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Wir schaffen Wissen – heute für morgen

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MELCOR and CORQUENCH MCCI analyses in a KONVOI containment

EMUG, Brusseles 3/2015

Content

- Introduction: MELCOR/CORCON MCCI analyses
- Why we still need CORQUENCH
- Base case SBO calculations by MELCOR and CORQUENCH
- Sensitivity CORQUENCH calculations
- Conclusions

Introduction: MELCOR for MCCI and selected scenarios

Old MELSIM input deck of KONVOI 1000MWe PWR was translated for use with MELCOR 1.8.6 by deleting and/or adapting all MELSIM functions and MELSIM related commands

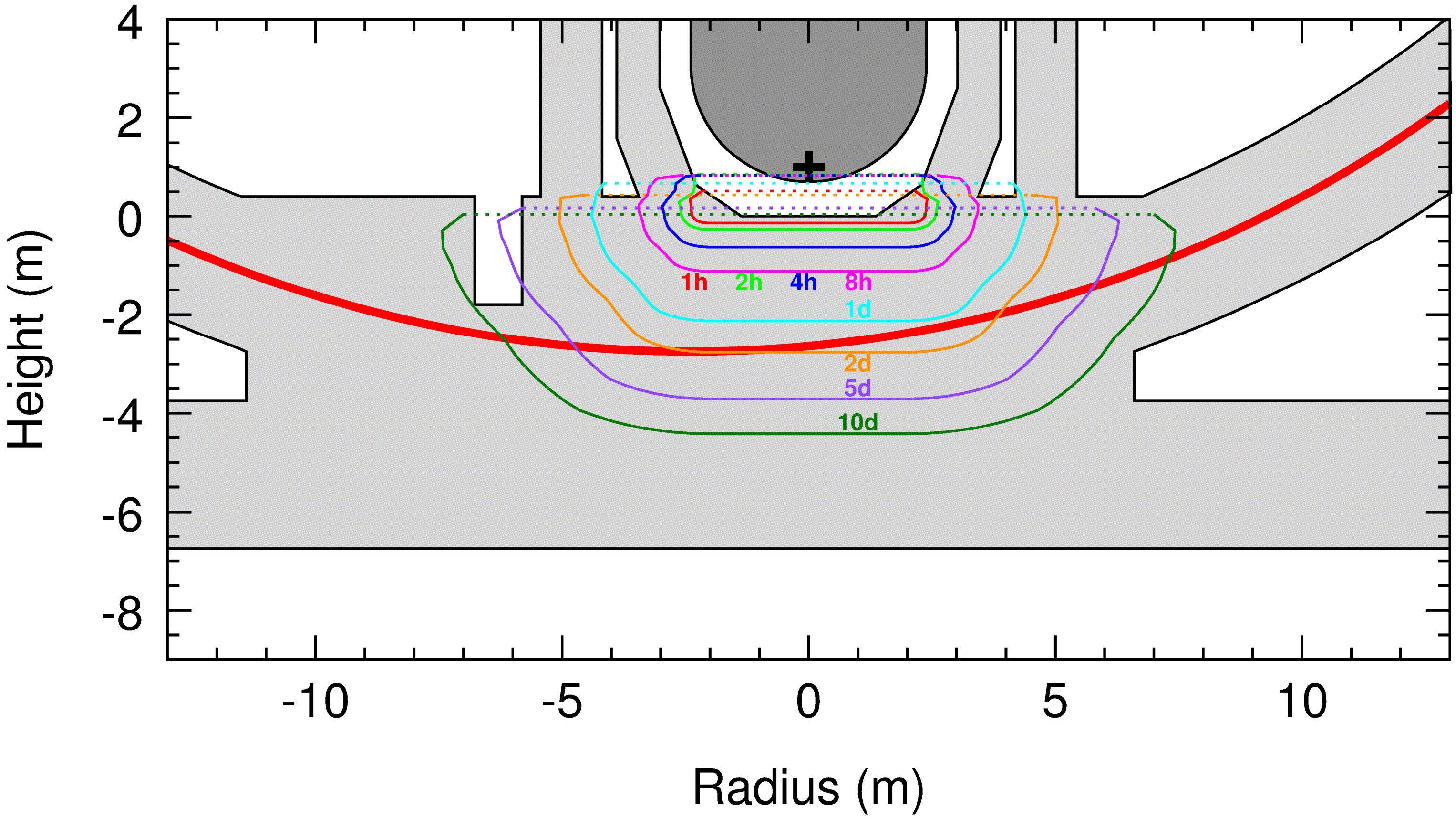
An SBO sequence was chosen for the long-term accident progression simulation, including MCCI; mostly defaults used in MELCOR/CORCON analyses, also the homogeneous melt option

Basemat ablation was the main parameter of the study, radial ablation thought to be less important here; containment pressurization from MCCI mitigated by FCVS

