OECD/NEA WG on the Analysis and Management of Accidents (WGAMA); activities in the SA Field

Nils Sandberg  NEA, Safety Division
Luis E. Herranz  CIEMAT, Spain
Didier Jacquemain  IRSN, France

IAEA TM on the V&V of Severe Accident Management Guides
Vienna, 12-14 December, 2016
Background

- CSNI is responsible for the NEA activities that support maintaining & advancing the scientific and technological knowledge base of nuclear-installation safety.

- Groups are created & activities are approved by the CSNI.
Outline

• Background, WGAMA structure and history
• Some recent severe accident related activities
• On-going activities
• Conclusions
**Background**

**OECD/NEA Joint Projects**
- Halden RP, SCIP III, CIP
- ATLAS, PKL, LOFC
- BIP, STEM, THAI
- HYMERE
- HEAF
- PRISME
- BSAF
- CADAC, CODAP
- FIRE, ICDE

**Committee on the Safety of Nuclear Installations**

- **CSNI Programme Review Group (PRG)**
- **Working group on Risk Assessment (WGRISK)**
- **Working group on Analysis & Management of Accidents (WGAMA)**
- **Working group on Integrity and Ageing of Components and Structures (WGIAGE)**
- **Working Group on Human and Org. Factors (WGHOF)**

**Senior Expert Group on Safety Research Opportunities Post-Fukushima (SAREF)**

- **Working Group on Fuel Safety (WGFS)**
- **Working Group on Fuel Cycle Safety (WGFCS)**
- **Working Group on External Events (WGEV)**
- **Working Group on Electrical Systems (WGELEC)**
### Overview: ongoing WGAMA activities

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Spent-fuel pond (SFP) loss-of-cooling accident (1/2)

Objectives

• Status of SFP accident and mitigation strategies
• Current experimental and analytical knowledge
• Strengths and weaknesses of analytical methods used in codes to predict SFP accident evolution
• Identify and list additional research activities, analyse code deficiencies, etc.

Participation: 12 main authors: Belgium, Canada, Czech Rep., EC-JRC, France (lead) Germany, Hungary, Italy, Japan, Spain, Switzerland & USA

Scope

• Loss-of-cooling/coolant for wet storage facility focusing on the fuel-building SFP
• Past accident and precursor events including the Fukushima Daiichi SFPs.
• Important aspects of the accidents and phenomenology: criticality risk; pool behaviour (racks & fuel assemblies); progression (partial/complete LoCA); H2; etc.
• Assessment of the current experimental knowledge.
• Review of the SOAR computer codes used for SFP-accident analysis.
Spent-fuel pond (SFP) loss-of-cooling accident (2/2)

Recommendations

• More specific modelling for SFPs is desired where current codes are intended mainly for SA analysis (source-term estimation is a challenge)

• Vis-à-vis CANDUs, presently no complete SA code exists: development of a CANDU-SFP tool is needed

• Produce specific user guidelines for code applications to SFP accidents

• The NEA SFP project benchmark helped identify limitations: a similar exercise needed for other SFP accident scenarios & codes

• Experiments targeting LWR SFP accidents are planned (DENOPI, IRSN; QUENCH, KIT): important & require support; more needed.

• Identify important uncertainties via a PIRT exercise

• A State-Of-the-Art Report should be written as a function of ongoing & planned research results

Hydrogen Management & Related Computer Codes

Main objectives
• Review approaches to HM in member states covering:
  – safety requirements;
  – mitigation systems & their implementation;
  – accident management options;
  – code validation.
• Identify advantages & drawbacks of the HM options.

