High Combustion Risk Sequences. Identification and Characterization

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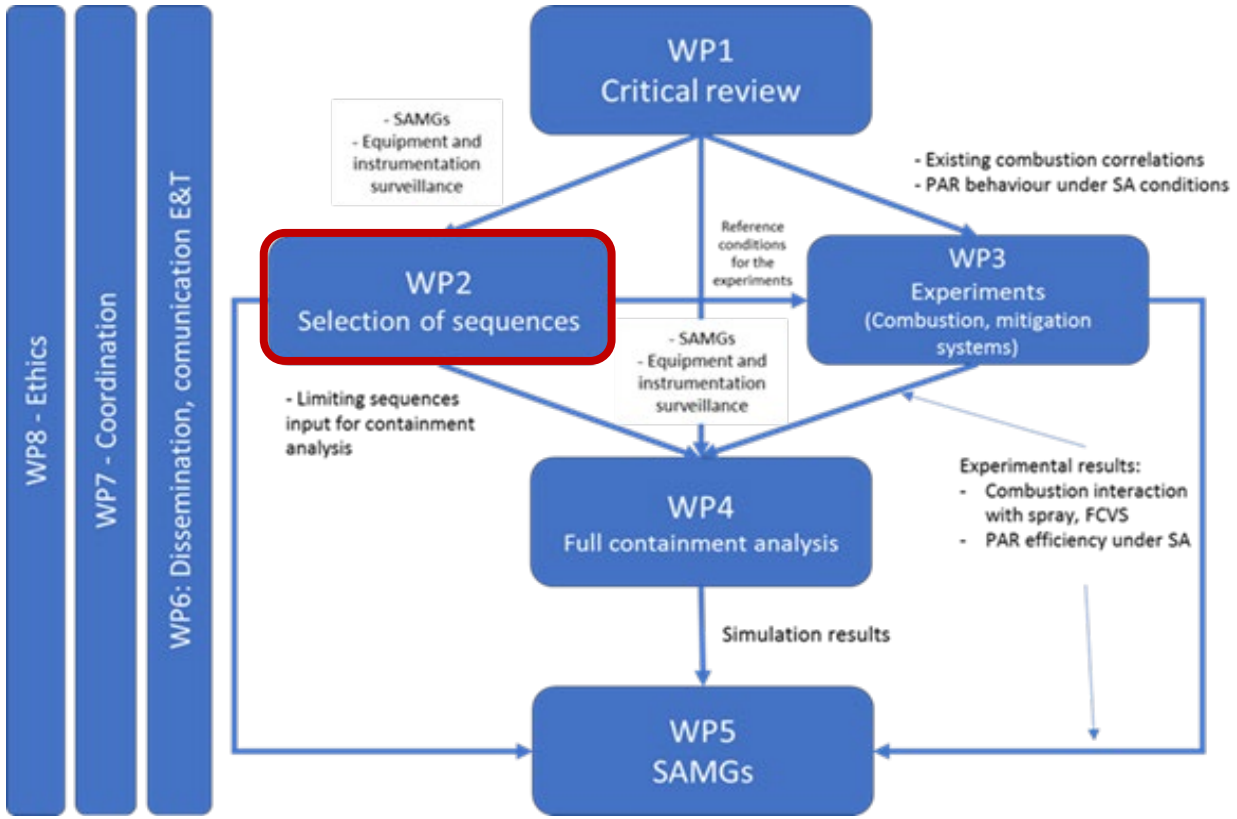
Introduction

- ***Motivation & Framework***
  - *Explosion risk has been identified as high priority issue in different frameworks.*
  - *AMHYCO project devoted to H_2/CO combustion risk management.*
- ***Objectives***
  - *To identify the most challenging conditions in terms of gas combustion.*
  - *Build-up of a Scenario Database to be used in accident management analyses and in experimental research.*
- ***Scope***
  - *Konvoi plant: PWR-KWU*
  - *Western design: PWR-W (Westinghouse & Framatome)*

Introduction

- *Towards an Enhanced AM of the H_2/CO Combustion Risk (AMHYCO).*

(PWR-W; -K; -V)



Study Approach: Selection Criteria

General criteria

- *High molar fraction of comb. gases (Shapiro diagram)*
- *Large total masses of comb. gases*
- *Fast release rates (in-vessel phase)*

Practical criteria

- ***Flammability boundaries***
  - $X_{H2} + X_{CO} > 9$ vol.%
  - $X_{O2} > 5$ vol.%
  - $X_{H2O} < 55$ vol.%

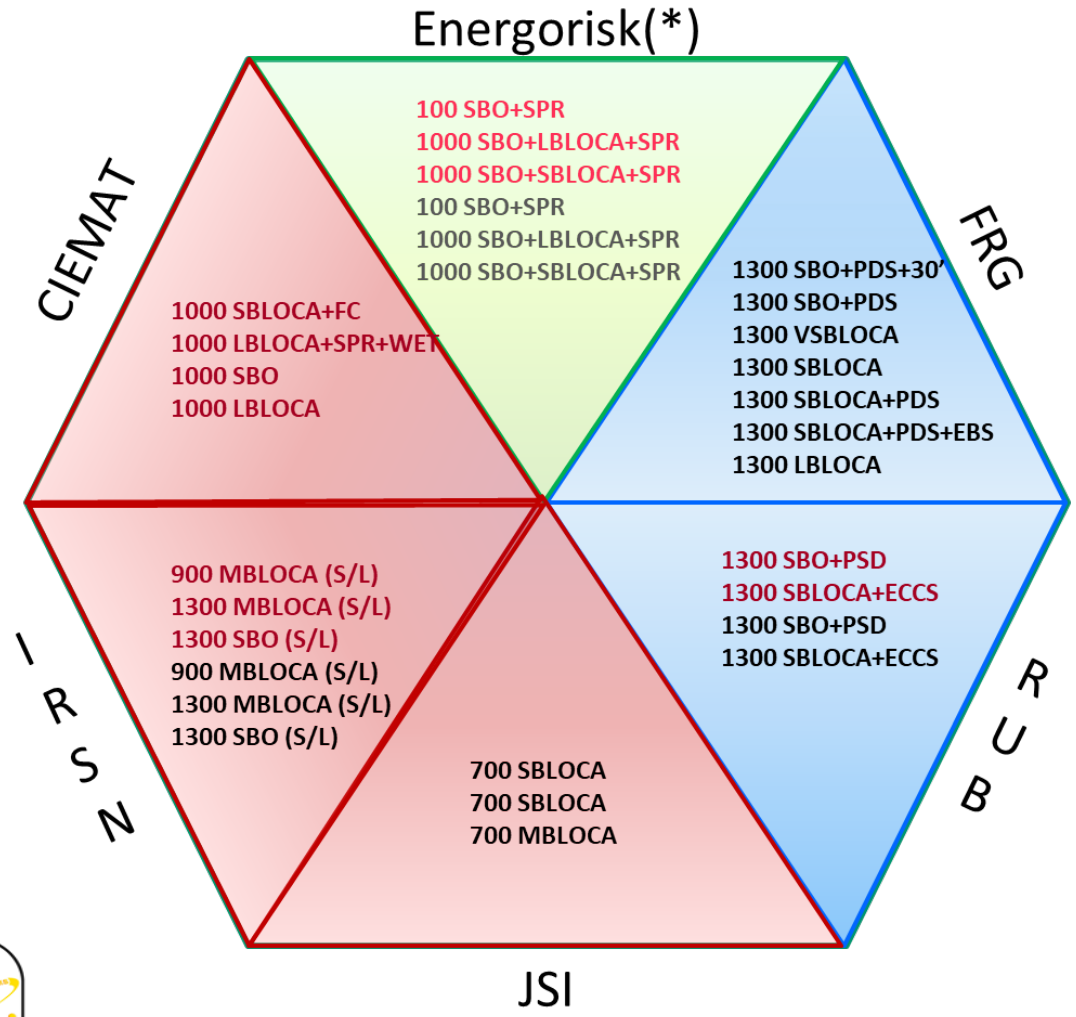
  Shapiro diagram
- *Compartments with big volume*
- *Sequences w/o PARs*

