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Wir schaffen Wissen – heute für morgen

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Modelling of Molten-Corium Concrete Interaction using MELCOR 1.8.6

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OUTLINE

- Introduction
- Accident Scenario
- Modelling of Cavities
- Conclusions and recommendations
- Outlook

General Approach

- Plant analysis strategy is based on use of MELCOR as front line tool
  - MELCOR 1.8.5 has been used by PSI in applications
  - MELCOR 1.8.6 is being assessed for use as the production version
    - improved models for late phase/in-vessel retention and CRP release
  - MELCOR 2.1 is the code for future model development
- Part of 2 tier strategy (System level, subsystem/component level)
- Activities have included plant applications, support to experimental programmes, code assessment and model development
- Assessment activities were performed in the frame of international collaborations: SARNET, USNRC/CSARP, ISTC, ISTP, PHEBUS FP and QUENCH

Accident Scenario

Pressurized Water Reactor with 380 MWe (Westinghouse)

Station Blackout Scenario

Hotleg Failure, Surge Line Break and SGTR not modelled

Failure of emergency cooling

No Steam Condensors available

No Hydrogen Recombiners available

Consequences:

RPV Failure at 150 bar and relative low temperature (Creep)

Time of LH Failure: 7.1 h after SCRAM (No DCH)

First release of Corium: 7.8 h → (set to 0h for MCCI)

Mass of Corium (first slump): 50 t (~ **6 m^3**) (Total: 64 t)

UO_2 in Core: 44 t

Retained in RPV: < 5 % of UO_2

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Cavity Description

Geometry for Spreading area of the molten Corium

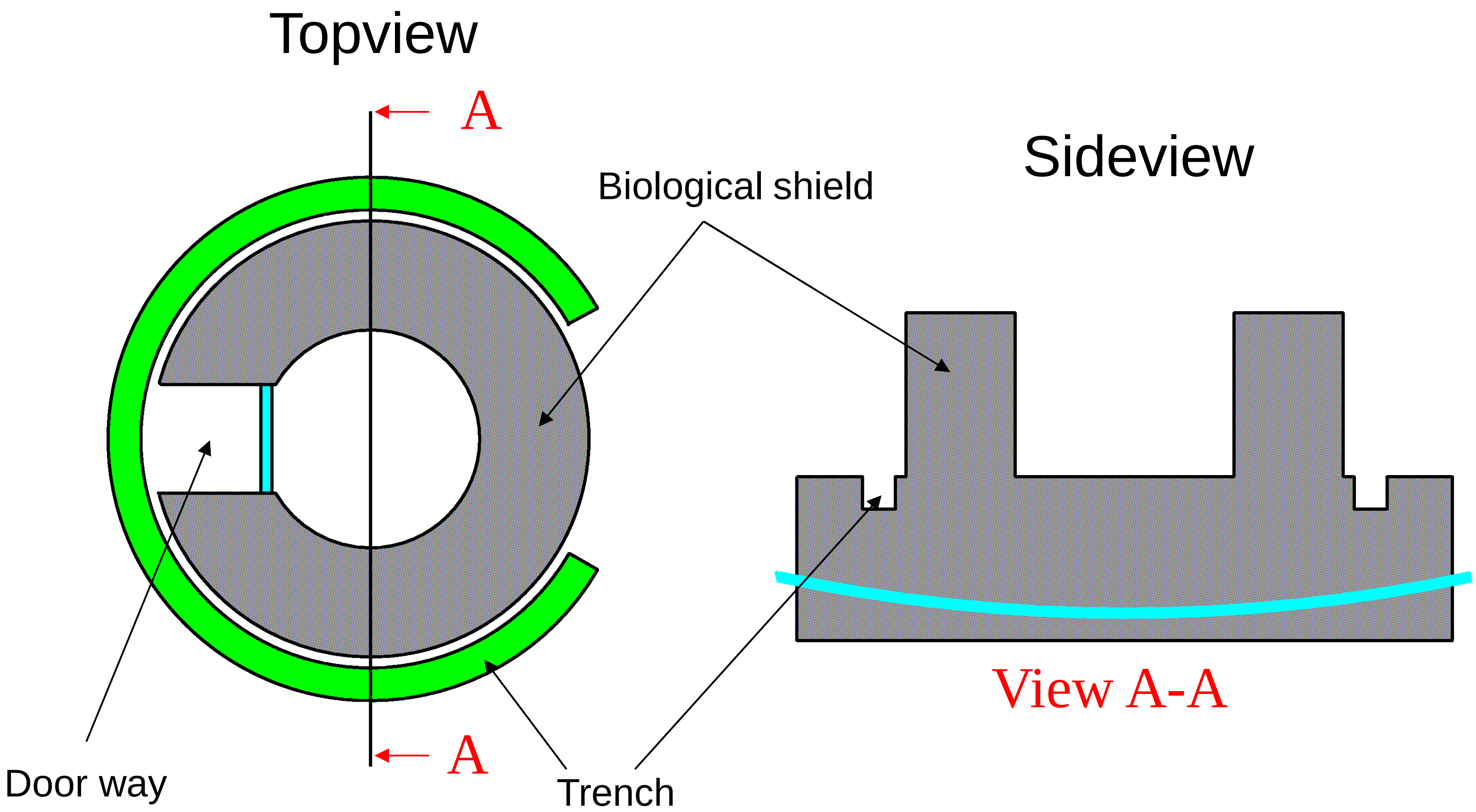
Cavity diameter inside the biological shield: 4m

A steel door separates the cavity from the lower floor

A trench of 0.5 m depth and 0.5 m width surrounds a great part of the biological shield (Volume ~ **5 m^3**)

Outside of the trench about 80 m^2 are available for further melt spreading

Cavity Description



<u>Modelling limitations of the concrete area</u>

Only cavities with cylindrical flat bottom can be modelled

Mass flow from cavity to cavity is one-way

Control functions are used for mass transfer (Geometry!!)

Volume to wall ratio for trench can not easily be modelled

<u>Note:</u> Trench volume can hold most of the corium!!

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Control Functions

Logical control function:

.TRUE. Cavity has failed

Real control function:

Gives level of cavity where overflow takes places

CORCON coordinates are downwards positiv!!

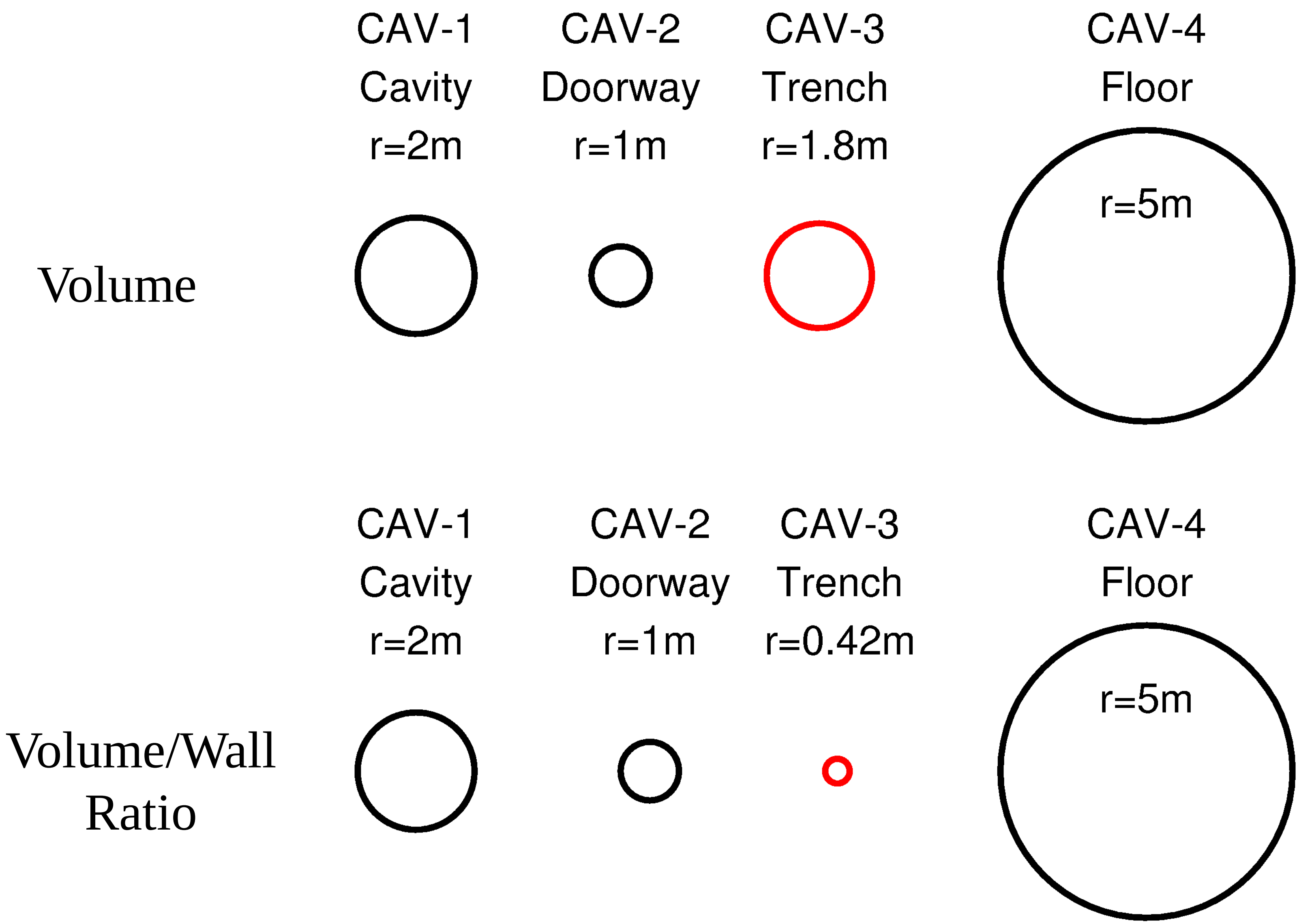
Zero level of cavity is at upper edge!!