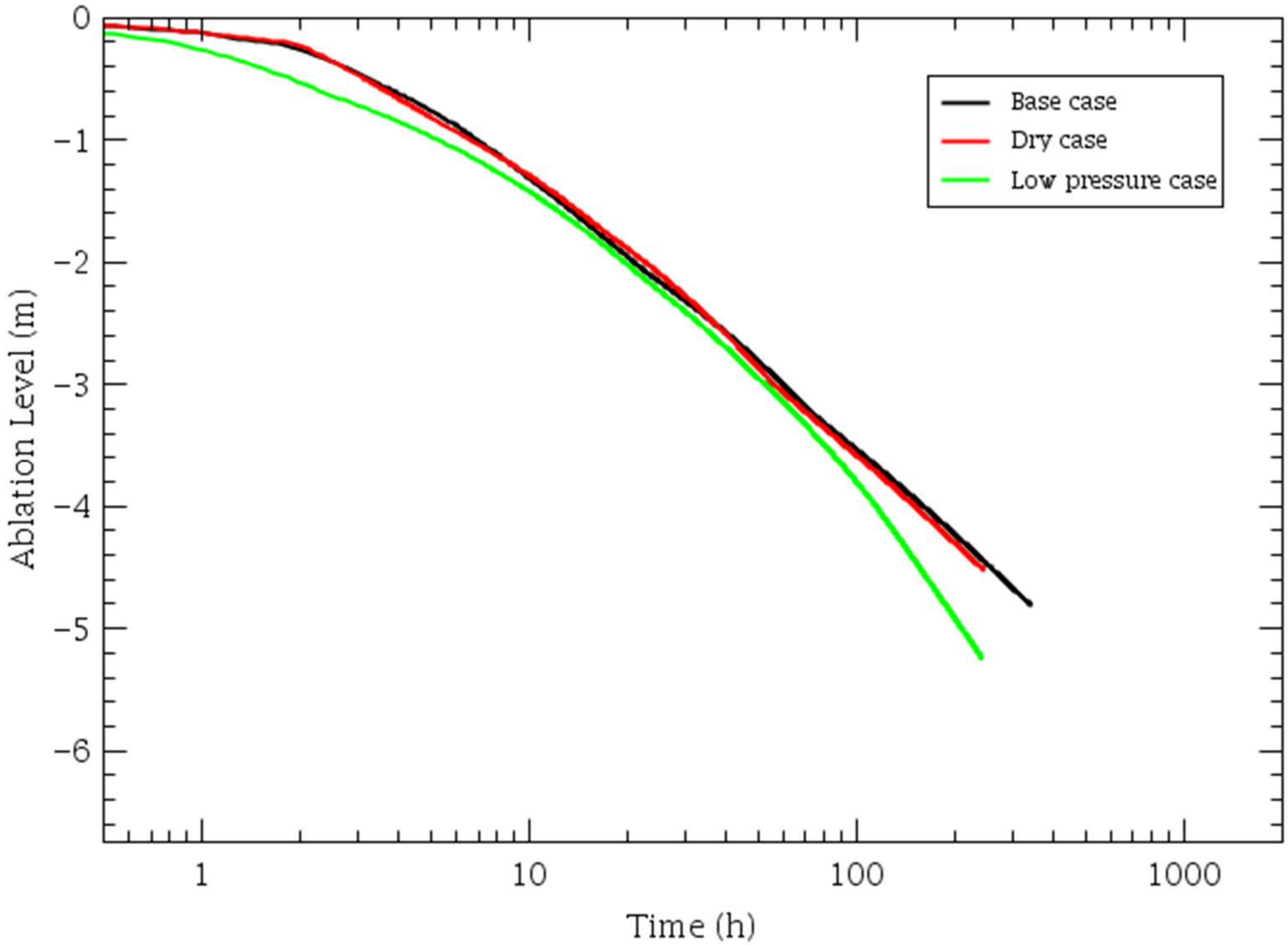
A high pressure scenario used to get the starting conditions for MCCI, with water on top of the melt just after VF, recalculated also with M2.1

A "dry case" and a low pressure scenario were also calculated as sensitivity cases