Participation: 16 countries, Canada leading

Scope
• Review HM approaches in DBAs & SAs including national requirements, mitigation, measurement strategies
• Engineered systems (sprays, air cooler, blow-out panels, etc.) & potential impact
• Advantages & consequences of different HM options (enough for regulators/SAM)
• All water-cooled reactors, viz. PWR, VVER, BWR & PHWR
• Address capabilities & validation status of dedicated codes
Hydrogen Management & Related Computer Codes

Conclusions

• Further efforts needed to close research gaps, enhance code capabilities and reduce code uncertainty, mainly as follows:
  • research on impact of engineered systems (containment spray, air cooler, etc.) on H2 distribution is on-going in some countries; assessment is needed of how knowledge gained from R&D has been implemented in NPP safety analysis & how it is considered in SAMG;
  • studies performed by some countries in a PSA level 2 context showed that flame acceleration cannot be ruled out even when passive autocatalytic recombiners are used; hence, pressure loads due to H2 &/or CO combustion on containment & equipment (especially where this is safety related) need to be assessed in in-vessel & ex-vessel conditions where this may be plant specific.

Filtered Containment Venting (FCV)

Objectives
• Compile the status of FCV implementation for water-cooled reactors including systems already installed or contemplated
• Describe national FCV-implementation requirements & filter performance
• Briefly describe available systems & demonstrated/expected performance
• Discuss possible risks, e.g., inadvertent opening, containment under-pressure
• From SAM perspective, identify any room for hardware or system-qualification improvements
• Summarize status of as-implemented CV strategies especially those needing interfacing with decision-making processes to actuate CV.
• Participation 9 main authors: Canada, EC, France (lead), Germany, Spain, Switzerland and USA; contributions from a further 9 countries
Filtered Containment Venting (FCV)

Conclusions

- Compile FCV requirements differ worldwide: more-or-less prescriptive; FCV not necessarily mandated or not considered primary means to avoid containment over-pressure.
- FCV considered an extra system to protect containment integrity. Typically part of the overall SAM strategy for PWRs & BWRs; also in DBA for some PHWRs. Operation sometimes foreseen for SAM other than over-pressure avoidance, e.g., BWRs with loss of heat sink to remove decay heat or reduce containment H2.
- Generally, all contributing countries accept FCV potential benefits for emergency response, reduced land contamination & health effects plus increased societal acceptance of NPPs. Still, FCV to be considered along with other SAM strategies, e.g., containment by-pass must be managed by non-FCV measures.
- FCV implemented before Fukushima: mainly manage long-term pressurization; new systems may aim to deal with more challenging conditions (manage early accident phases, cycling or long-term use in SAs). System safe use & reliability/robustness in such conditions should be further assessed.

In-Vessel Accident Progression Benchmark

Objectives
Based on previous benchmark (TMI-2) conclusions, extend scope by challenging several codes to the full extent of their capabilities to predict core-melt progression and impact of SAM actions in a variety of SA situations focusing on core reflood & molten core slumping +corium behaviour

- simulate representative sequences with well-defined boundary conditions;
- sensitivity studies on more important and uncertain key parameters.

Participation: 8 countries, 10 organizations: Belgium (Tractebel), Bulgaria (INRNE), France (IRSN), Germany (GRS, KIT, RUB), India (BARC), Italy (ENEA lead), Russian Fed. (IBRAE), Slovak Republic (IVS)
In-Vessel Accident Progression Benchmark

Conclusions and recommendations

• Code robustness confirmed.

• Early-phase degradation: similar in all codes (after input-decks harmonized)

• Late-phase degradation: marked divergence in results due mainly to different degradation models + choices of model options & discretization schemes.

• Timing of vessel failure can strongly depend on the different failure criteria used.

• Stochasticism, e.g., melt break-up during slumping, can give divergent outcomes: only analysis of alternate assumptions/parameters captures all possibilities.

• Reflood phase, highly-degraded core: strongly depends on relocation & lower-head models & user-defined parameters; uncertainties still high, more effort on models.

• Late phases (corium in the lower plenum): not necessarily the most uncertain; their uncertainty always seems high due to accumulation of earlier uncertainties.

• Future benchmark: focus on separate degradation phases to identify those inducing the largest uncertainties.

