Assessment of containment conditions and SAM strategy using MELCOR 2.2 and ASTEC V2.2 codes

Mirco Di Giuli

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1 – Introduction

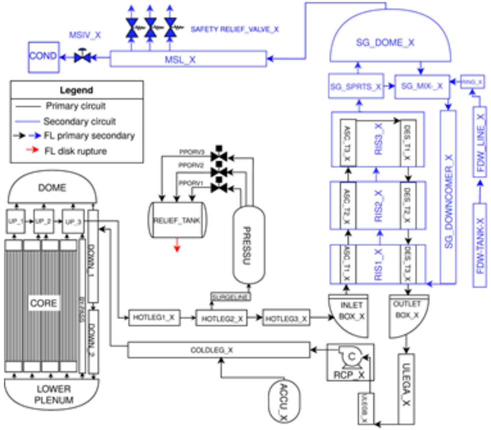
1-Introduction

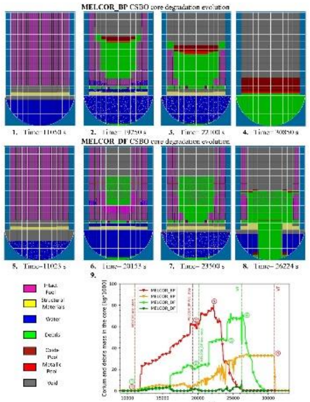
Severe Accident Analysis in Tractebel

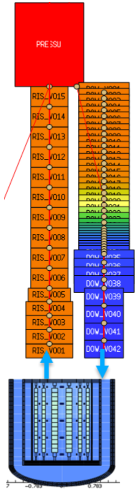
- **MELCOR 2.2** is the reference code used to perform integral studies on Belgian reactors (Deterministic/PSA 2)
  - *Thermal-hydraulic phenomena in the RCS*
  - *Core degradation, Containment response*
  - *R&D : MUSA project*

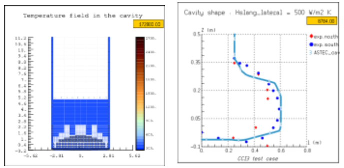
- **ASTEC V2.2** code is used mainly in stand-alone or coupled mode for analyzing specific aspects and for R&D:
  - *UaSA of iodine chemistry in the containment*
  - *MCCI/Debris coolability*
  - *R&D: SMR modeling, ASCOM*

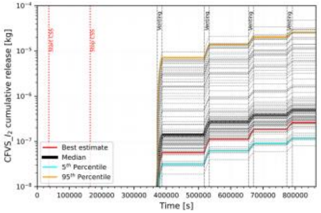
CODE to CODE benchmark activities

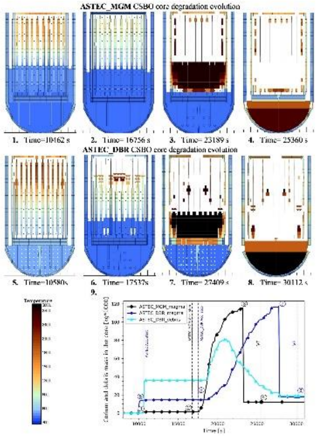












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2 – Long Term Containment Conditions (LTCCs)

2-Long Term Containment Conditions

Main factors governing LTCCs

- In case of severe accident involving the VF without containment failure, the main factors governing the LTCCs are four:
  - ***Core decay heat***
  - ***Type of concrete of the reactor pit***
  - ***Amount of water injected***
  - ***Debris/corium coolability***
- The entire progression of a severe accident is difficult to predict using integral codes
  - ***The "ex-vessel" phenomena are still poorly predicted***
  - ***The efficiency of a SAM strategy depends on the containment conditions***
- To reduce the uncertainties related to ex-vessel phenomena a different approach is adopted by Tractebel.