Study Approach: Figure of Merits

Figures of Merit	Sequence selection	I & B conditions
Gas molar fractions & release rates	Yes	Yes
Temperature and Enthalpy associated to the release	Yes	Yes
Density of injected gases and water	No	Yes
Pressure difference between volume in the break	No	Yes
Containment characteristics: pressure & temperature	Yes	Yes
Breach size	No	Yes
Power sinks/sources due to ESF	No	Yes
Heat transfer from cavity	No	Yes
Initial gas composition	No	Yes
Initial pressure and temperature (gas and walls)	No	Yes
Initial amount of water	No	Yes
Inter-compartment gas velocity	No	Yes

- Atmosphere composition
- Gas generation/release
- I & B conditions
- ESFs

Matrix of sequences



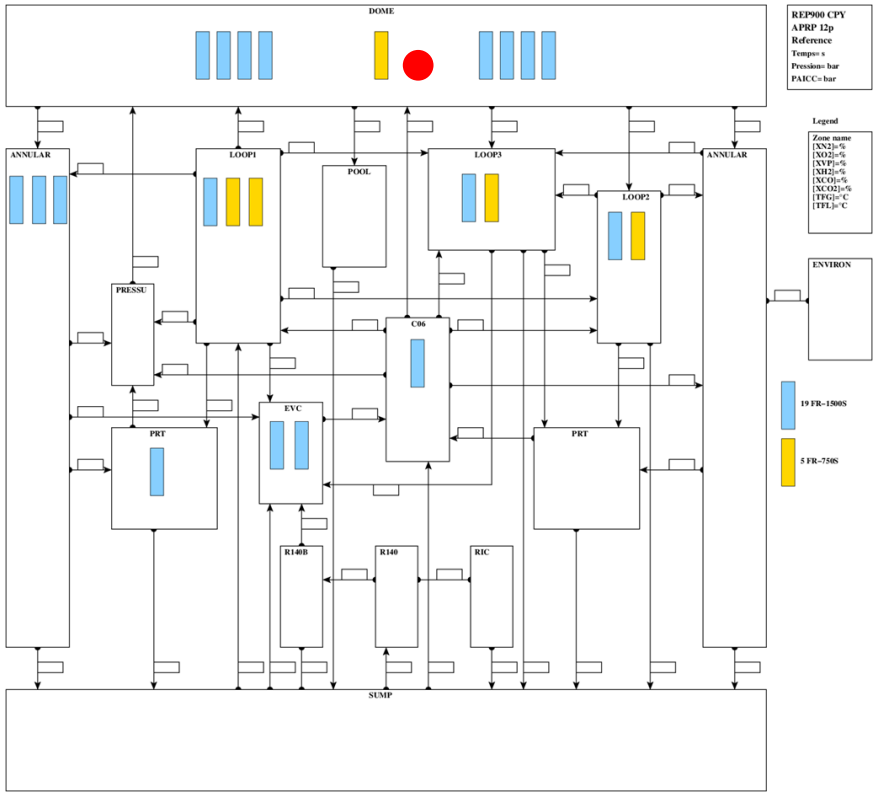
Plant Model Summary

Reactor type	Code	plant nodes	containment nodes
PWR-W-900	ASTEC v2.1	~160	14
PWR-W-1300	ASTEC v2.1	~160	18
PWR-W-700	MELCOR v2.2	139	13
PWR-W-1000	MELCOR v2.2	157	19
PWR-K-1300	MELCOR v2.2	69	30
PWR-K-1300	AC^2 2019.1	283	23

(*) PWR-VVER results not available at the time of the conference. Results will be added to the Scenario Database