Base case by MELCOR/CORCON

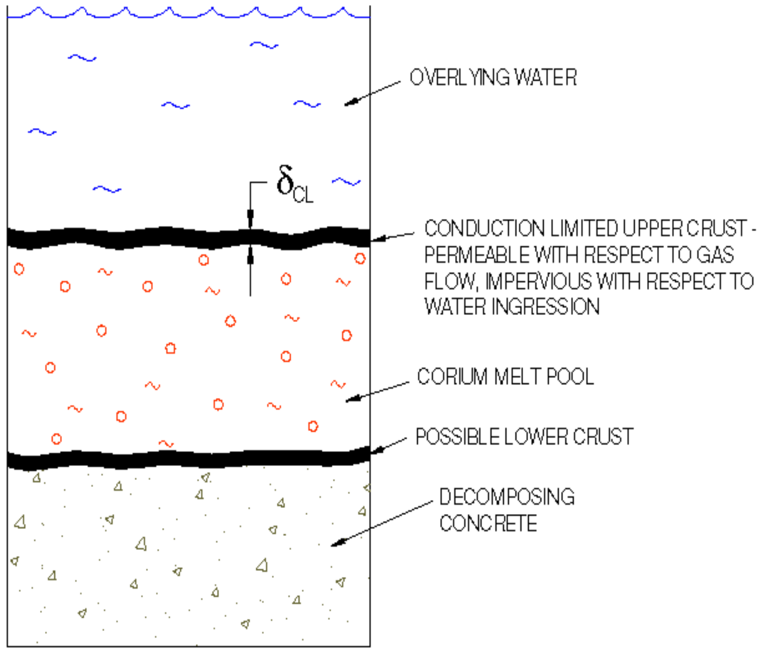


Sensitivity on long-term downward erosion by MELCOR

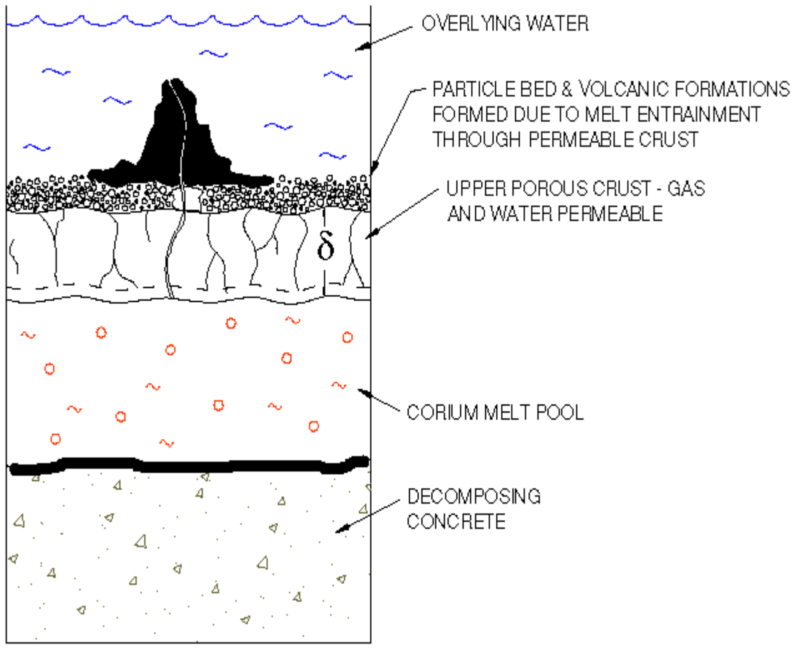


Introduction: CORQUENCH

- **why we need CORQUENCH (for cases with water atop the melt)?**
  (Farmer et.al, Nucl.Eng.Technol., 2009)



(a)



(b)

traditional view of MCCI,
also CORCON in MELCOR

water ingression, melt eruptions,
and also unstable crust,
all modeled in CORQUENCH
(plus heat conduction into concrete)