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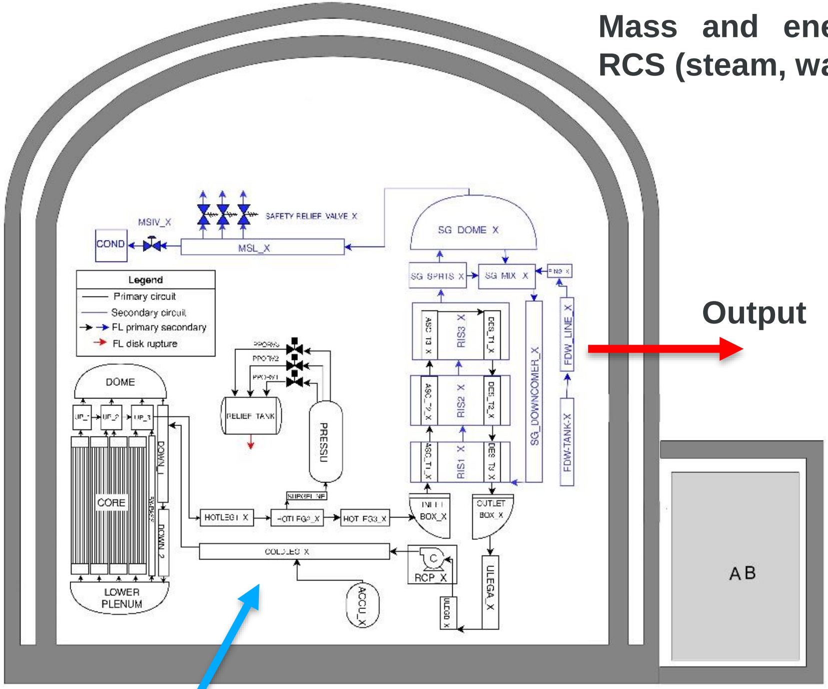
2-Long Term Containment Conditions

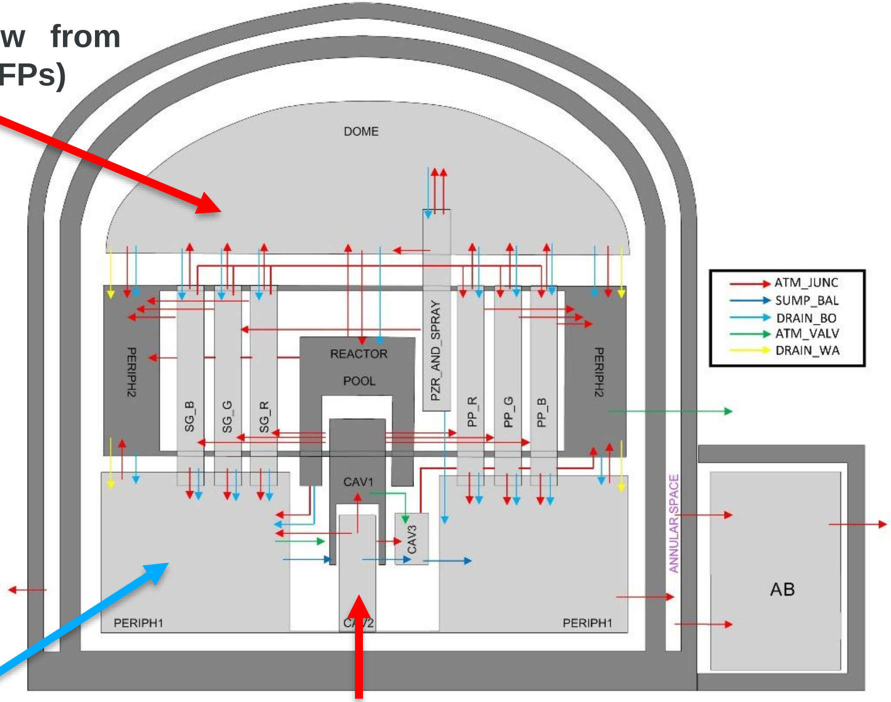
Integral calculations → Containment calculations (1/2)

- ***Integral case*** (several days of calculation)
- ***Containment case*** (some hours of calculation)



Output

Mass and energy flow from RCS (steam, water, H_2, FPs)



Initiating event

Accident conduction (RCS+Containment)

Accident conduction (Containment)