Cavities are indipendent from each other.

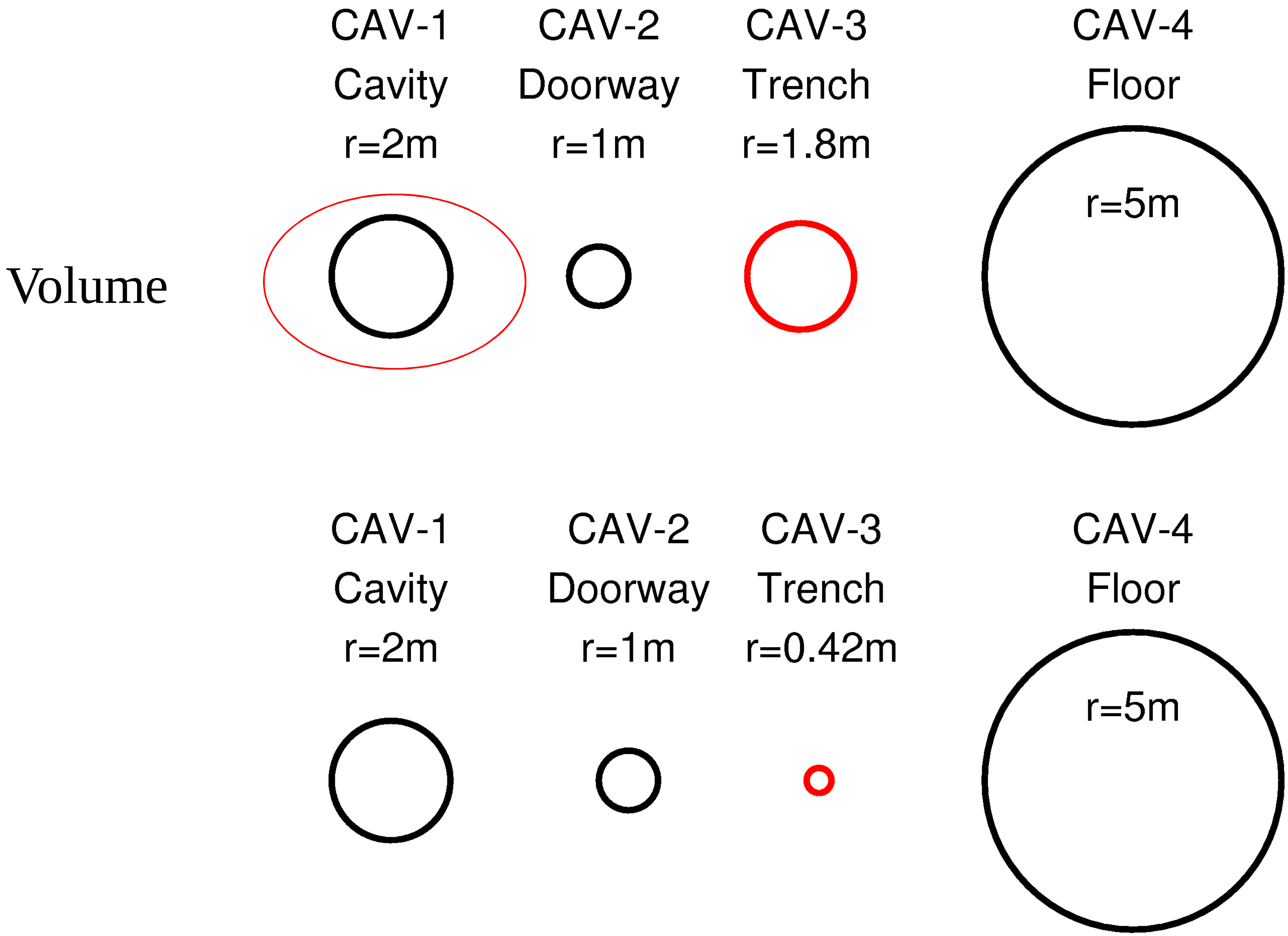
Level control has to be done by the user.

Mass flow control by user (DT control variable)

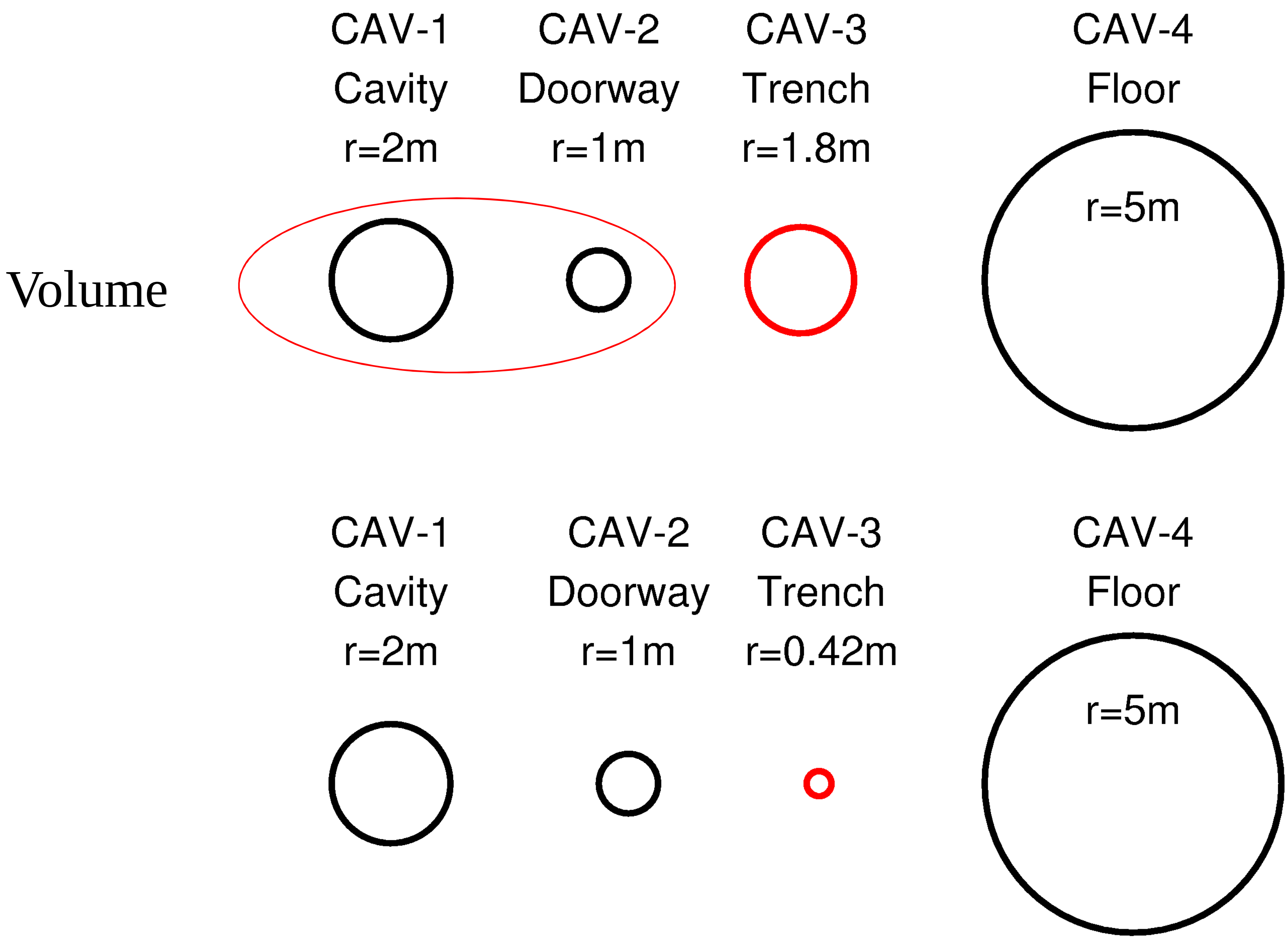
NODALIZATION OF CAVITIES – Treatment of Trench