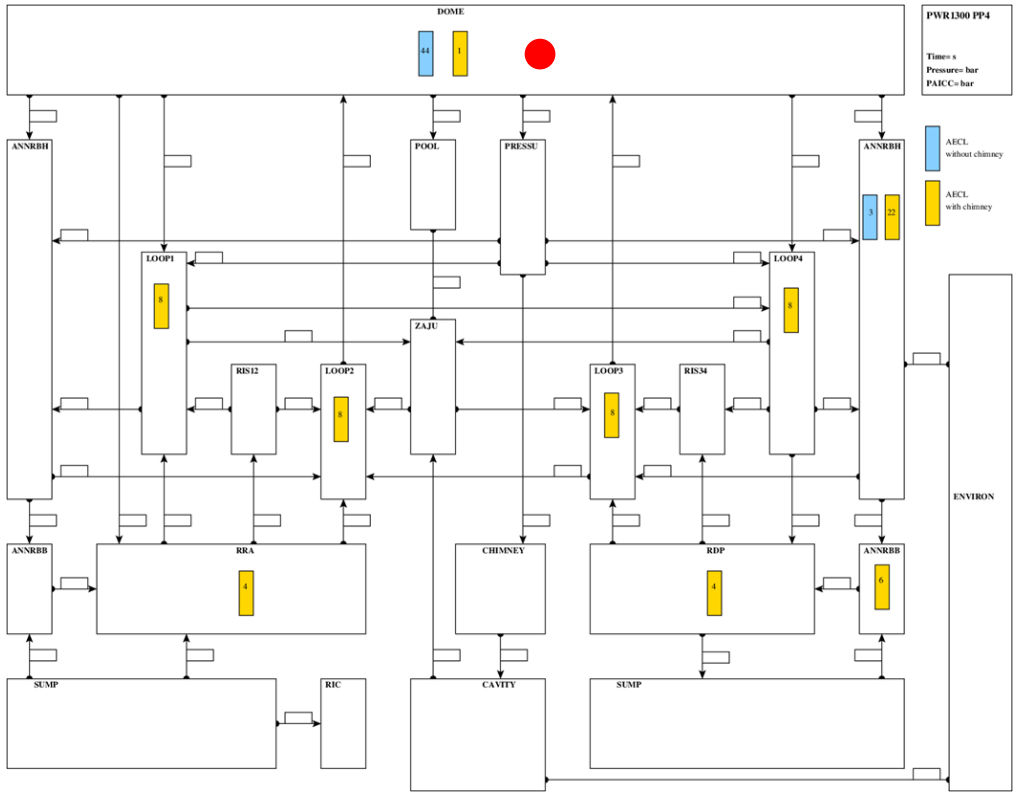
Containment Model: PWR-W (French-W)

PWR-900



14 nodes

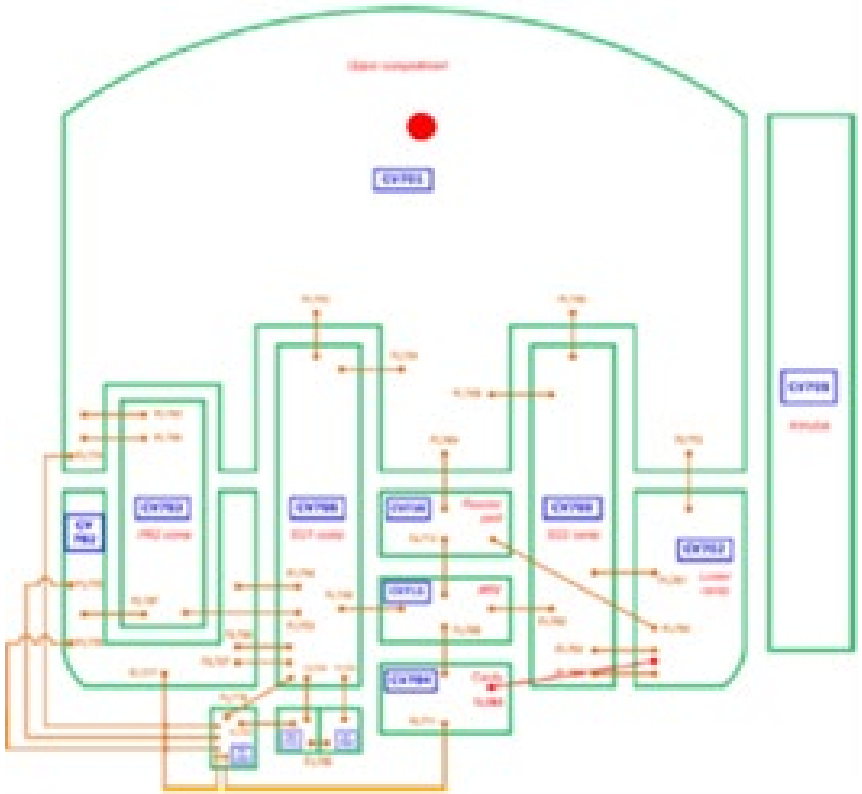
PWR-1300



18 nodes

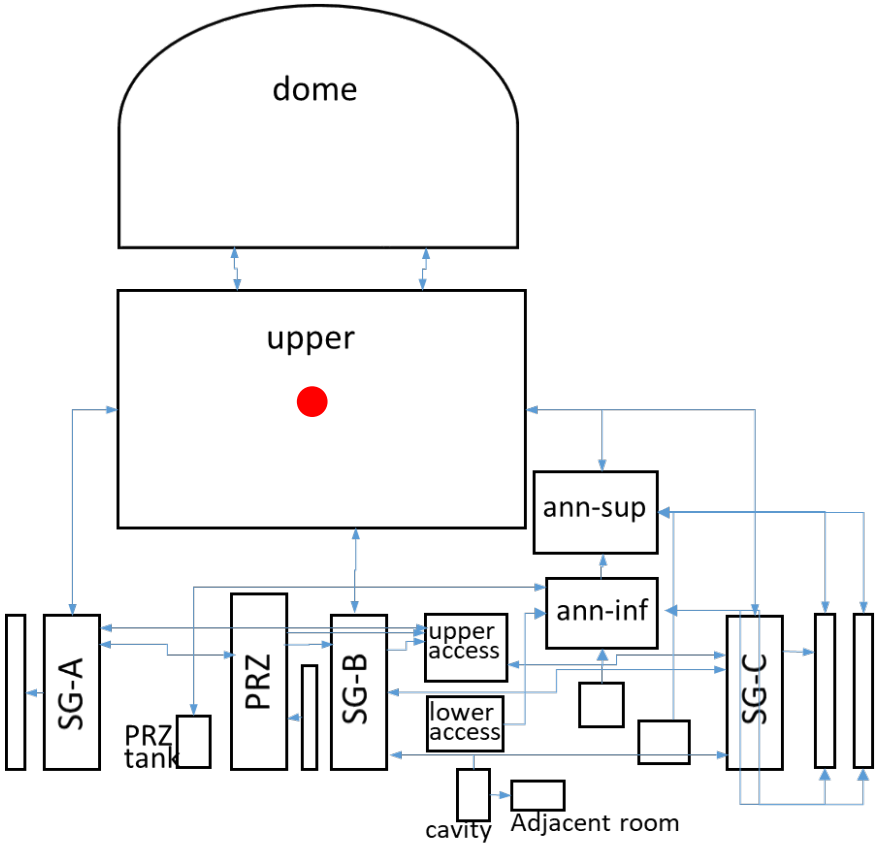
Containment Model: PWR-W (Westinghouse)