Mass and energy flow from MCCI (steam, water, H_2, CO, CO_2) and decay heat

2-Long Term Containment Conditions

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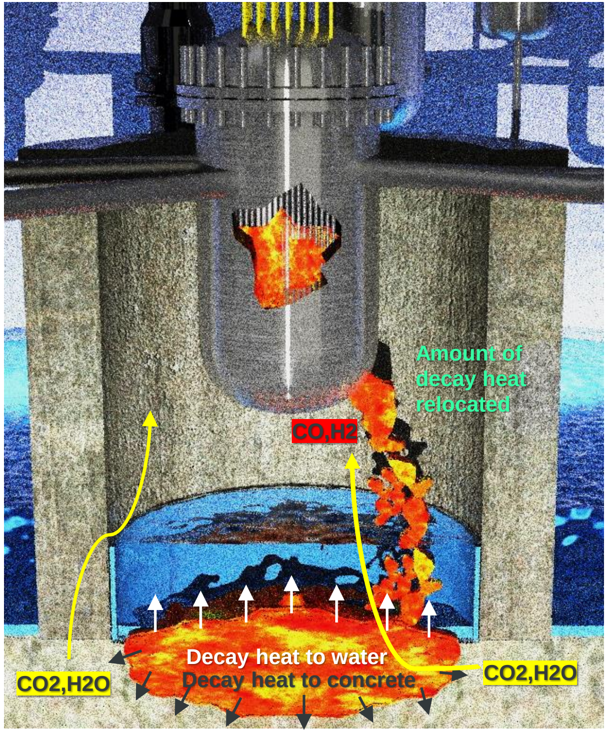
Integral calculations → Containment calculations (2/2)

- The main advantage to perform containment/SA calculations is the possibility to vary:
  - ***The core decay heat relocated in the reactor pit***
    To bound uncertainties on the LH failure models (Time, size, rate)
  - ***The decay heat distribution between water and concrete***
    To simulate coolable, partially coolable or not coolable geometry of the corium/debris
  - ***The NCG/steam released from the concrete***
    In agreement with the debris geometry features
  - ***The FP and H2 kinetics of release***
    To test the PAR performances and assess the FP escaping through the containment leaks



- **By varying these B.C. to delimit the uncertainties associated with SA phenomena, a wide range of containment conditions can be reproduced quickly**

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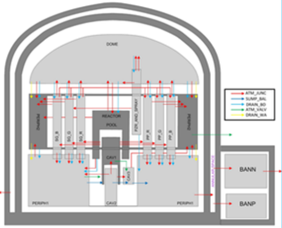
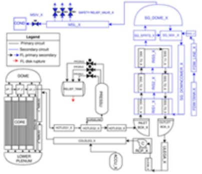
3 – Methodology description

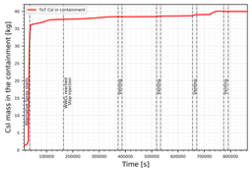
3-Methodology description (1/4)

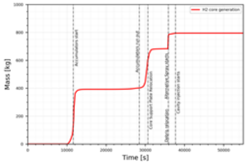
Flow diagram

Identification of most challenging or likely SA scenario









Run MELCOR/ASTEC integral case (10 days)

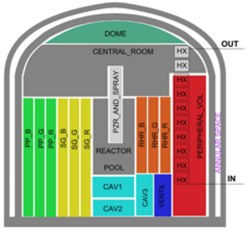
Extraction MELCOR output : Mass and energy release from RCS and MCCI

Run MELCOR/ASTEC containment base case setting the output extracted as B.C.

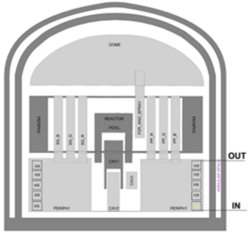
Cross check

1. Implement the SAM strategy in the containment stand-alone model
2. Varying the decay heat
3. Varying the debris power distribution
4. Varying the NCG release
5. Varying water mass injected

