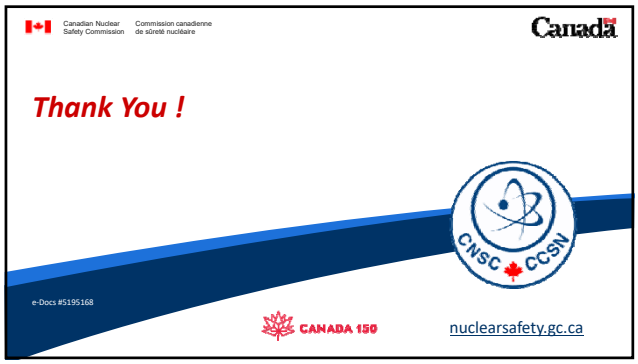
- In addition to various computer code simulation activities currently devoted to inform SAMG and actions, a number of countries are adopting use PC-based or full-scope severe accident simulators in the SAMG training and verification and validation processes

Summary

- This NEA/CSNI/WGAMA report provides a state-of-the-art summary regarding the use of analytical simulations to inform SAMG actions
  - analytical support could and should play an important role in the development, implementation, review, evaluation, maintenance, and periodic update of generic or plant-specific SAMG, particularly in terms of understanding the phenomenology of severe accidents and their plant-specific symptoms revealed by plant conditions and available instrumentation

Recommendations

- Other SAMG verification and validation aspects are not addressed in this report, such as
  - independent expert review of SAMG documentation
  - evaluation of SAMG training requirements
  - conduct of plant accident drills
  - independent evaluation of SAMG exercises
  - integration into an overall assessment of SAM effectiveness
- Overviewing curent practices on those aspects is recommended, with the objective of providing a more complete basis for SAMG verification and validation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