PWR-700



14 nodes

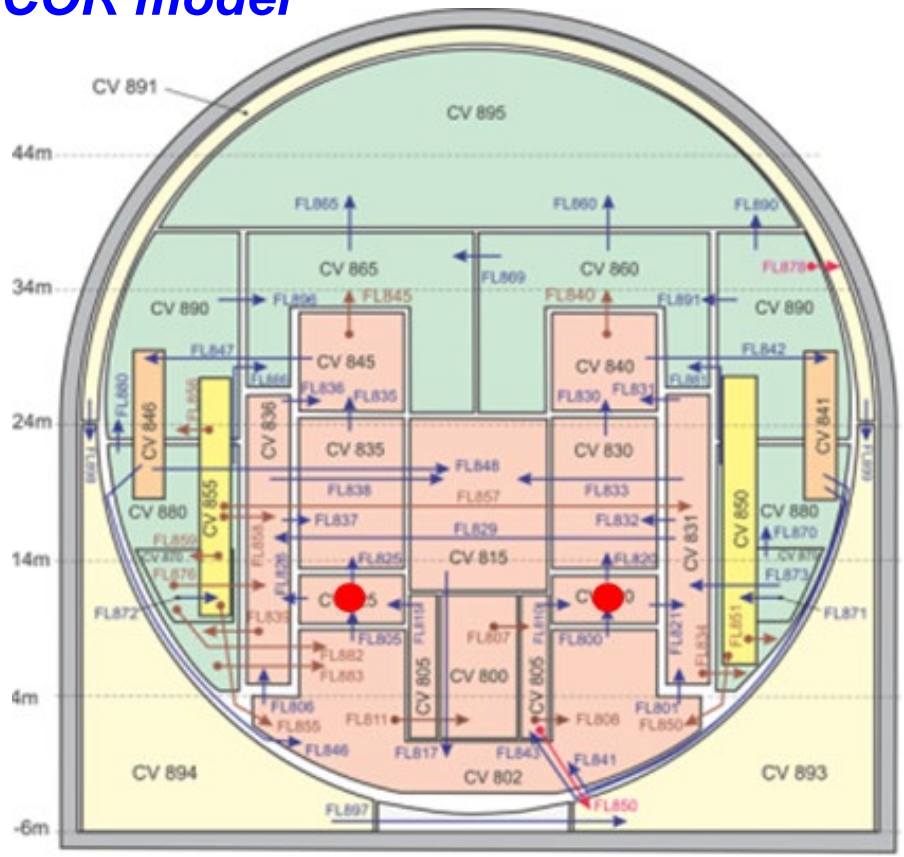
PWR-1000



18 nodes

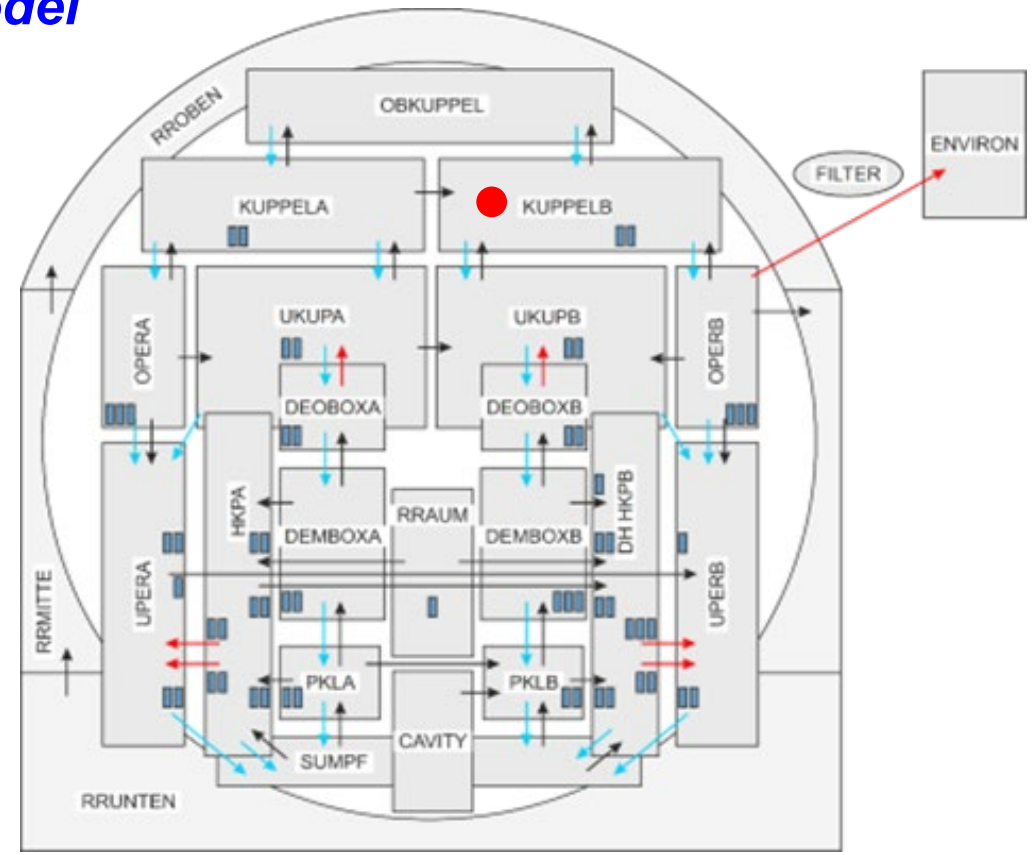
Containment Model: PWR-W (KWU)