B.C. + variation



B.C. + variation



Run MELCOR/ASTEC containment sensitivity case and implementing the SAM

SAM strategy assessment

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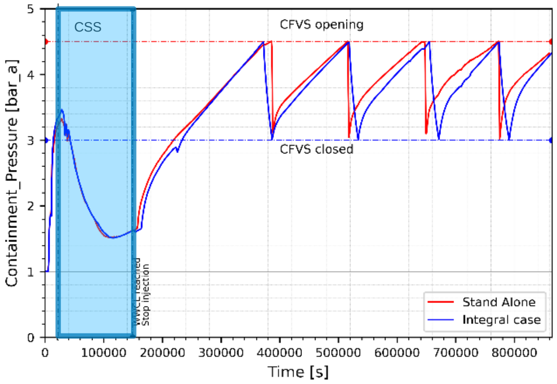
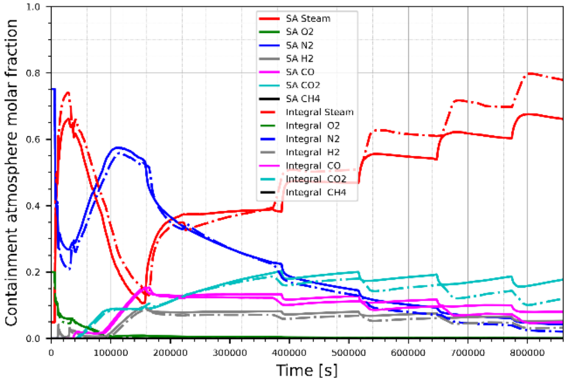
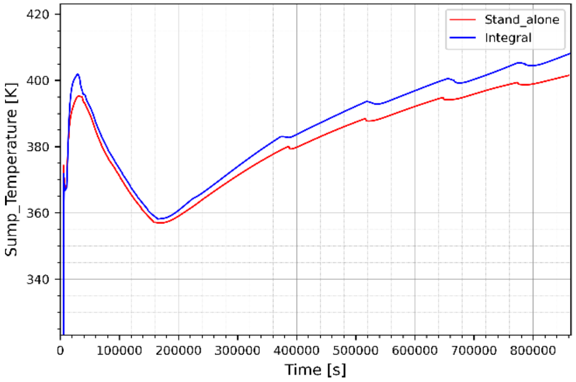
3-Methodology description (2/4)

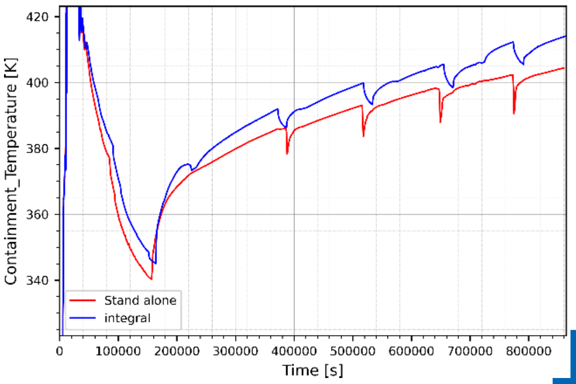
Base case SA results vs Integral results

- A 10 days CSBO sequence with CSS intervention and PAR/CFVS availability is reproduced ($CaCO_3$ concrete)
- The comparison of the main TH parameters shows a quite good agreement
  - ***The containment response of the 10 days CSBO scenario reproduced are similar***
  - ***The discrepancy in the steam molar fraction is due to a different modelization of the CFVS***
  - ***Based on the results is possible to say that the SA deck is almost equivalent to the integral one***







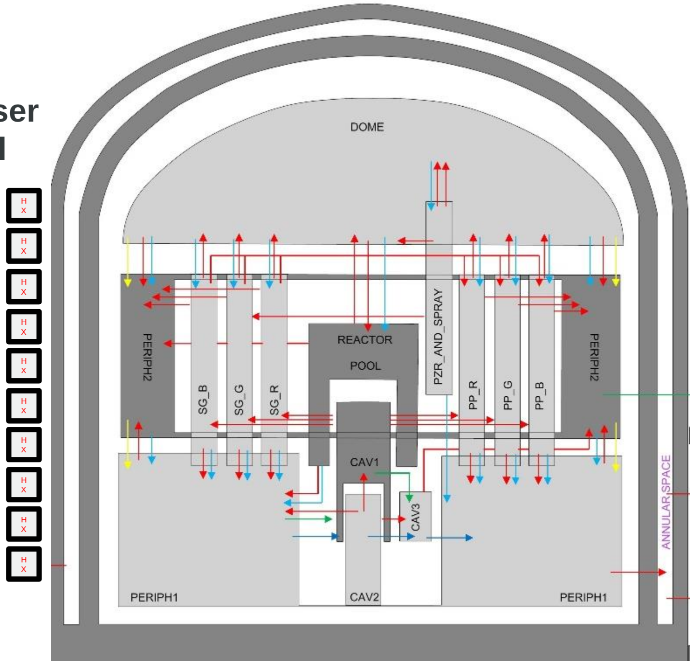


3-Methodology description (3/4)