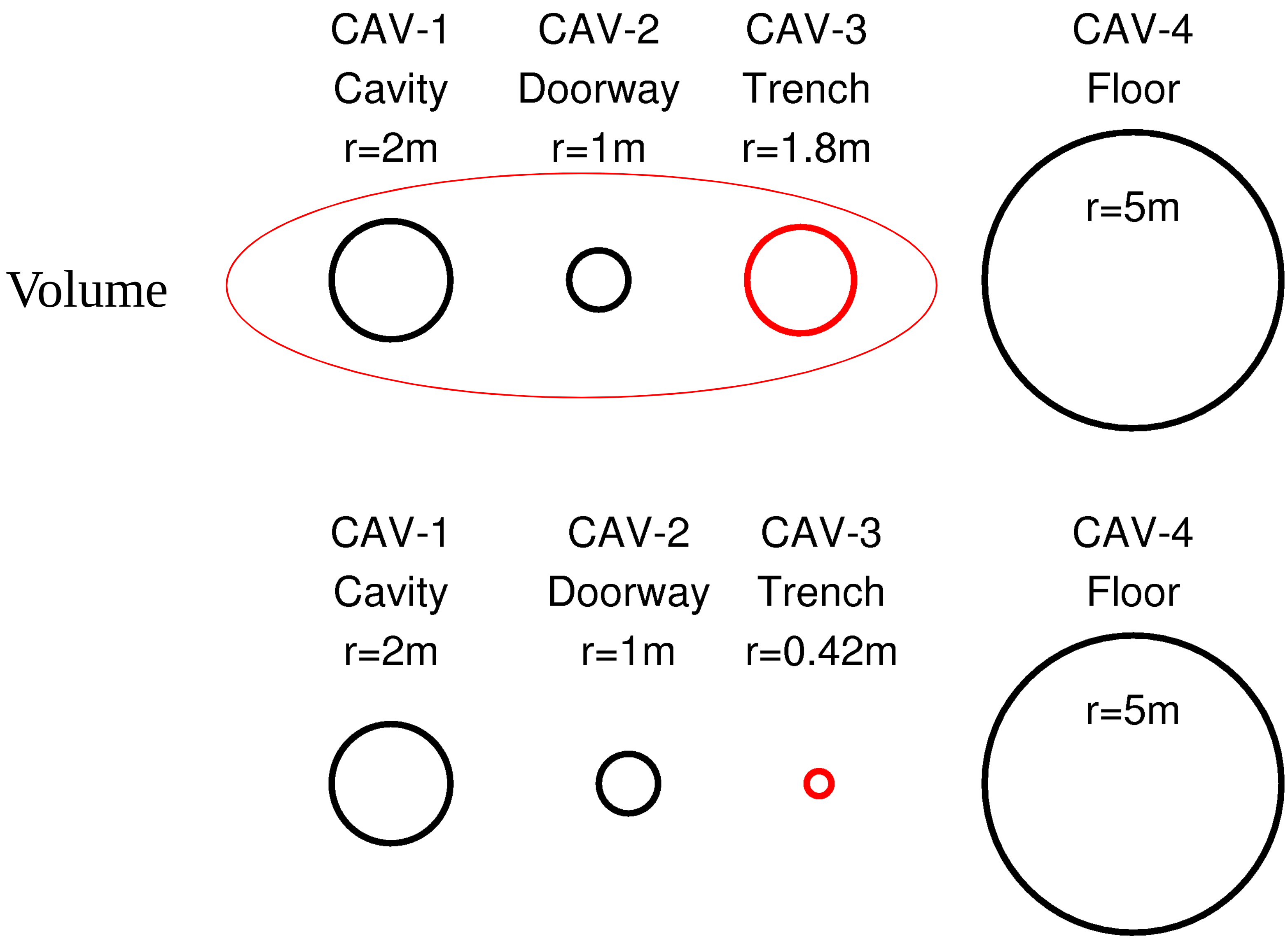
CASE 1 – Reactor Cavity only



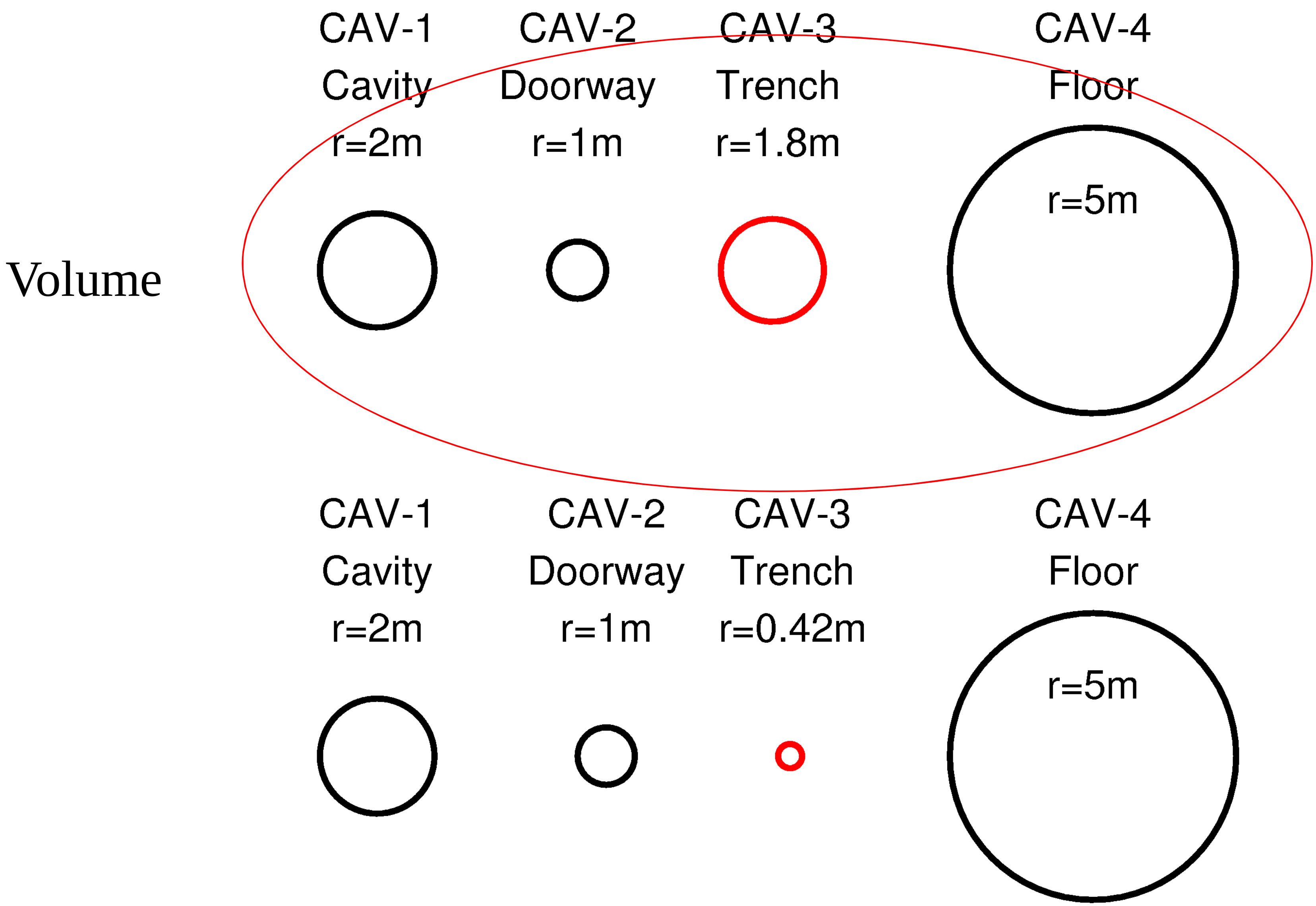
CASE 2 – Reactor Cavity and Doorway



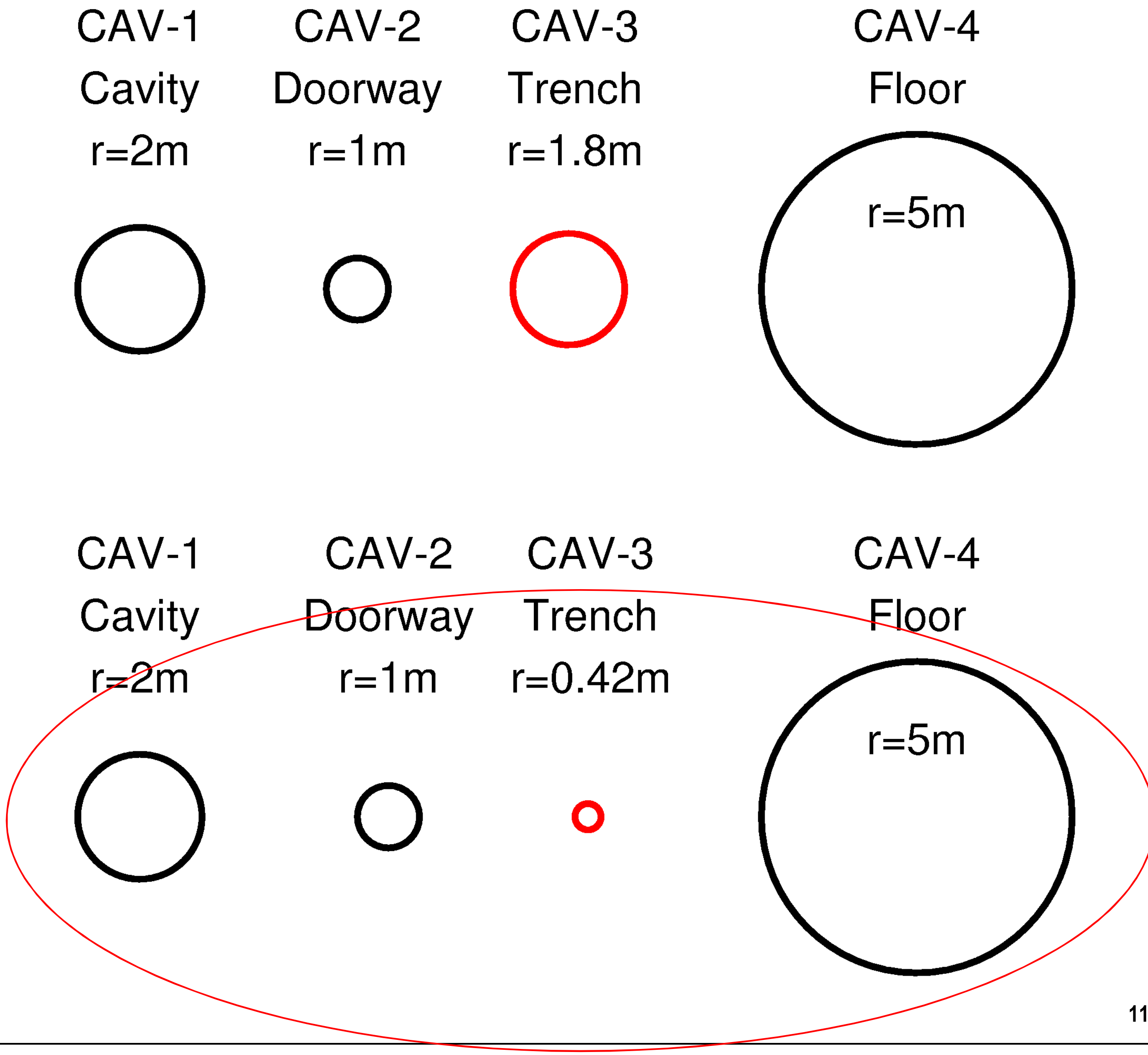
CASE 3 - Cavity, Doorway and Trench



CASE 4 - Cavity, Doorway, Trench and Floor



CASE 5 - Cavity, Doorway, Trench and Floor



Volume/Wall Ratio

Contour Plots

