Assessment of control rod release models of MELCOR 1.8.6

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Outline

- Introduction
- Conversion of Quench Input Deck (ISP45)
- Implementation of Control Rod Models
- Assessment studies
  - QUENCH-07 (B₄C)
  - QUENCH-13 (SIC)
- Conclusions
QUENCH simulations

- Pre- and post-test analyses of all QUENCH experiments
  - MELCOR used in tandem with SCDAP/RELAP5 to provide
    - confirmatory pre-test analyses
    - assessment of MELCOR 1.8.6 and non-regression relative to 1.8.5
    - aerosol and gas release from control rod (not modelled by SCDAP/RELAP5)

- Selected results
  - bundle temperature (QUENCH-07,13)
  - hydrogen generation (QUENCH-07)
  - carbon gases (QUENCH-07)
  - SIC release (QUENCH-13)
'Lower head' conversion was problematic

'Upper dome', boundary conditions had to be changed

Comparison of results showed:

- Argon material properties have changed
- Additional changes in heat conductivity models (not described in UG or RM)
Implementation of $\text{B}_4\text{C}$ Control Rod Model

- MELCOR accommodates only a limited number of core materials
  - not enough for all the actual materials
  - copper was modeled as stainless steel (so that $\text{B}_4\text{C}$ could be modeled with the correct properties)

- Control Rod was completely modeled as non-supporting structure (KNS card)
  - Needed to avoid problems of premature collapse to debris and burning

- BORON-CARBIDE and $\text{B}_4\text{C}$-INT models were used for comparison
ASSESSMENT USING QUENCH-07

QUENCH-07 B4C Reac. Temp. 1700 K

Heater rod temperature at 950 mm

Temperature (K)

Time (s)

COR-TCL_315
Exp. Data
ASSESSMENT USING QUENCH-07

Calculation tried to mimic operator actions needed to stabilise temperatures.
ASSESSMENT USING QUENCH-07
ASSESSMENT USING QUENCH-07

Strong local effect of B4C oxidation
ASSESSMENT USING QUENCH-07

QUENCH-07 B4C Reac. Temp. 1700 K

H2 Production

- H2_exp
- COR-DMH2-B4C
- COR-DMH2-TOT
- COR-DMH2-ZIRC

Mass (kg) vs. Time (s)
ASSESSMENT USING QUENCH-07

QUENCH-07 B4C Reac. Temp. 1700 K

Carbon gas production

- CO_exp
- COR-DMCO-TOT
- COR-DMCO2-TOT
- CO2_exp

Mass (kg)

0.015
0.01
0.005
0

Time (s)

0
1000
2000
3000
4000
5000
6000

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Summary of QUENCH-07 analysis

- Onset and total CO$_2$ production well calculated
- CO is small in calculation but almost the same as CO$_2$ in the experiment
- H$_2$ production is underestimated in quench phase
  - evidence of strong oxidation of molten metallic in experiment
- Oxidation of steel/B$_4$C mixture and molten B$_4$C not included in model

- Temperature criterion instead of cladding failure used for start of B$_4$C reaction
- B4C-INT model: reaction switches off at liquefaction of B$_4$C
Modeling of SIC control rod

- Structure of input model similar to QUENCH-07
- Definition of vapor pressure, diffusion coefficients and molecular mass of CR materials with SC
- Addition of horizontal heat structures for aerosol sedimentation
- Definition of sedimentation paths
- Using measured power history
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ASSESSMENT USING QUENCH-13

QUENCH-13
Shroud temperatures at 950 mm

Temperature (K)

Time (s)

Exp. Data
COR-TCN_415

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ASSESSMENT USING QUENCH-13
ASSESSMENT USING QUENCH-13

QUENCH-13 Radial Temperature Distribution

Temperature [K]

CR  1. HR  2. HR  Corner rod  Shroud

Time: 5000 s

Exp.Data  MELCOR
ASSESSMENT USING QUENCH-07

QUENCH-07 Radial Temperature Distribution

- Exp.Data
- MELCOR

Time: 2700 s

Temperature [K]

CR  1. HR  2. HR  Corner rod  Shroud

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QUENCH-13
Hydrogen production

- Exp. Data
- COR-DMH2-TOT

Mass (kg)

0.05
0.04
0.03
0.02
0.01
0

Time (s)

0
5000
10000
15000
20000

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ASSESSMENT USING QUENCH-13

Fast refill of lower volume accompanied by surge of water into bundle

Possible liquid entrainment, not calculated
Control rod release

Aerosol composition

Exptl MELCOR Estimate*

after CR failure:
- Ag: 3% 55%
- In: 48% 10%
- Cd: 49% 35%

Before quench phase:
- Ag: 11% 80%
- In: 43% 15%
- Cd: 46% 5%

*very approximate
Summary of Quench-13 analysis

- Release of droplets into RN classes is not modeled
- Only failed COR nodes are allowed to release CR materials, therefore discrete release steps are calculated
- Only one CR material can be released from COR package into RN package
- 3 runs necessary to calculate Ag, In and Cd release
  - Cd release in agreement with experimental data
  - In release overestimated by a factor of 3
  - Ag release strongly overestimated
- Model to calculate also release from reheated conglomerate, reduces overall release???
Conclusions

- Conversion of QUENCH input files from 1.8.5 to 1.8.6 is not straight forward
- Differences of MELCOR 1.8.5 and MELCOR 1.8.6 results cannot be explained completely
  - minor differences between YK, YR and YT releases
- Control rod release models of MELCOR 1.8.6 are incomplete
  - no separate treatment of Ag, In and Cd
- Total B₄C oxidation is in fair agreement but deficiencies remain
  - start of reaction should be coupled with cladding failure
  - using of B₄C-INT is unclear
  - oxidation of molten B₄C or B₄C-steel mixture needed
- Calculation on different computer platforms gave same results
- No compiler or optimization dependencies were observed

Thank you for your Attention