Implementation of the containment SAM strategies to assess

- Once the reliability of the SA deck is verified, a SAM strategy is selected and implemented in the model.
- To remove heat from the containment the following SAM countermeasures can be adopted:
  - ***Installation of a condenser in the containment atmosphere zone***
  - ***Installation of a Heat eXchanger (HX) in the containment sump***
  - ***Use of the CSS in recirculation mode with external HX***
  - ***Prolonged use of the Containment Filtered Venting System (CFVS)***
- Each of the above SAM strategies can be reproduced with every severe accident code

Condenser model



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3-Methodology description (4/4)

Selection of the sensitivity cases

- The cases selected should cover the larger range of containment conditions

Case	Decay heat	NCG (Decay heat to concrete)	Condenser exchange area	Water
Base case	Base case= DCH_pool	Base case	Not present	Base case
FULL_Cond	Base case= DCH_pool	Base case	500 m^2	Base case
FULL_2_Cond	Base case= DCH_pool	Base case	1000 m^2	Base case
BMMT*_Cond	DCH_pool + DCH concrete	35% Base case	500 m^2	Base case
BMMT_Cond_120%_DCH	120% (DCH_pool + DCH concrete)	35% Base case	500 m^2	Base case
BMMT_Cond_50%_Water	DCH_pool + DCH concrete	35% Base case	500 m^2	50% Base case
BMMT_Cond_25%_Water	DCH_pool + DCH concrete	35% Base case	500 m^2	25% Base case
COOL_Cond	DCH_pool + DCH concrete	3% Base case	500 m^2	Base case

(*BMMT label -> basemat ablation maximum deep 2.5 m)

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4 – Calculations and Results

4-Calculations and Results (1/6)

Criteria to assess the SAM strategy

- A preliminary assessment of the SAM strategy is evaluated based on the following 4 criteria:
  - ***Maximum temperature in the RB***

  - ***Maximum pressure in the RB***

  - ***Formation of flammable gas mixtures in the containment***

  - ***Amount of fission product released***

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4-Calculations and Results (2/6)

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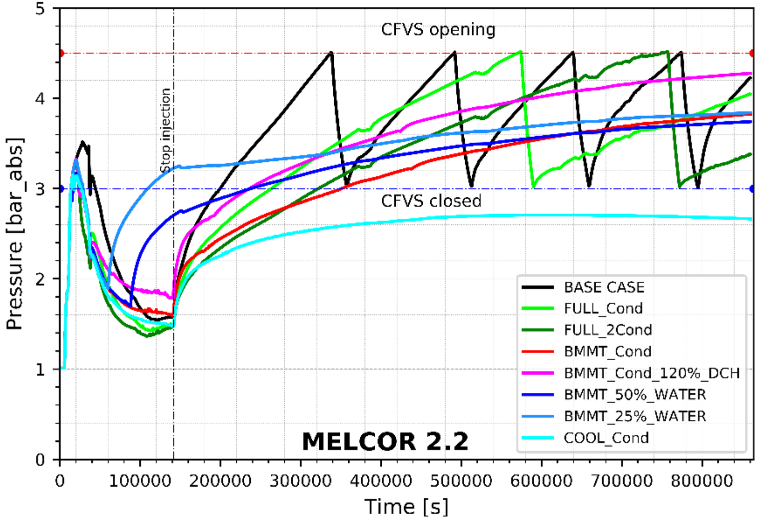
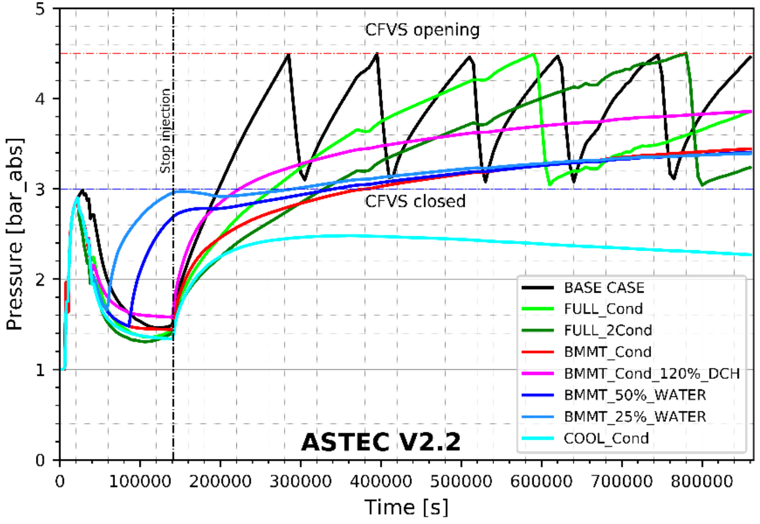
Containment pressure