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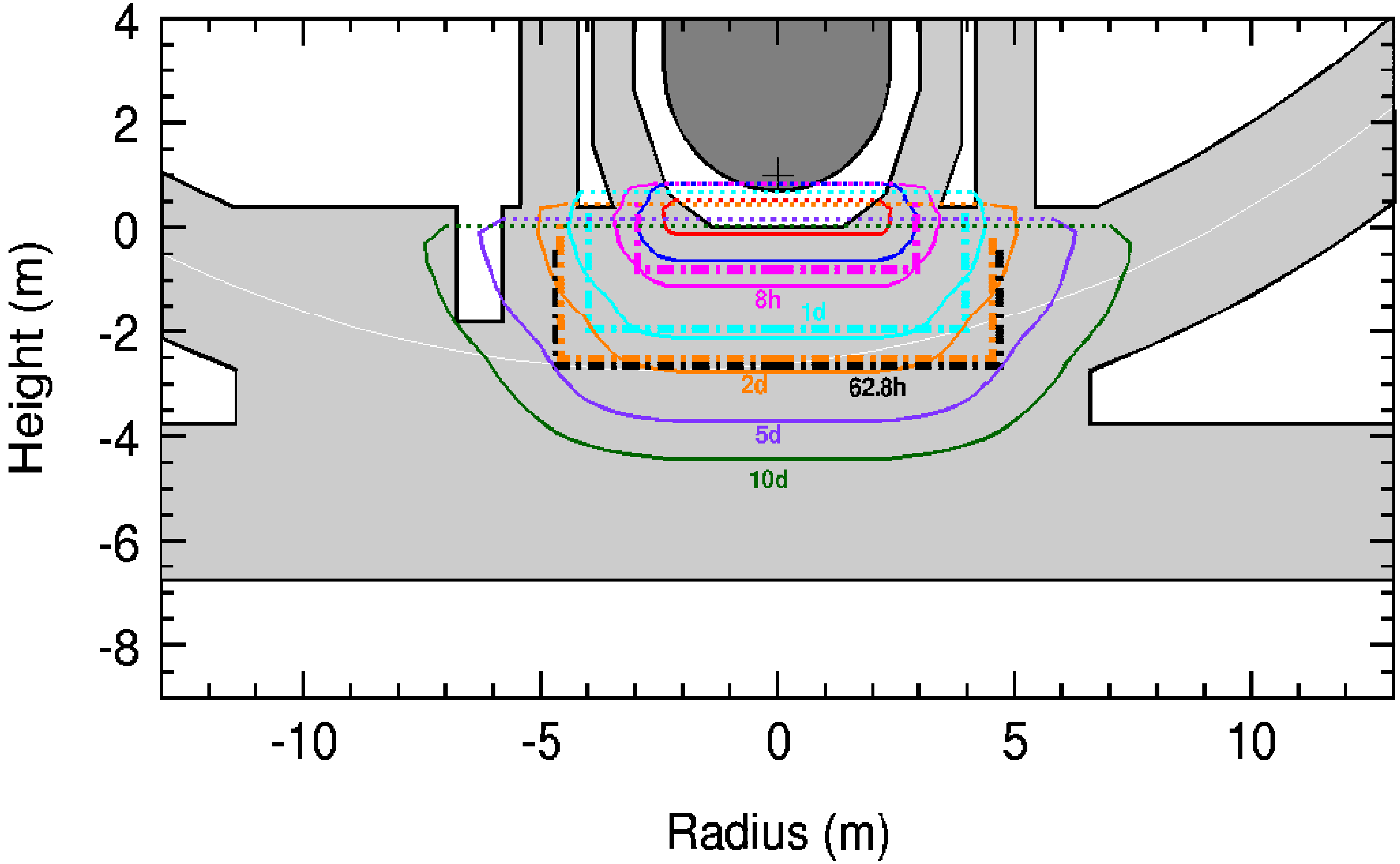
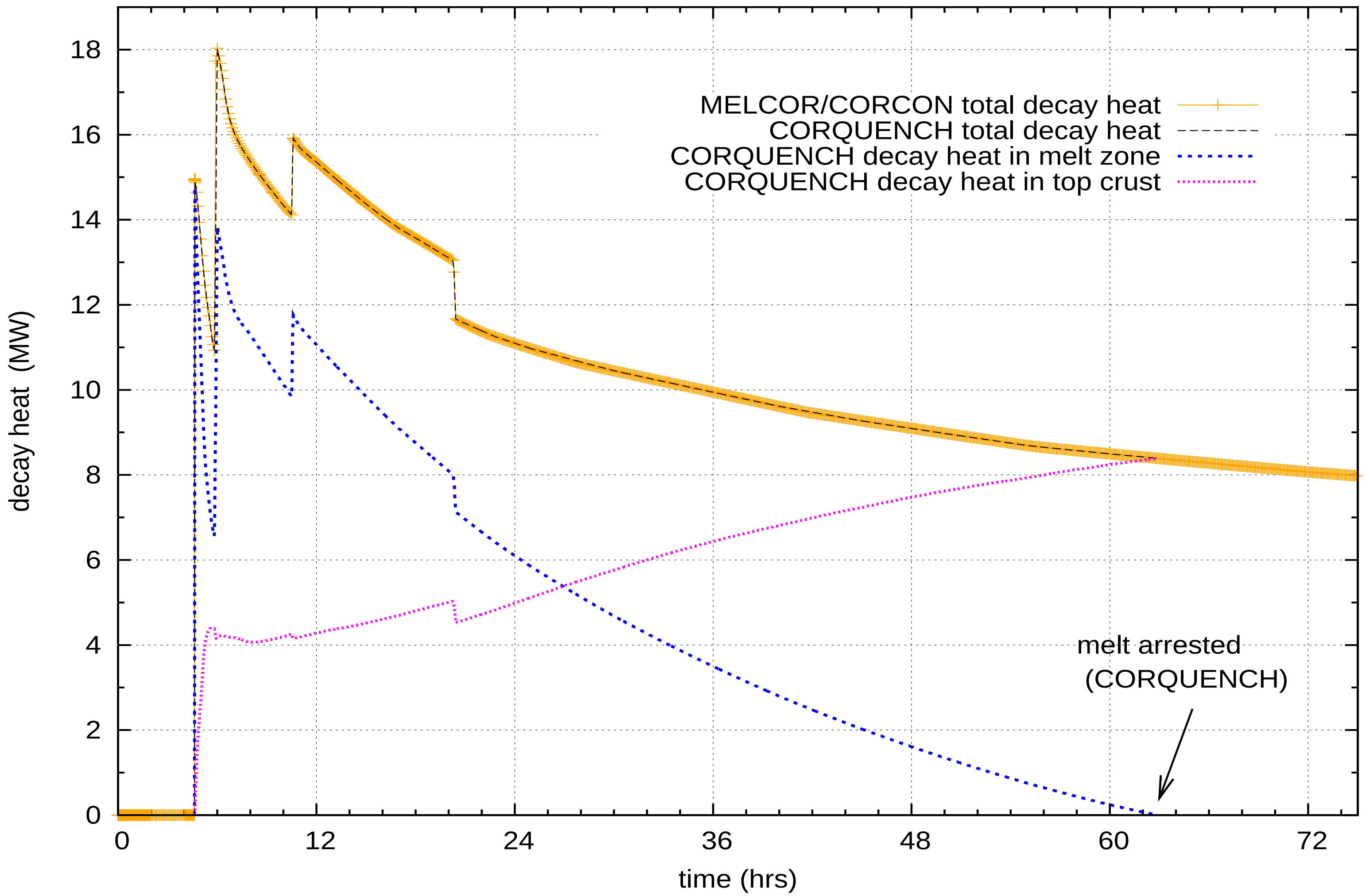
CORQUENCH modeling

- Base case with the same modeling options as in MELCOR/CORCON calculations, typically
  - homogeneous melt layer
  - melt-concrete interfacial heat transfer by gas_film model; the slag_film model also used for base case and for most of sensitivity cases
  - limestone/CS concrete with ~26%wt $CaCO_3$
- Trying to mimic the decay heat exactly as given by MELCOR calculations (even though there might be some issues with MELCOR), trying to have the right amount of water atop the melt for about the right time for the base case
- Sensitivity calculations mostly concerned with coolability models, different ways, for long-term water addition
- Main parameter for comparisons is the maximum ablation depth axially (downwards), potentially, of course, quenching of the melt