Contour plots are produced due to a program extracting data from the binary PTF file

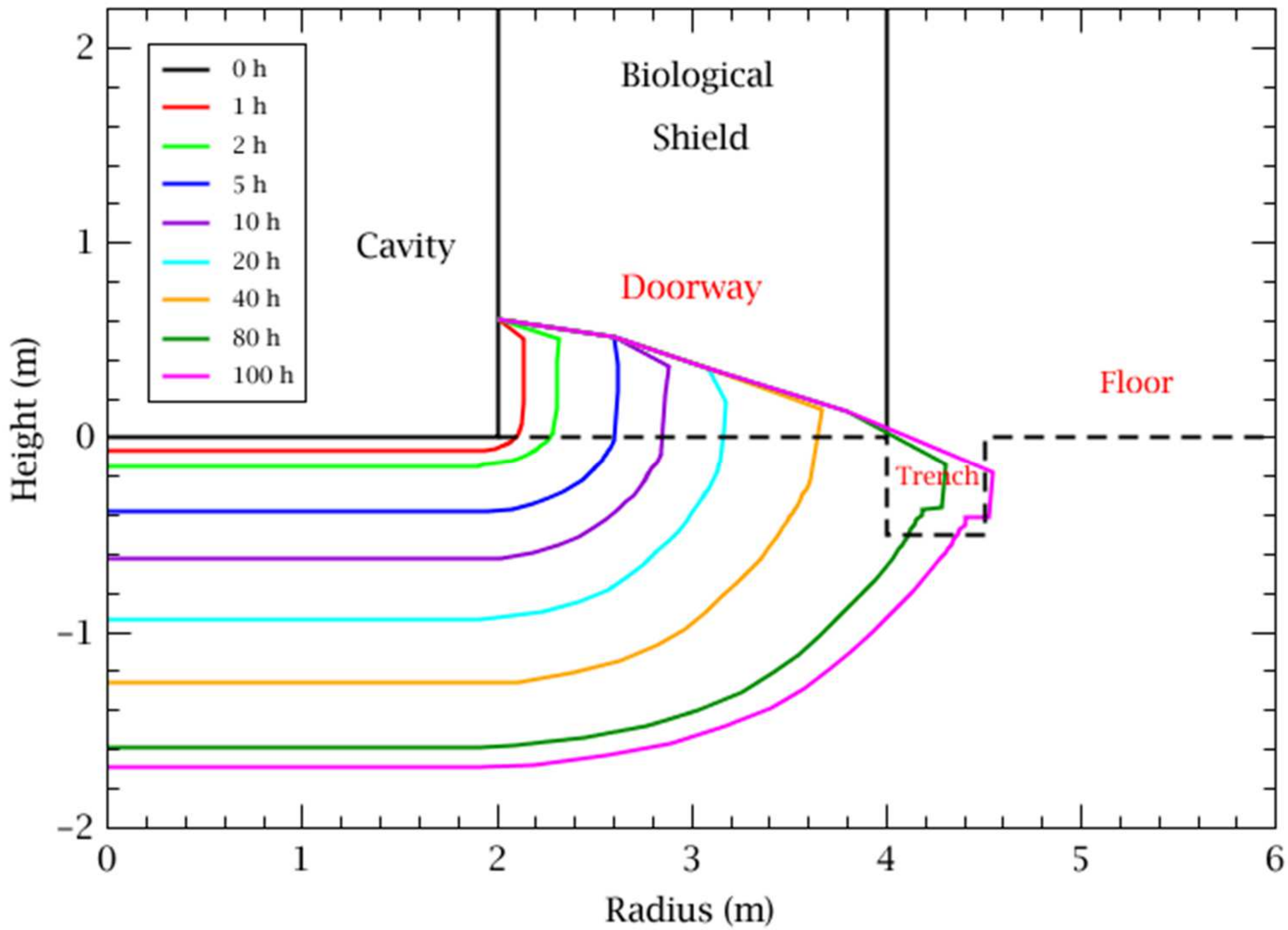
Times for output have to be defined

Output is possible as normal plot or reflected plot for all cavities

Starting coordinates for each cavity output can be given

Data are stored formatted as X-Y data pairs (AptPlot)

Progression of Ablation Shapes (CASE 1)