- The insertion of a condenser can avoid the CFVS opening in the case of:
  - ***The cumulative NCG release stops at the BMMT***
  - ***The decay heat and water injected do not significantly affect the SAMS efficiency***
- Using the base case NCG release the CFVS triggering occurs (Independently by HX surface)

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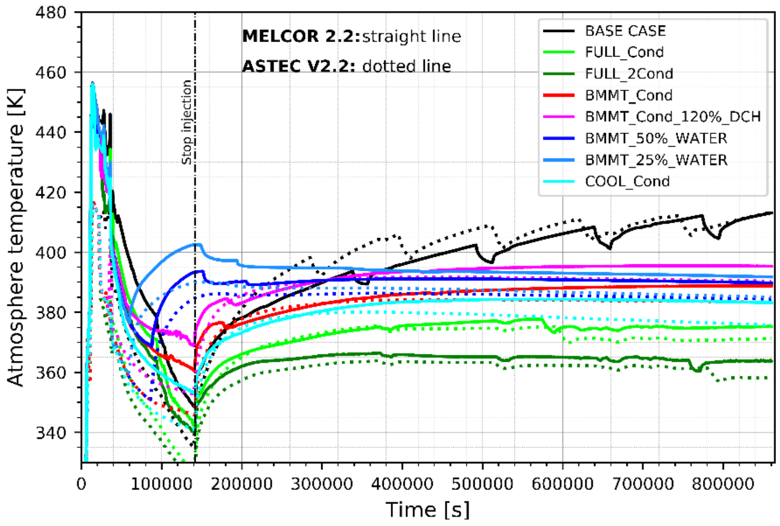
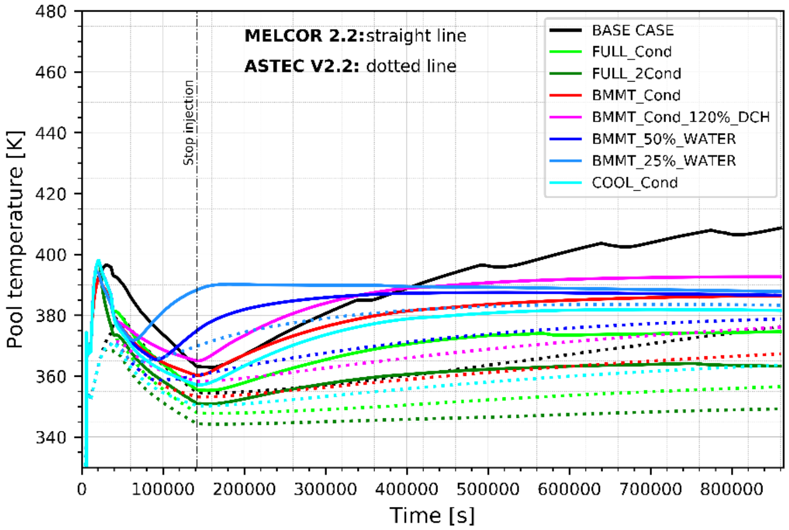
4-Calculations and Results (3/6)