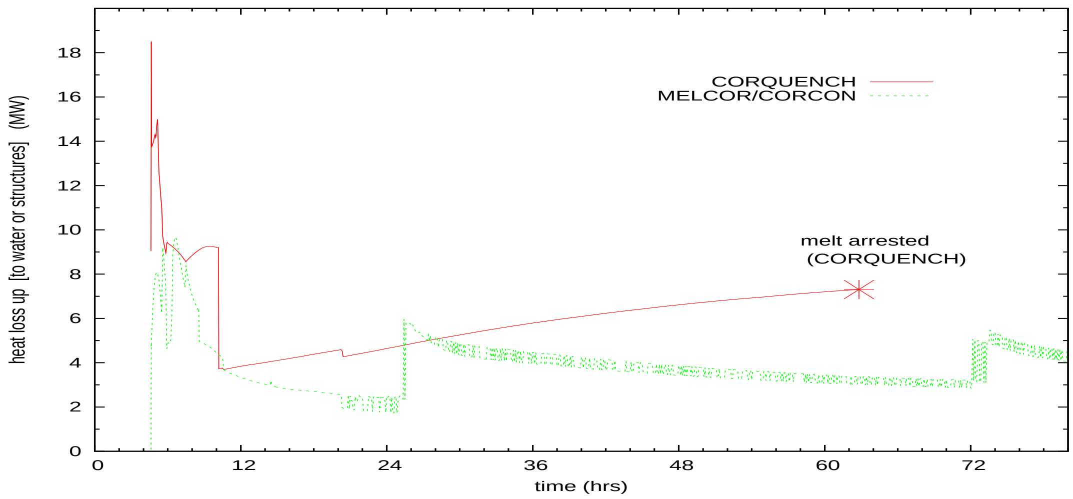
Base case (gas film model) CORQUENCH

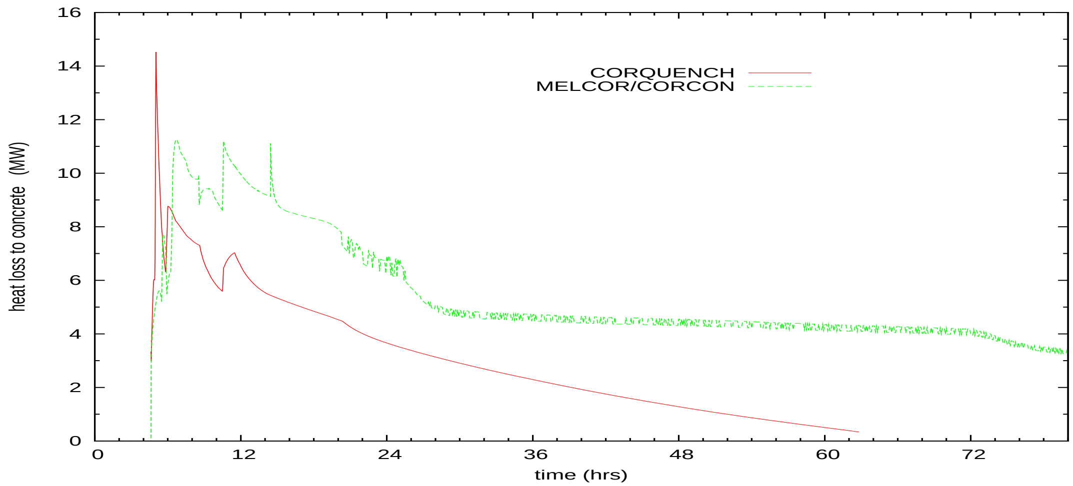


Base case: Decay heat