MELCOR model



30 nodes

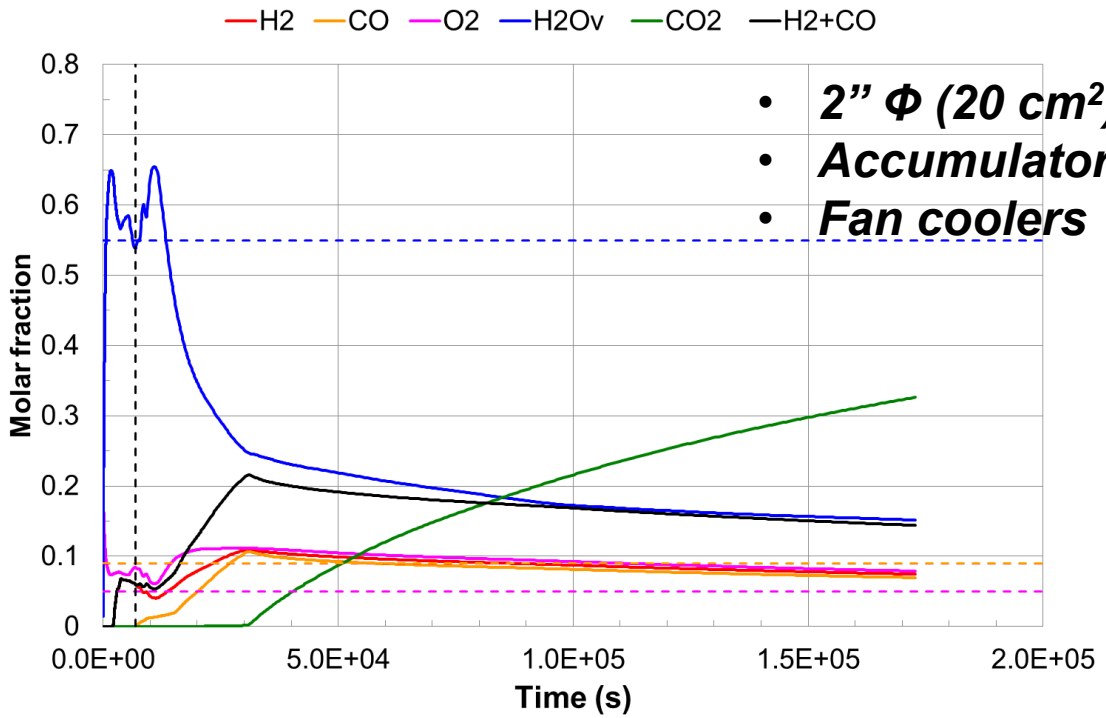
AC² model



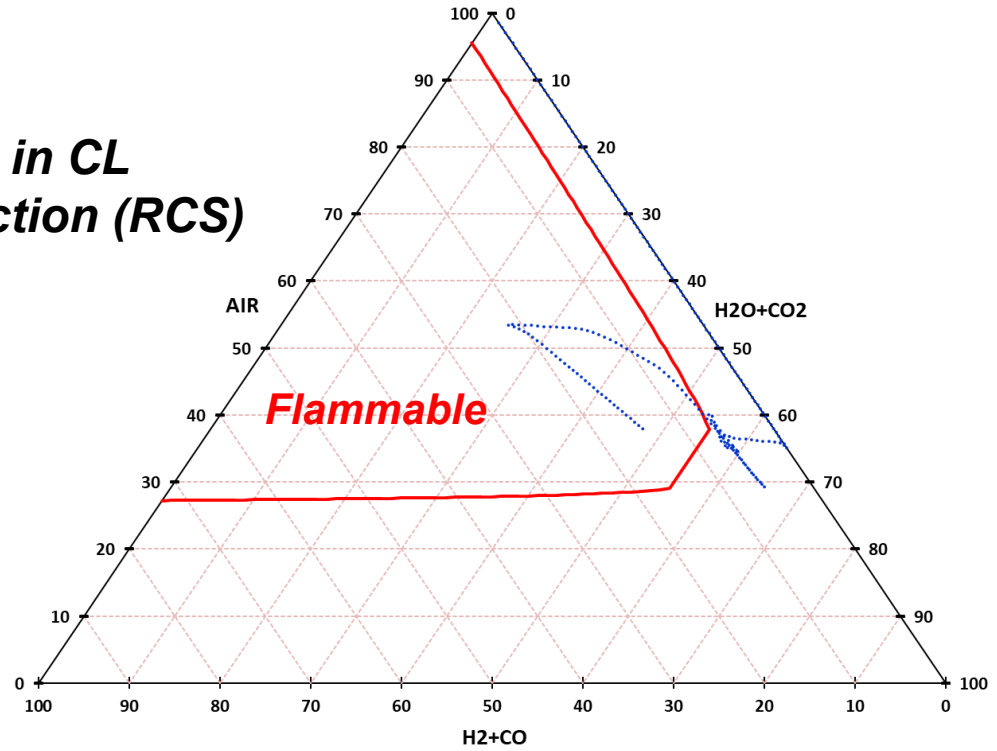
23 nodes

Results and discussion: PWR-W (1)