Containment temperature





- The insertion of a condenser reduces the maximum containment atm/pool temperature:
  - ***Increasing the HX surface and reducing the DCH to the pool temperatures decrease***
  - ***The reduction of water injected has effect in the first days of the accident***
  - ***For the remaining case the temperature assumes a stationary and similar value after 4 days***

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4-Calculations and Results (4/6)

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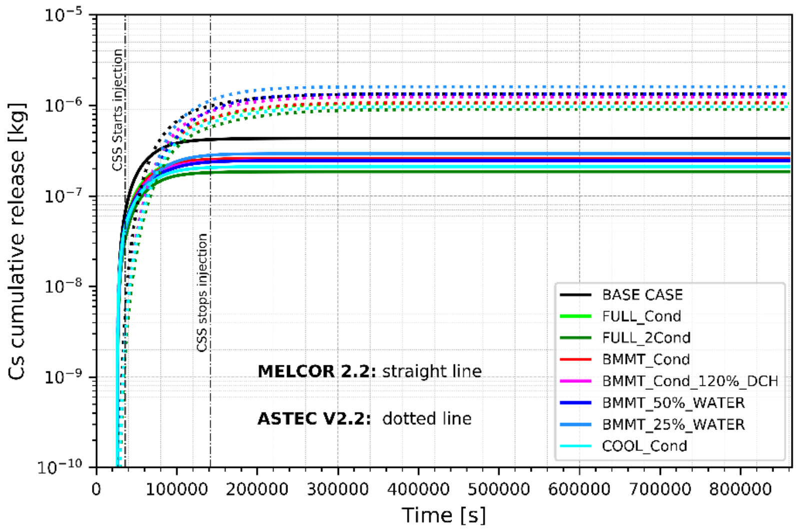
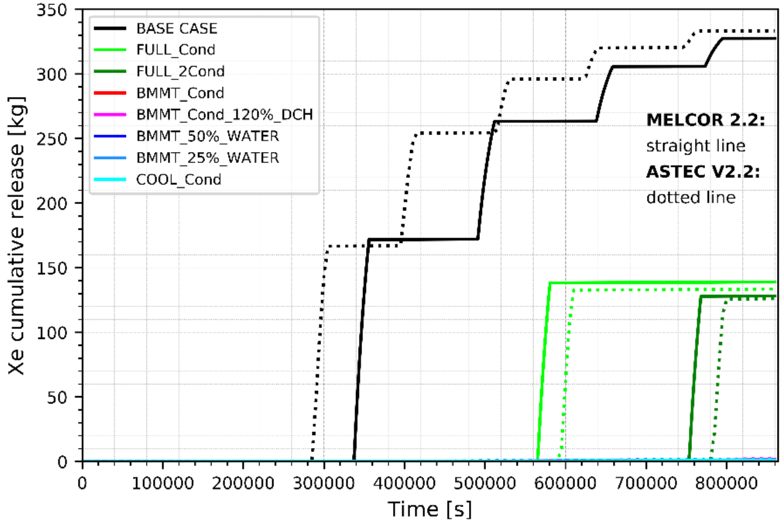
Fission product release





- The insertion of a condenser does not reduce the FP release through the leakage
  - ***They occurs in the early phase when the effect of the condenser is not predominant***
- The insertion of a condenser does reduce the FP release through the CFVS
  - ***In the worst case more than 50% of the noble gas are retained in the containment***