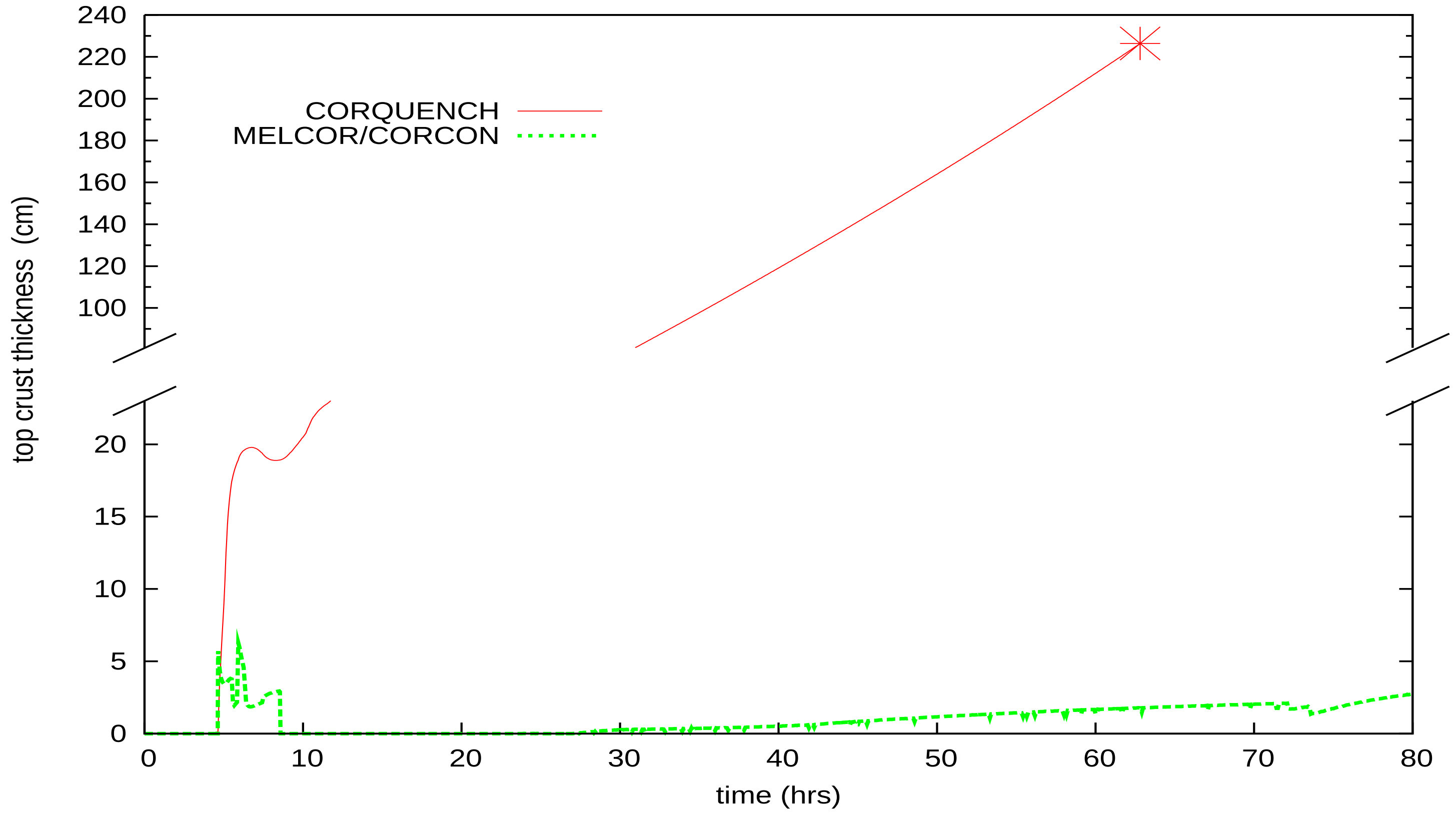


Base case: Heat losses "up" and heat losses to concrete

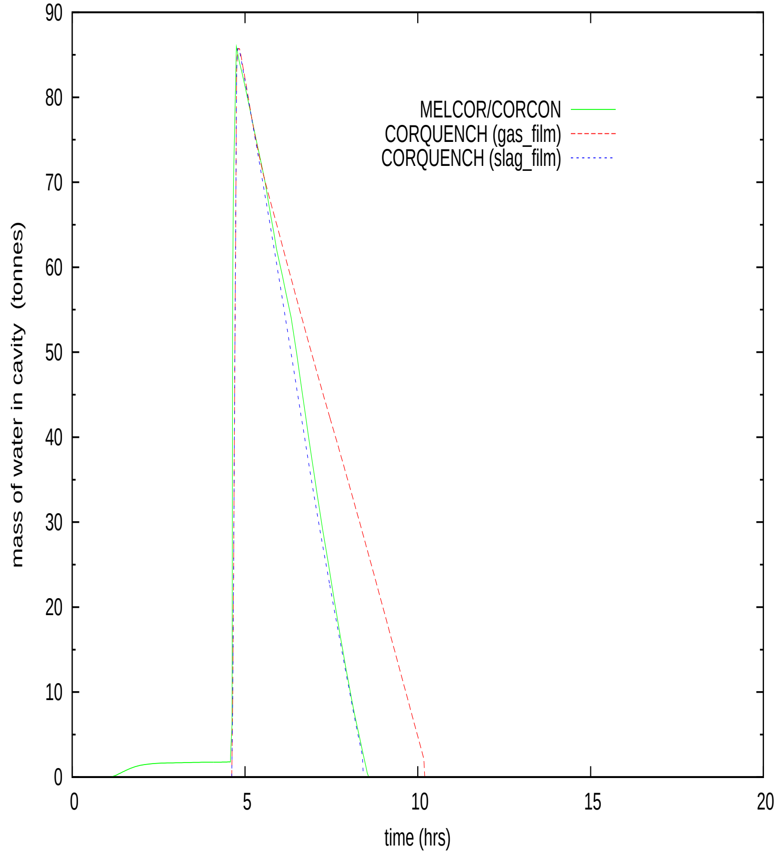


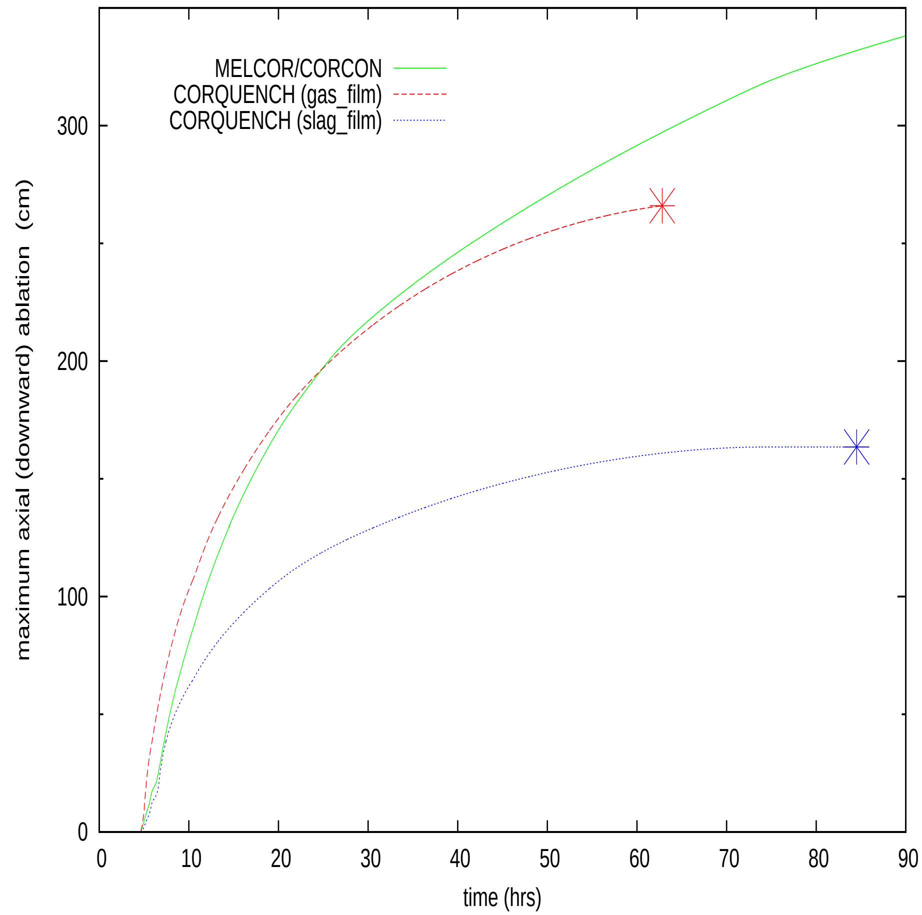