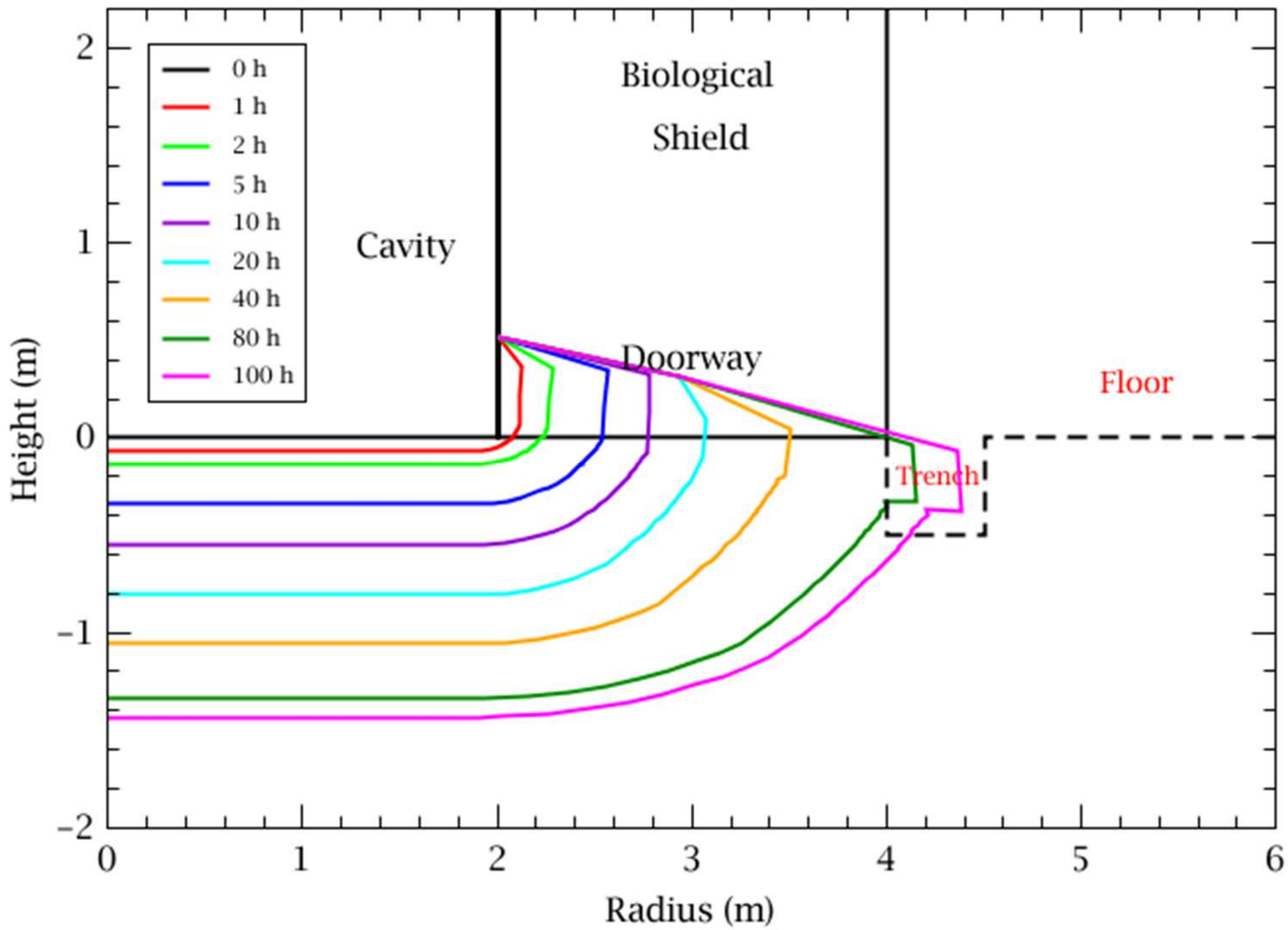


Only cavity inside biological shield modelled

Failure of biological shield after 2.5 days

Height of melt about 60 cm

Progression of Ablation Shapes (CASE 2)

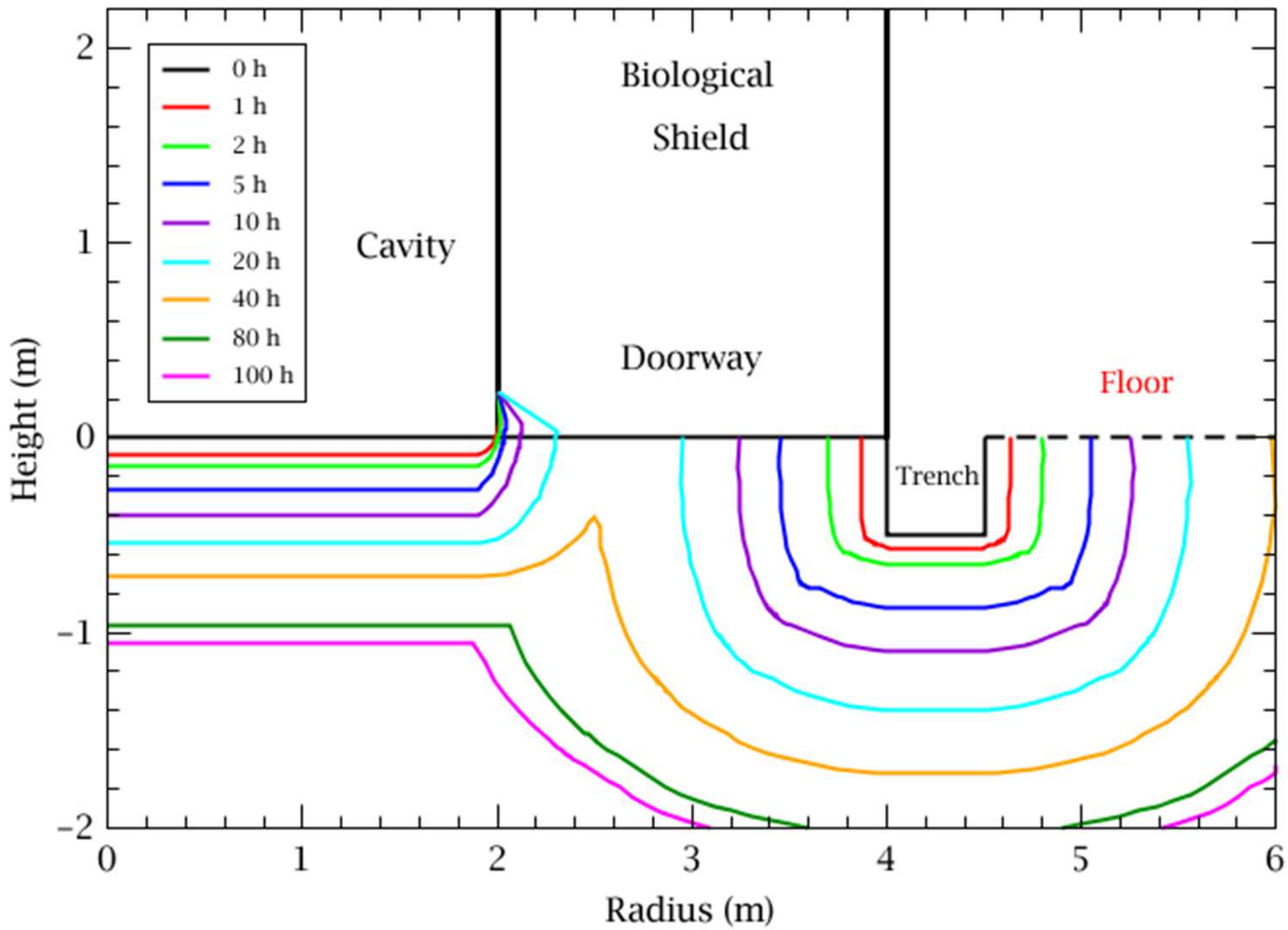


Cavity and doorway modelled

Failure of biological shield after 3 days

Height of melt about 50 cm

Progression of Ablation Shapes (CASE 3)