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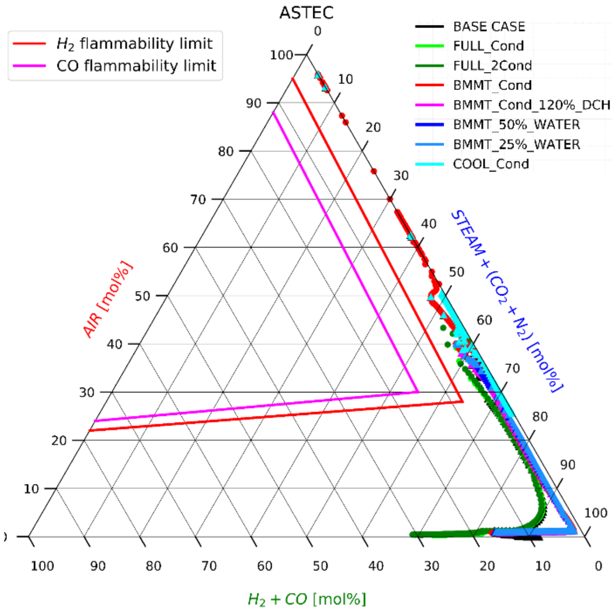
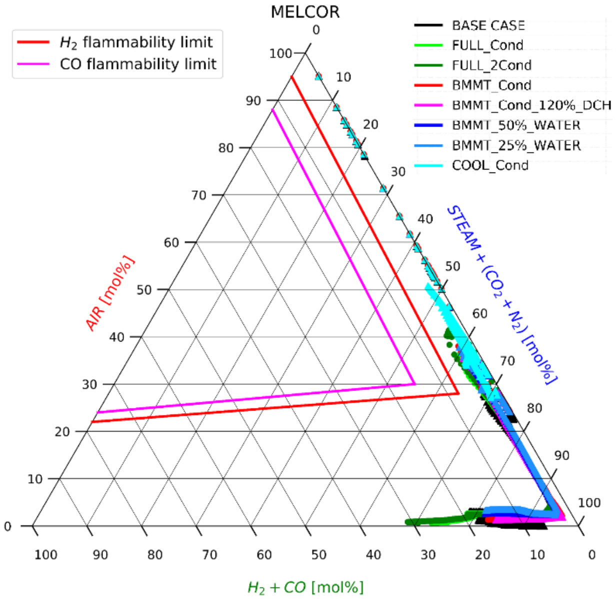
4-Calculations and Results (5/6)

Containment atmosphere composition





- The insertion of a condenser does not increase the risk of inflammability
  - ***This aspect should be investigated with more detailed tools (GASFLOW, ANSYS FLUENT, GOTHIC 3D)***

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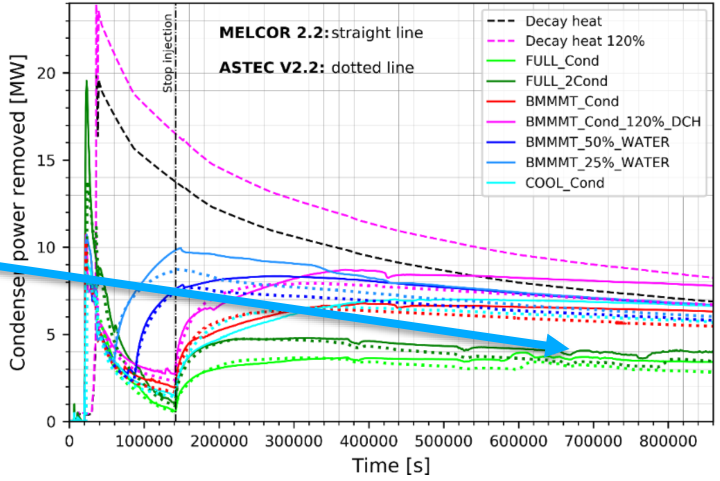
4-Calculations and Results (6/6)

SAM strategy assessment

- The insertion of a condenser satisfies all the criteria in most of the cases investigated
  - ***The most limiting parameter affecting the performance of this SAMS is the mass of NCGs***
  - ***The presence of NCGs degrades dramatically the rate of heat transfer by steam condensation.***
  - ***The amount of decay heat (+20%) and water injected (-50%) have a not negligible effect in the first days of the accident***
  - ***The debris coolability is the key phenomena determining the success of this SAMS***



- Ensuring the continuous flooding of the reactor pit

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5 – General Conclusions

5-General conclusions

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- This methodology can be applied to assess the adequacy of containment SAM strategies to reliably and safely perform their tasks.
- ***The containment calculations allow to simulate a wide range of containment conditions in a fast-running way not possible to reproduce with integral calculations***
- ***The containment calculations allow to perform long term analysis (over 30 days)***
- This approach can be used to carry out prefeasibility studies or to provide containment conditions to use for detailed design of the systems related to the SAM strategies.

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Thank you for your attention ! Any questions ?

Contact information

mirco.digiuli@tractebel.engie.com