Base case: Top crust and arrest of the melt



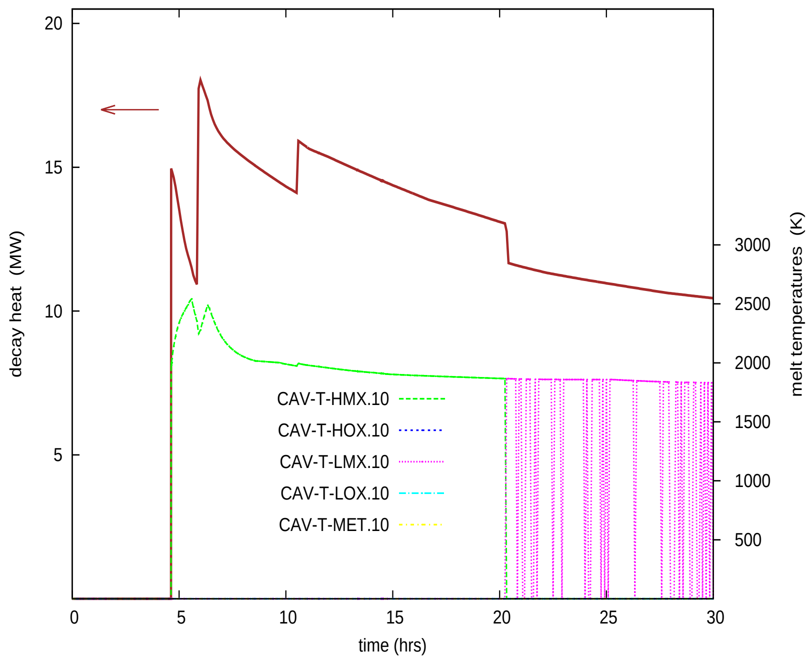
Base case: Water in cavity and maximum ablation depth