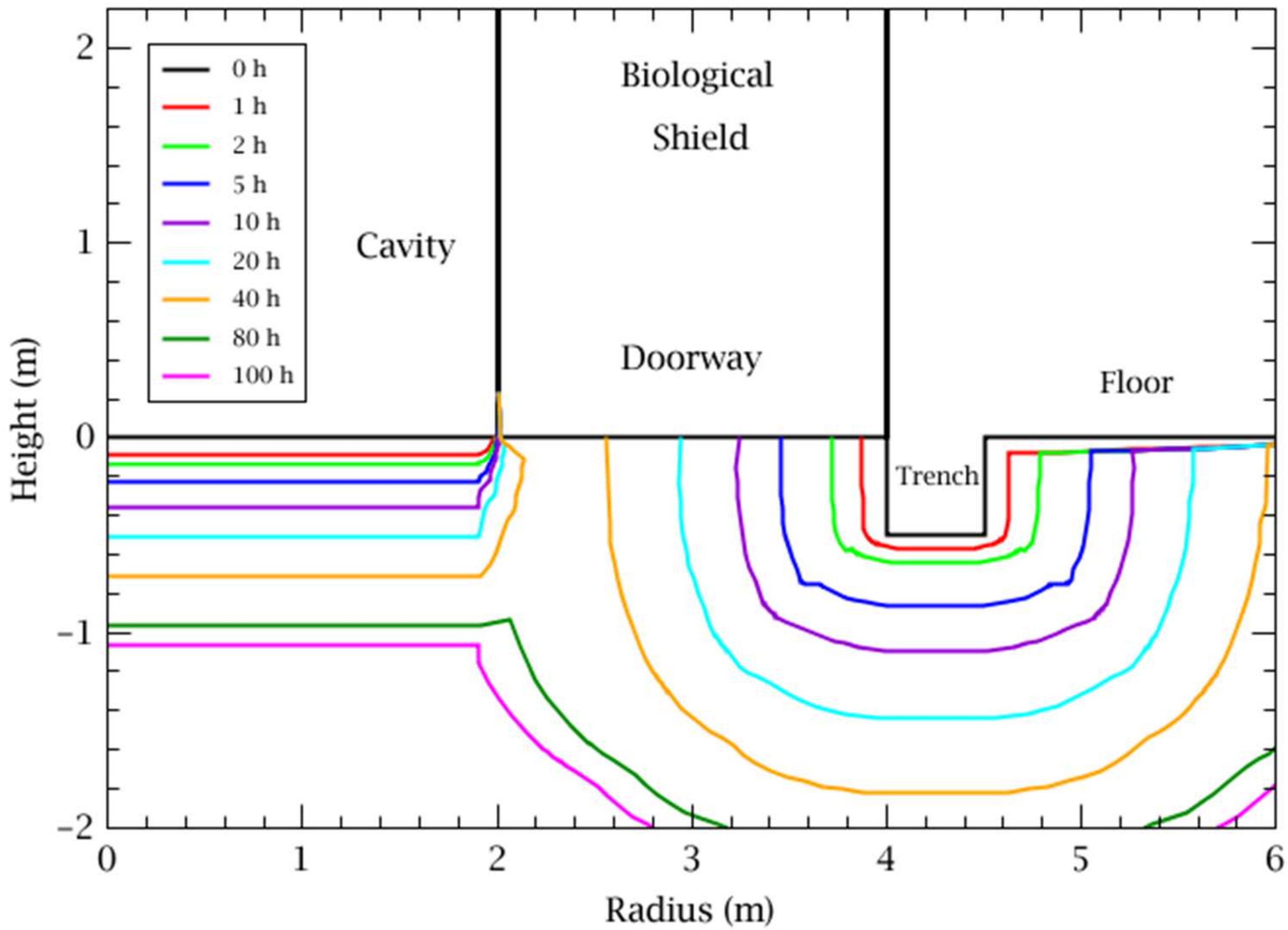


Cavity, doorway and trench modelled (Volume)

Failure of biological shield after 1.5 days

Height of melt about 20 cm

Progression of Ablation Shapes (CASE 4)

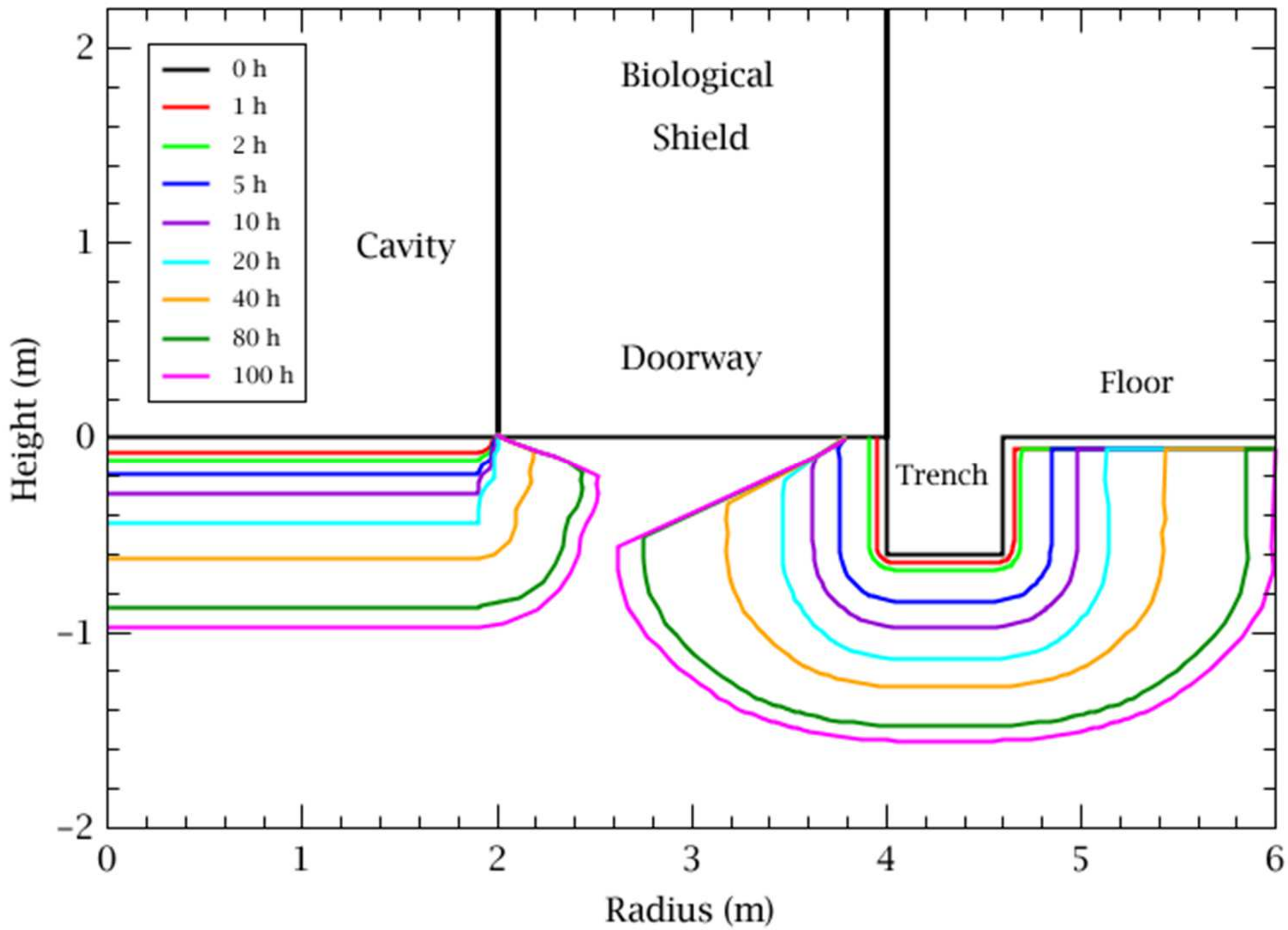


Cavity, doorway trench and floor modelled (Volume)

Failure of biological shield after 2 days

Height of melt about 15 cm

Progression of Ablation Shapes (CASE 5)



Cavity, doorway trench and floor modelled (Wall / Volume)

Failure of biological shield after 4 days

Height of melt about 15 cm

Important parameters

Comparison of some important Parameters:

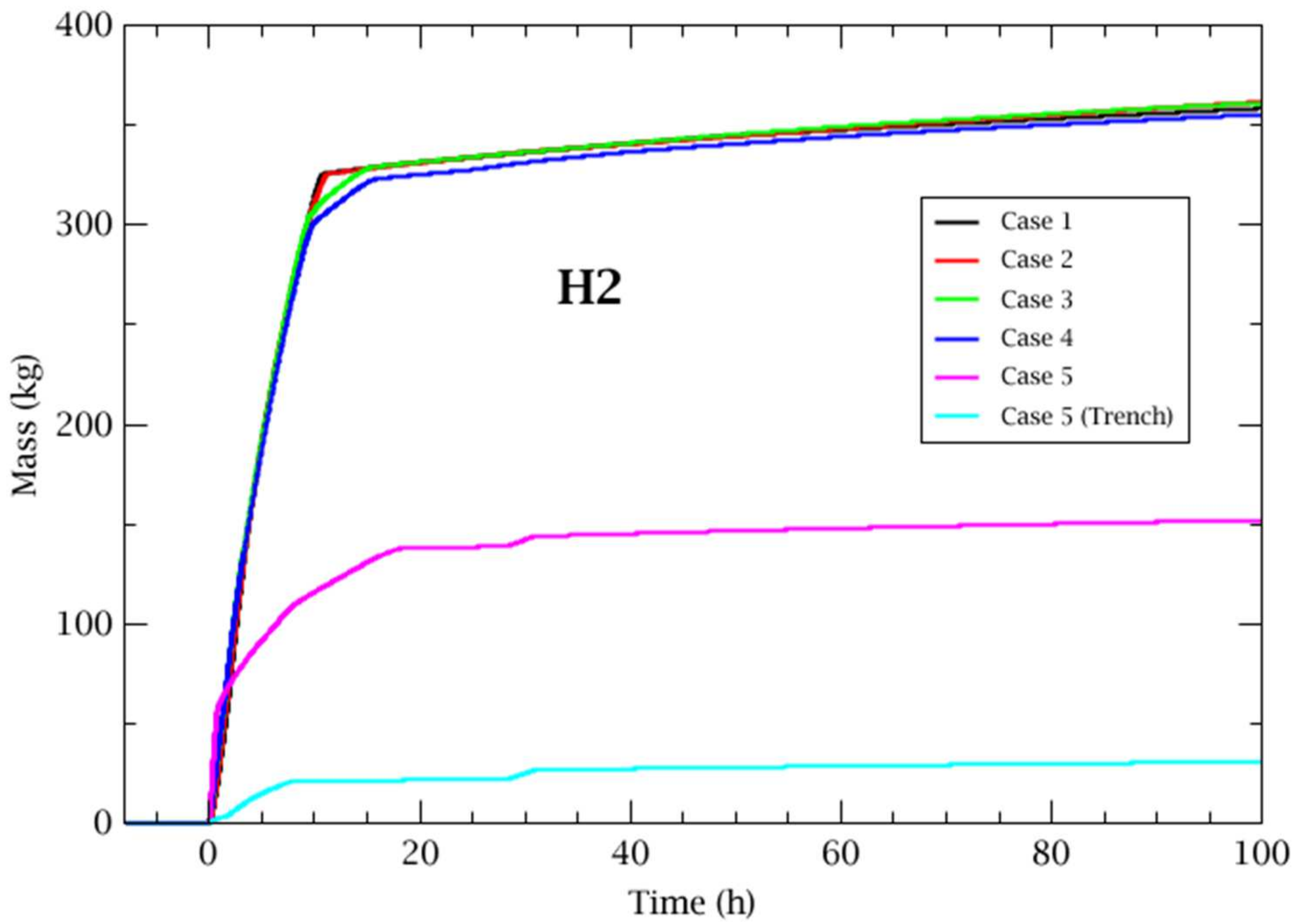
Hydrogen production

Carbon dioxide production

Upper Containment temperature

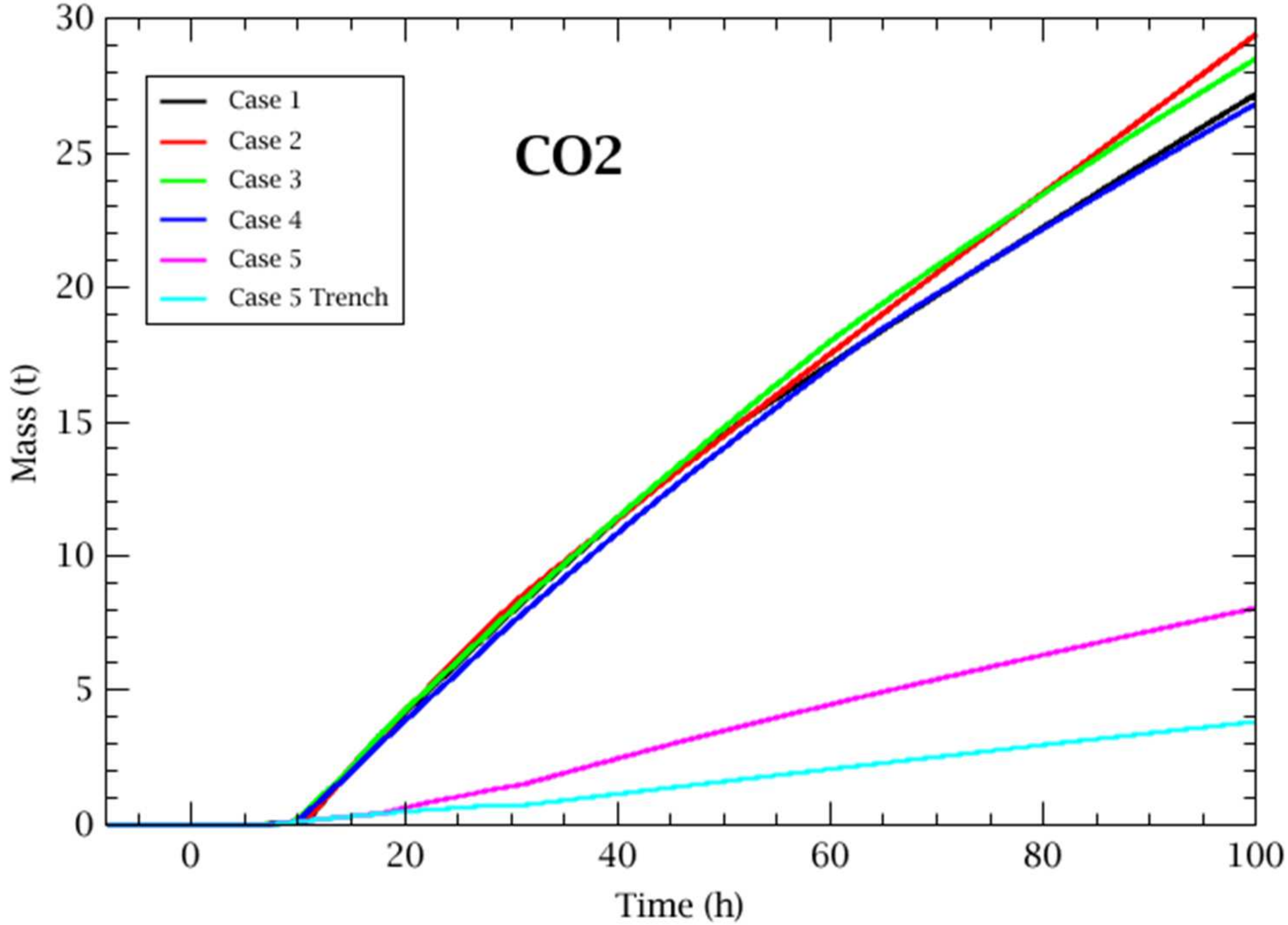
Containment pressure

Hydrogen production



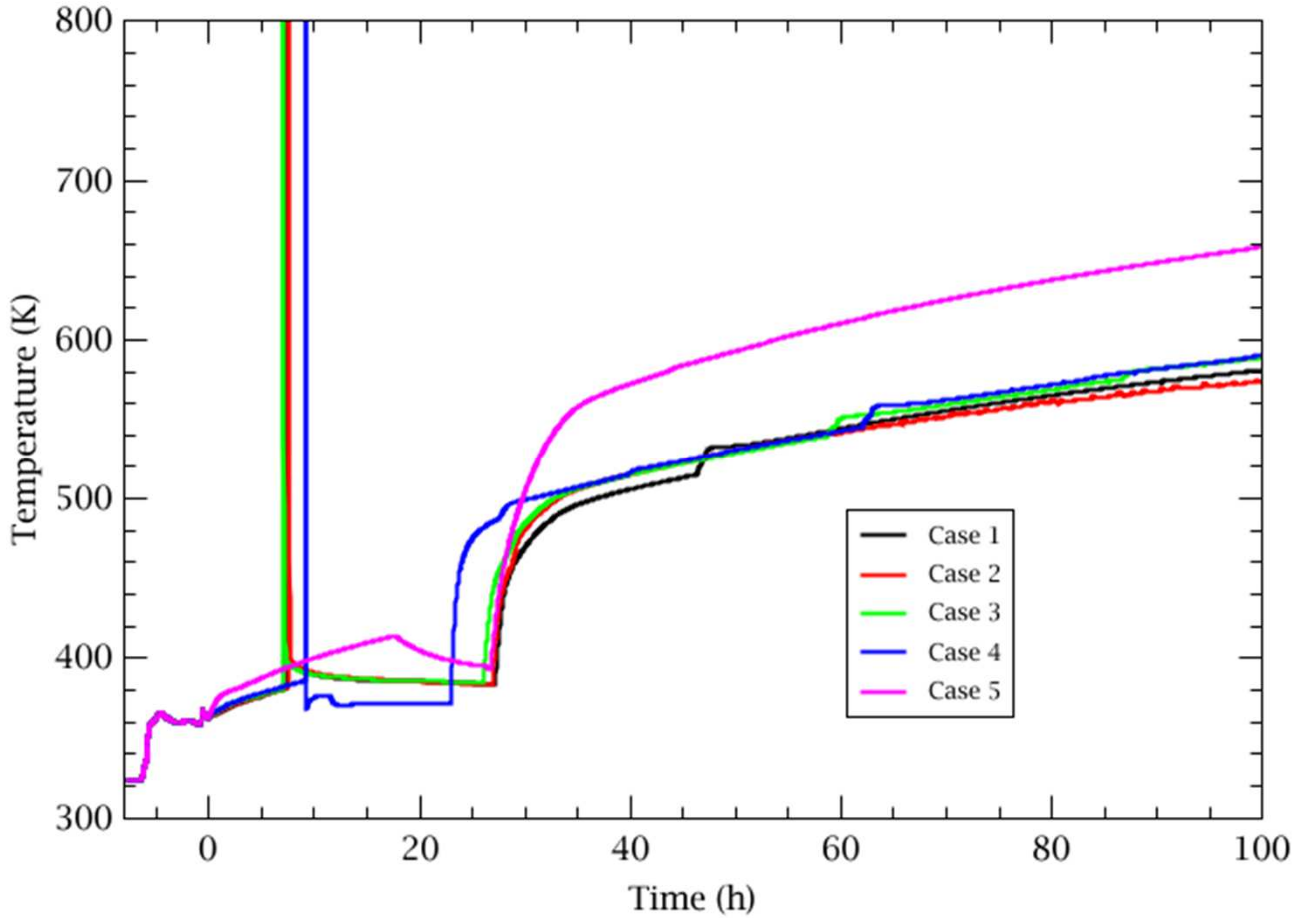
Hydrogen produced in “small trench“ is only 20 % of total Hydrogen produced from MCCI