International benchmark of fast-running software tools used to model FP releases during accidents at NPPs (1/2)

Objectives

- Benchmark software tools used to assess accident source terms and doses by organizations responsible for emergency planning & response for decision making
- Improve confidence in the simulated results of an accident via cross-comparison
- Improve understanding of relative strengths and shortcomings of available tools
- Participation: thirteen organizations contributed
International benchmark of fast-running software tools used to model FP releases during accidents at NPPs (2/2)

Method
• Tools for performing simulations of FP release were identified
• 5 hypothetical scenarios were developed
• A benchmark exercise, with as many combinations of tools/scenarios as possible was carried out

Conclusions
• Software tools likely to provide different source term and dose estimates when used with limited information for the same accident scenario
• Assumptions made with limited data had a major effect on source term prediction

Computational fluid dynamics (1/2)

CFD Uncertainty Methodologies, Review and Benchmarking

- Updated CSNI reports from the CFD writing groups have just been published:
  - Best Practice Guidelines for the use of CFD in Nuclear Reactor Safety Applications - revision
  - Assessment of CFD Codes for Nuclear Reactor Safety Problems - revision 2
  - Extension of CFD Codes Application to Two-Phase Flow Safety Problems - Phase 3

- Web-based Wiki-type information centre: major update almost complete
- Biennial workshop, CFD4NRS: application of CFD/CMFD codes to nuclear reactor safety and design and their experimental validation
- CFD4NRS-6 was successfully held in Sept. 2016, hosted by MIT
  - 58 presentations, 4 keynote talks, one plenary talk; 126 participants
  - special issue of Nuclear Engineering & Design dedicated to CFD4NRS-6
  - session devoted to the latest CFD benchmark (next slides)
- the next workshop, CFD4NRS-7, will be in Sept. 2018 in Shanghai
Computational fluid dynamics (2/2)

Current Benchmark Objective: promote, test & evaluate use of CFD simulations via a blind benchmark based on de-stratification of a containment atmosphere; a PANDA test (PSI) with an upward buoyant jet was used.

Participation: 19 submissions

Status

- A surprisingly large spread of results was observed.
- Many simulations seemed to fail to predict basic features of elementary flow, e.g., spread of a free jet:
  - lack of preliminary studies or inexperience?
- It is not known whether participants applied BPGs:
  - would applying BPGs have reduced spread of results?
  - was the domain too large (too onerous) for BPGs?
- A coarse-mesh GOTHIC analysis produced results of comparable quality to those of the best CFD ones
- For this type of large-domain problem, CFD may not yet have reached the stage of offering advantages over traditional containment analysis methods
Overview: recently approved reports

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<td>CSN/UPC</td>
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<td>State-of-the-art report on Molten-Core-Concrete interaction and Ex-vessel Molten-Core Coolability</td>
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Conclusions: a lot of useful SAM-related work has been and continues to be done within the NEA/CSNI framework

Reports: http://www.oecd-nea.org/nsd/docs/indexcsni.html

Acknowledgements: the many people who participate in the activities of the CSNI Working Groups

Thank you for your attention!

nils.sandberg@oecd.org
Extras: In vessel accident progression BM

**Scope:** accident sequences + scenarios = 8 analyses

**SBLOCA sequence**
(Small Break LOCA + SG-FW trip)
- No HPI/LPI
  - Recovery of HPI (28 kg/s)
    - 10 t core deg.
    - 45 t core deg.
- SBLOCA Base case
  - 1.1 Refl.
  - 1.2 Refl.

**SLB sequence**
(Surge Line Break + SBO)
- No HPI/LPI
  - Recovery of HPI (28 kg/s)
    - 10 t core deg.
    - 45 t core deg.
  - Recovery of LPI (360 kg/s)
    - 10 t core deg.
    - 45 t core deg.
- SLB Base case
  - 2.1 Refl.
  - 2.2 Refl.
  - 2.3 Refl.
  - 2.4 Refl.

**Contributions 11:**
- ASTEC (5), ATHLET-CD (2), MELCOR (1), ICARE/CATHARE (1),
  SOCRAT (1), RELAP/SCDAPSIM (1) + uncertainties with ATHLET-CD + sensitivities with
  ATHLET-CD (GRS), ASTEC (ENEA, BARC) & MELCOR (Trac)