Westinghouse PWR-1000 SBLOCA

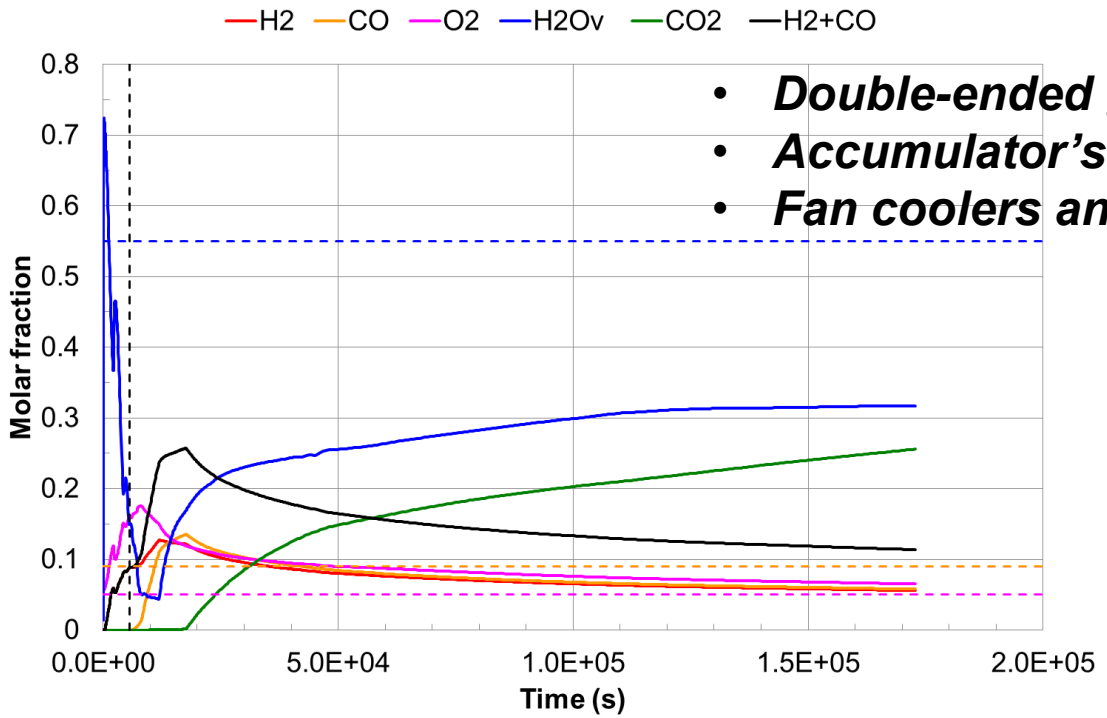


- *2" Φ (20 cm²) break in CL*
- *Accumulator's injection (RCS)*
- *Fan coolers*

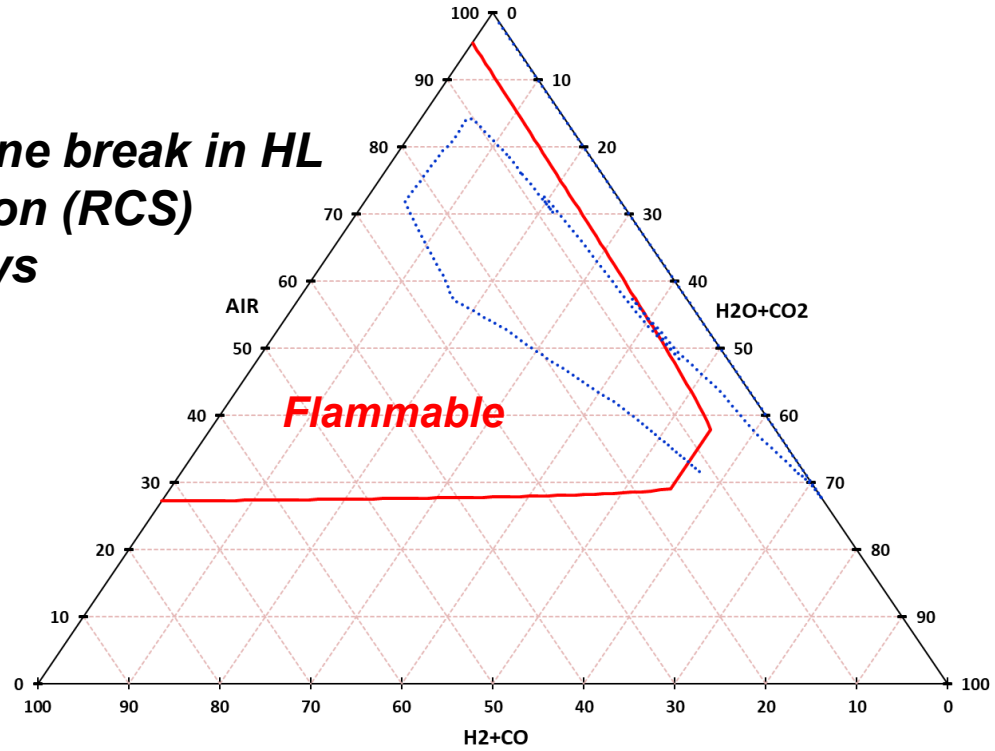


Results and discussion: PWR-W (2)

Westinghouse PWR-1000 LBLOCA

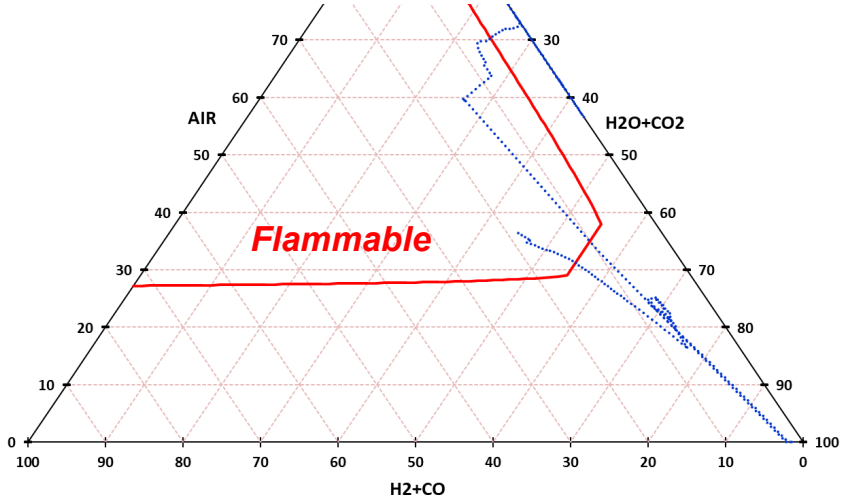


- *Double-ended guillotine break in HL*
- *Accumulator's injection (RCS)*
- *Fan coolers and sprays*



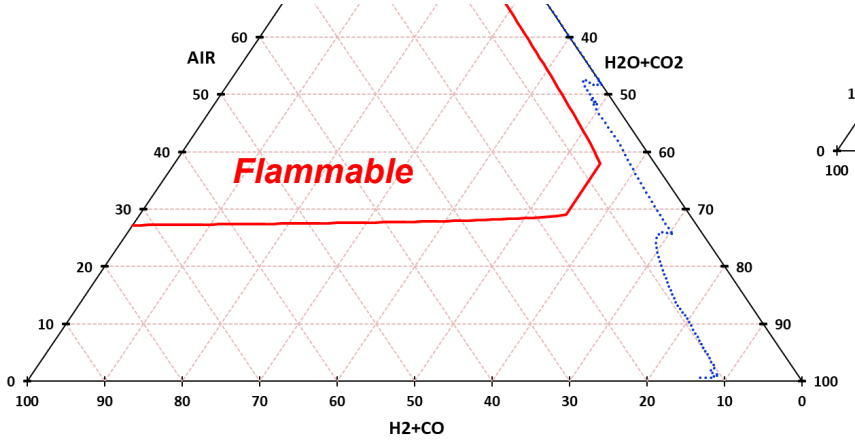
Results and discussion: PWR-W (3)

- *12” Φ (730 cm²) break in HL*
- *Accumulator’s injection (RCS)*
- *No containment safety systems*