Carbon dioxide production



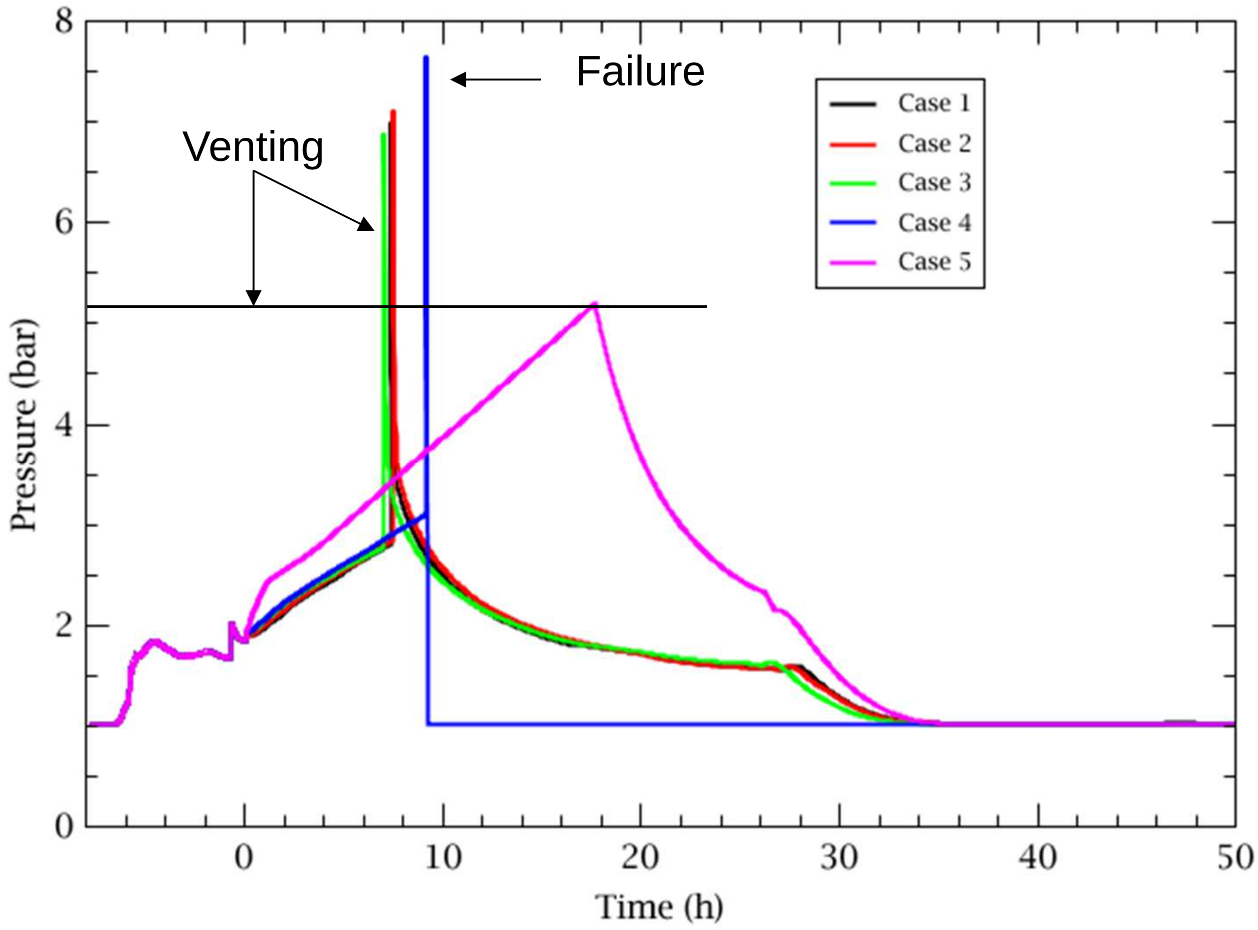
CO_2 produced in “small trench“ is about 50 % of total carbon dioxide produced from MCCI

Upper containment temperature



Large spreading area in floor region (Case 5) implies higher containment temperature due to heat radiation
Note also higher pressure

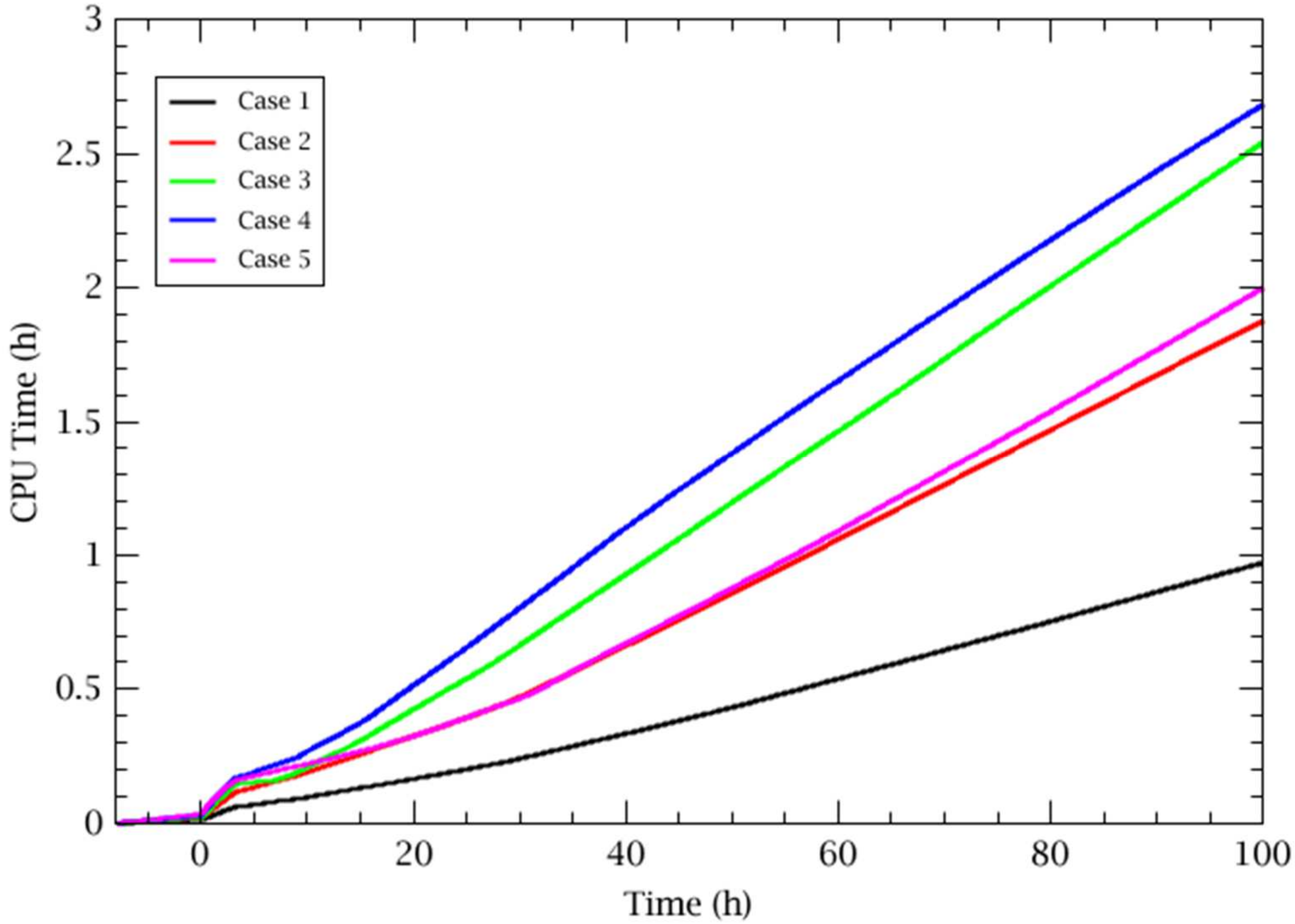
Containment pressure



Case 1 – 4
Containment failure or venting due to Deflagration

Case 5
no deflagration because of higher CO_2 / H_2 ratio
Containment venting due to Overpressure

CAV package CPU time



Maximum CPU time of CAV package (Case 4) is about 10 % of overall CPU time

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Conclusion

A geometrically complicated arrangement is difficult or impossible to model correctly.

Different trench modelling strongly influences the concrete ablation and therefore gas and aerosol release .....

Recommendations

Implementing the MELCOR coordinates into CORCON

Installation of an annular and a rectangular cavity model in the CAV package

OUTLOOK

- Assessment of MELCOR 1.8.6 and MELCOR 2.1 continues
  - feedback being provided to USNRC and Sandia Labs

Thank you for your attention