IEM on Severe Accident Management

in the light of the accident at the Fukushima Daïchi NPP

Progress, challenges and perspectives in the field of design features, as regards SAMG

IAEA, March 2014

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Introduction

Review the situation on current knowledge and solutions concerning severe accident mitigation, against the following objectives

- **Practical elimination of scenarios leading to large and early releases**
- **In case of core melt, only protection measures limited in area and time can be tolerated (eg no permanent relocation)**
- **"NPPs should be designed, constructed and operated with the objective to avoid accidents and, should a severe accident occur, mitigate its consequences in order to avoid [large, long term] off site contamination"**

» ***Considering the pre Fukushima state of the art and the severe accident features raised by Fukushima***

Agenda

- Introduction
- 1 Practical elimination of phenomenon leading to containment early failure
- 2 Core melt management
- 3 Specific severe accident features raised by Fukushima
- Conclusion

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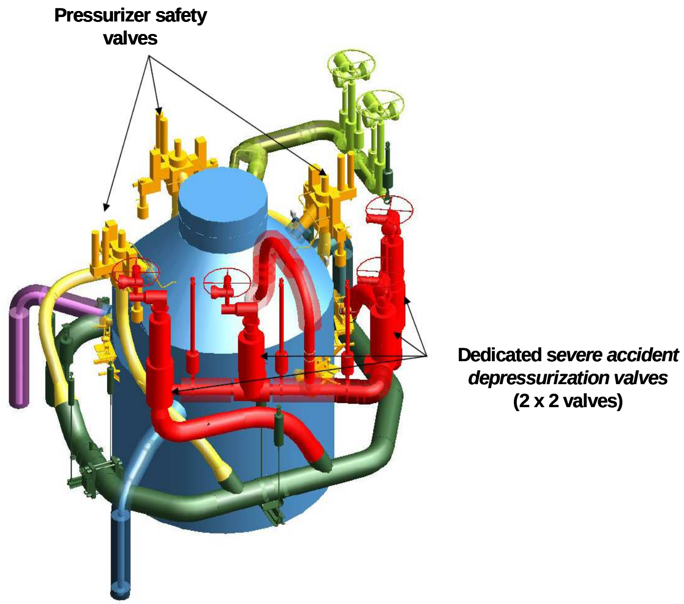
Pressure core melt

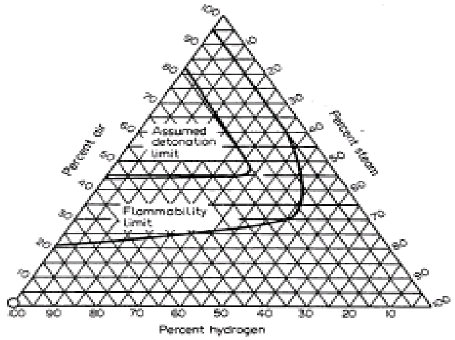
- **Current knowledge and solutions**
  - depressurize at the entry in severe accident
- **Key aspects**
  - robust signals *(eg temperature, dose rate)*
  - human factor *(the first action to take in SAMG)*
  - robustness and diversity of depressurization means
- **Insight from Fukushima**
  - ensure severe accident I&C in all situations
  - once open, depressurization valve should remain so in case of loss of power



Solutions exist for both new and operating reactors

Hydrogen

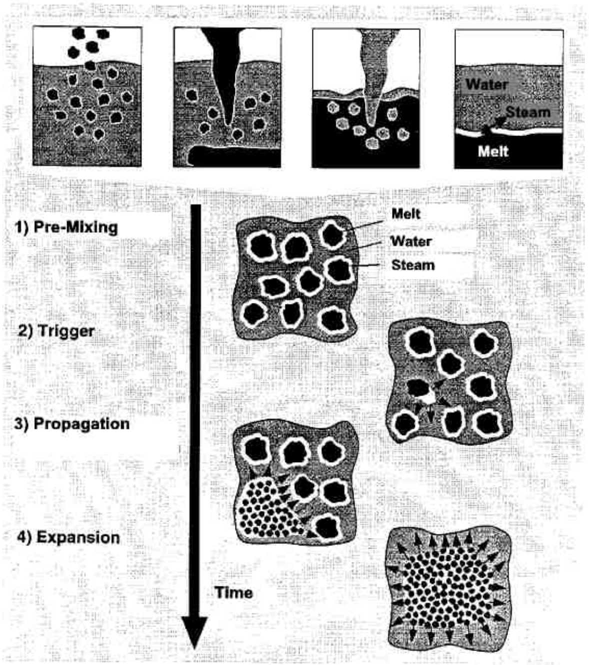
- **Current knowledge and solutions**
  - eg recombiners + comprehensive modeling
- **Key aspects**
  - demonstrate absence of detonation
  - demonstrate robustness to deflagration
  - comprehensive modeling needed
- **Insight from Fukushima**
  - avoid leakage to adjacent buildings
  - interest of solutions removing H_2 (eg recombining)