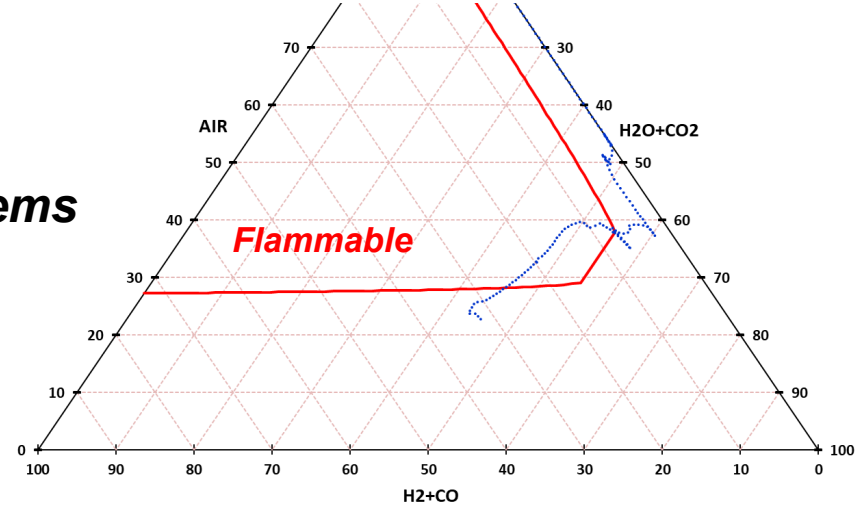
French PWR-1300 MBLOCA

- *6” Φ (180 cm²) break in CL*
- *No injection systems (RCS)*
- *No containment safety systems*
- *PARs modelled*



Westinghouse PWR-700 SBLOCA

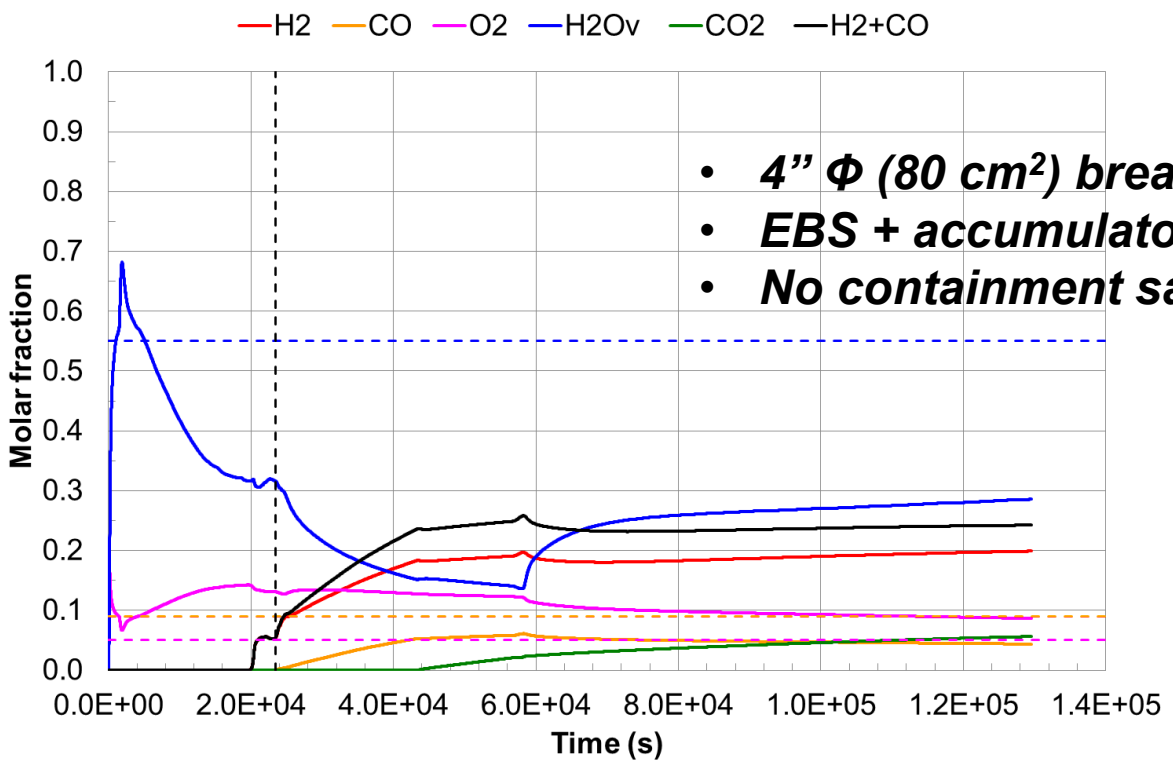
- *Safety tank discharge*
- *Accumulator’s injection (RCS)*
- *No containment safety systems*



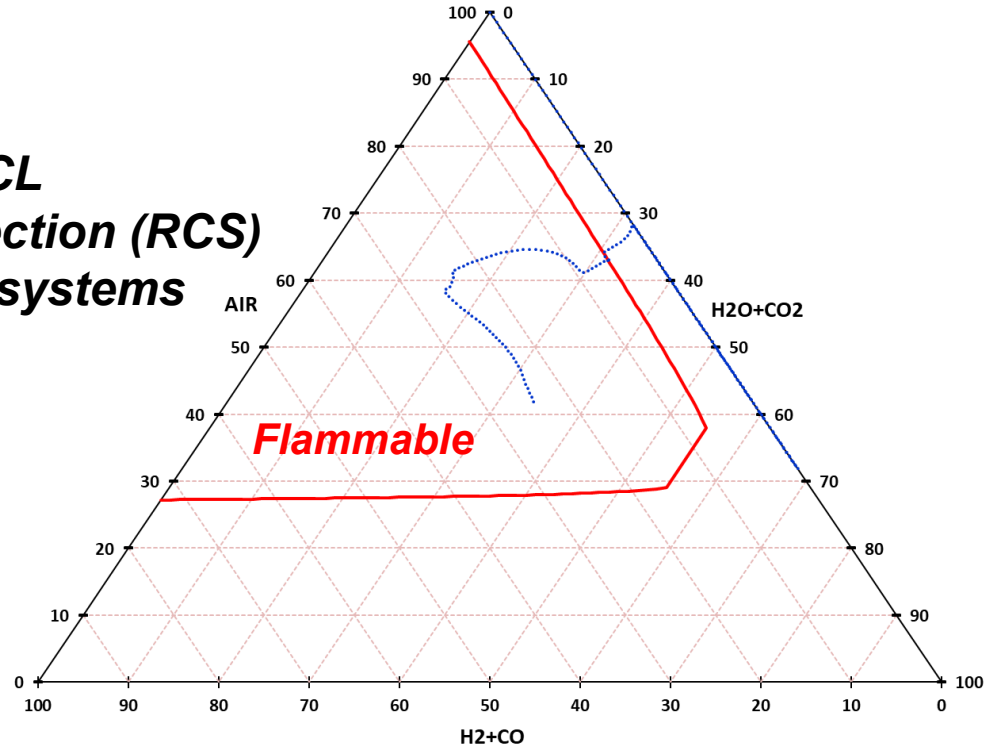
French PWR-1300 SBO

Results and Discussion: PWR-KWU (1)

Konvoi PWR-1300 SBLOCA

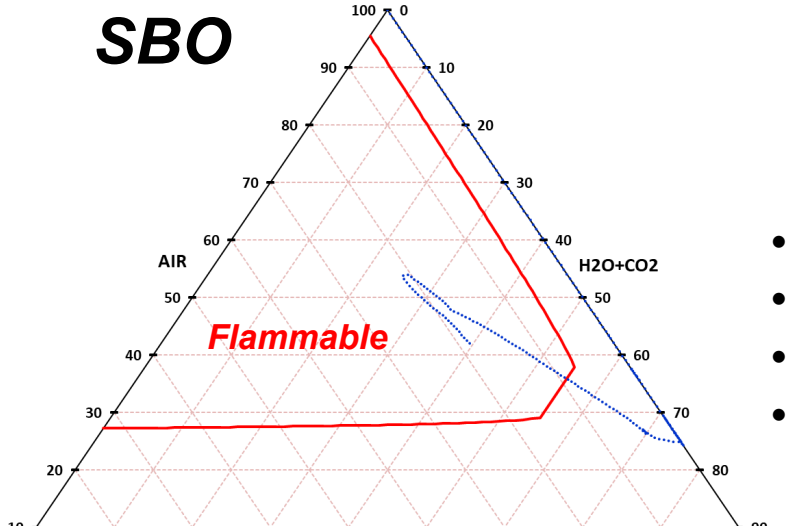


- *4" Φ (80 cm²) break in CL*
- *EBS + accumulator injection (RCS)*
- *No containment safety systems*



Results and discussion: PWR-KWU (2)

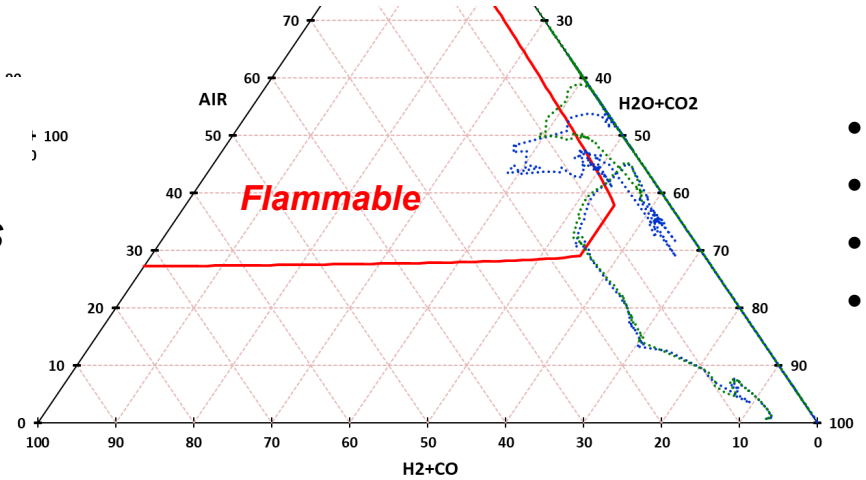
SBO



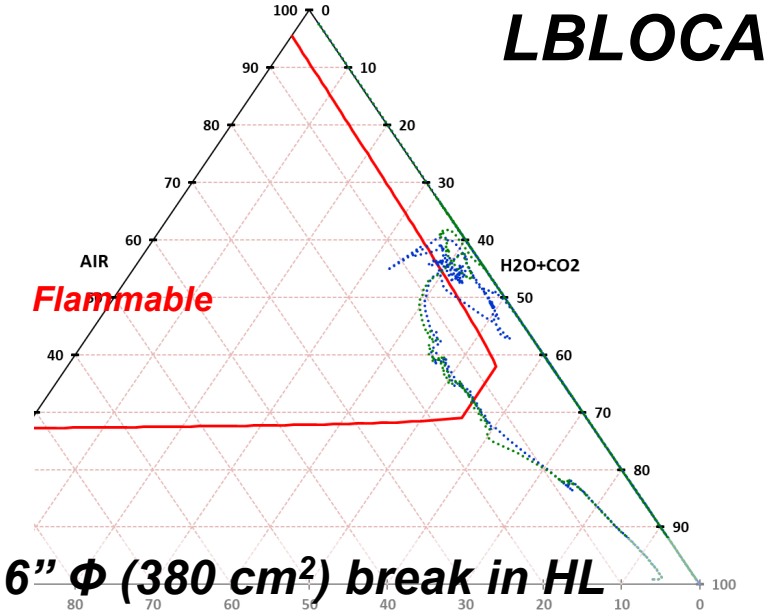
- Accumulator's injection (RCS)
- Primary side depressurization
- No containment safety systems

SBLOCA

- 4" Φ (80 cm²) break in HL
- EBS + accumulator injection (RCS)
- No containment safety systems
- PARs modelled



LBLOCA



- 8.6" Φ (380 cm²) break in HL
- EBS + accumulator injection (RCS)
- No containment safety systems
- PARs modelled

Final Remarks

- ***A scenario database with 30 PWR sequences has been created.***
- ***Selection of scenarios with the highest combustion risk for H_2&CO mixtures.***
  - *PWR-KWU:* ***SBLOCA*** *(80 cm^2).*
  - *PWR-W:* ***SBLOCA*** *(20 cm^2) &* ***LBLOCA*** *(double-ended guillotine).*
- ***I&B conditions for experimentation, CA methods and AM testing.***
- ***Major observations:***
  - *ESFs (other than PAR) huge impact on combustion risk through steam content .*
  - *The highest combustible gases accumulation found ex-v (H_2+CO mixtures).*
  - *If PARs, O_2 starvation in the ex-v phase makes mixture exit the flammable zone.*
  - *Concrete might heavily affect combustible gas concentration.*

Thanks for your attention!!

ACKNOWLEDGEMENT

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