H2 risk prevention deserves a comprehensive approach

Steam explosion

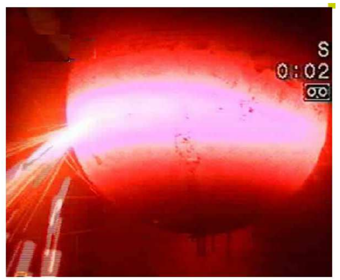
- **Current knowledge**
  - in vessel : containment challenge widely considered as ruled out.
  - ex vessel : still much uncertainty
    - conditions and likelihood of occurrence
    - energy and impact on containment
- **Key aspects**
  - dry pit or flooded pit ?
  - use conditional probability or global probability ?
  - safety approach concerning “practical elimination”
- **Insight from Fukushima**
  - ex vessel : dry pit



Global R&D and convergence needed about steam explosion risks

In vessel retention

- **Current knowledge**
  - significant progress on physics modeling
  - critical heat flux, focusing effect
  - much uncertainty about success by sole external cooling
- **Key aspects**
  - appreciation of ex vessel steam explosion risk
- **Insight from Fukushima**
  - data on corium / vessel interaction to be collected



(KTH, Sweden)

No alignment around the world on the safety philosophy as regards IVR and steam explosion. R&D and convergence needed. Dry pit: on the safe side in a deterministic approach.

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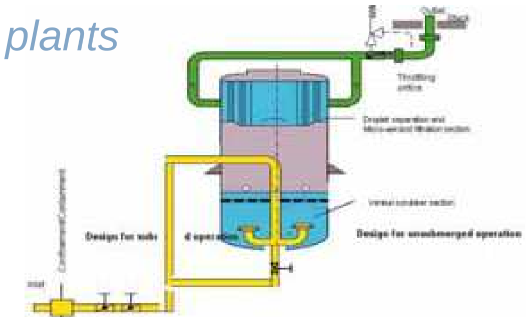
Residual heat removal from containment

- **Objective : protect containment from overpressure**
- **Current knowledge and solutions**
  - dedicated fixed systems (heat exchange)
  - mobile systems
  - filtered venting

new or operating plants



- **Insight from Fukushima**
  - lining-up, rupture disk, manual actions
  - timing for venting, grace period, articulation with public authorities
  - robustness of containment protection provisions under BDH”

Solutions exist for both new and operating reactors

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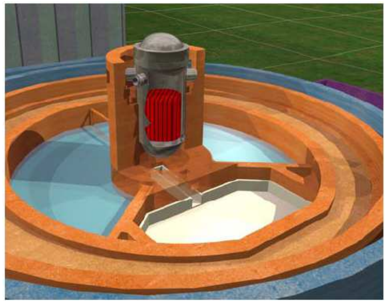
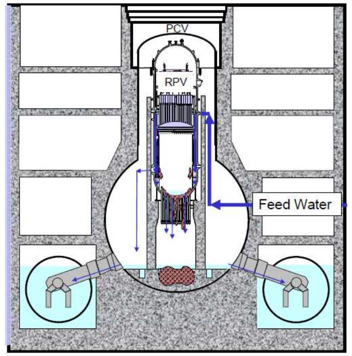
Basemat protection from melt-through

- **Current knowledge and solutions**
  - new reactors: “core catchers” are developed and qualified
  - existing reactors
    - little possibility to retrofit core catchers
    - more R&D necessary to show possibility to stop basemat ablation



- **Key aspects**
  - slow process
  - effectiveness of cooling by the top ?
  - non condensable gas pressure build up to be managed



- **Insight from Fukushima**
  - expertise of the extent of the core concrete interaction will be very valuable

R&D still necessary for operating reactors

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I&C

- The loss of all I&C is probably the most crucial point of the Fukushima Daiichi accident.
- Powered by DC, the loss of which is at the heart of the catastrophic development of the accident.
- Nuclear industry in the same situation as many others from this point of view (eg aviation)

Vital I&C must be protected, hardened and supported in order to be able to mitigate severe accident under all circumstances.

Site isolation and devastation

- **Ensure site autonomy**
  - fuel
  - water reserves
  - communications independent from network
- **Hardened crisis management centre**
- **Plan for mobility on the site and transportation with the outside in harsh conditions**

Implement the equipment and features needed to manage severe accident if the site were isolated and "devastated".

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Multi unit accident

Overall a human resource and EP&R topic

As far as equipment and systems are concerned, ensure the adequate redundancy and availability to face multi unit severe accident

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Spent fuel pool

- severe core degradation in the spent fuel pool might have unbearable consequences
- scenario to be practically eliminated

Spent fuel pool integrity, adequate water-tightness and residual heat removal must be ensured under all circumstances

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Conclusion

- **Fukushima reminds that SA are to be comprehensively implemented in DiD**
  - an important issue since WASH 1400, TMI, Tchernobyl
  - solutions were developed to protect containment under SA (considerable R&D)
  - included in DiD requirements: INSAG 10, SSR-2-1, WENRA
- **Continuous R&D and improvement remain necessary**
  - convergence desirable on steam explosion risk / in vessel retention
  - periodic safety reassessment as a good practice
- **Some new features were raised by the accident**
  - spent fuel pool, multi unit, Isolation, chaotic site
  - beyond design hazards

» ***Means to mitigate severe accident should demonstrate sufficient robustness and remain operational in case of beyond design hazards.***