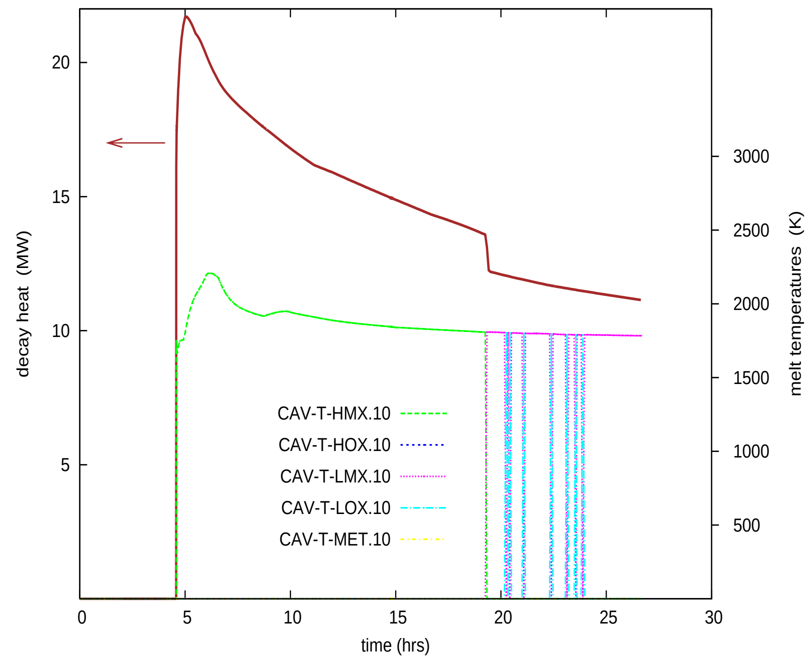


MELCOR/CORCON implementation issues

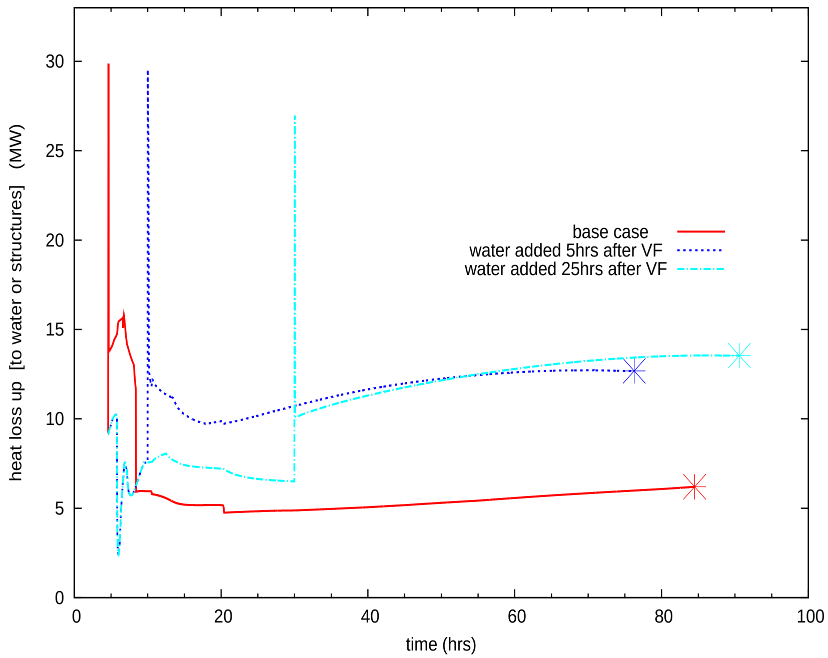
MELCOR 1.8.6

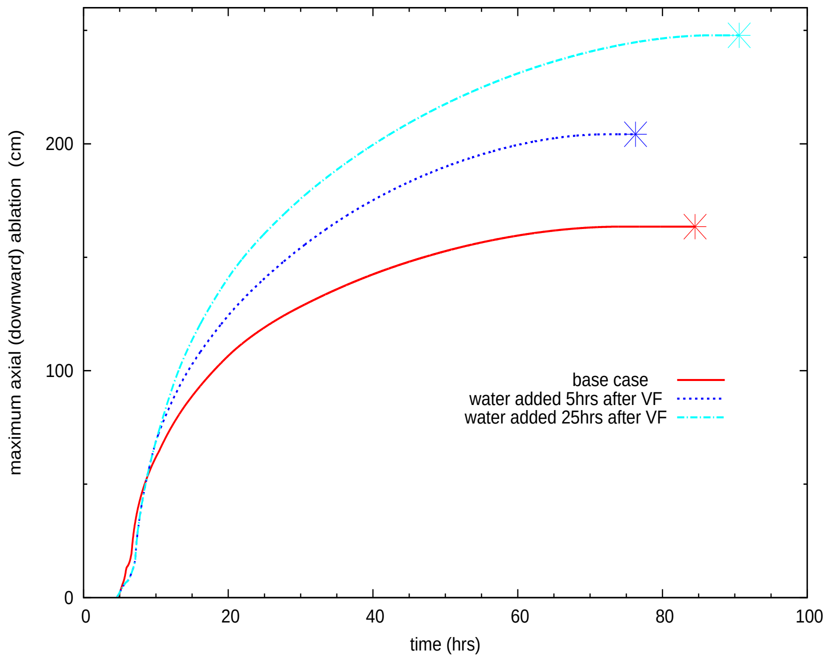


MELCOR 2.1



CORQUENCH sensitivity analyses: time of water addition

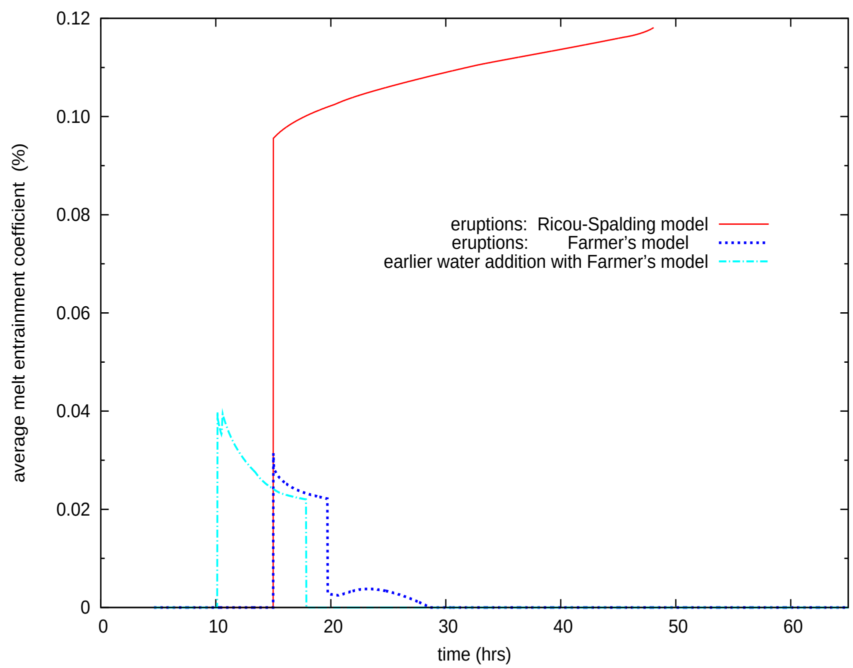


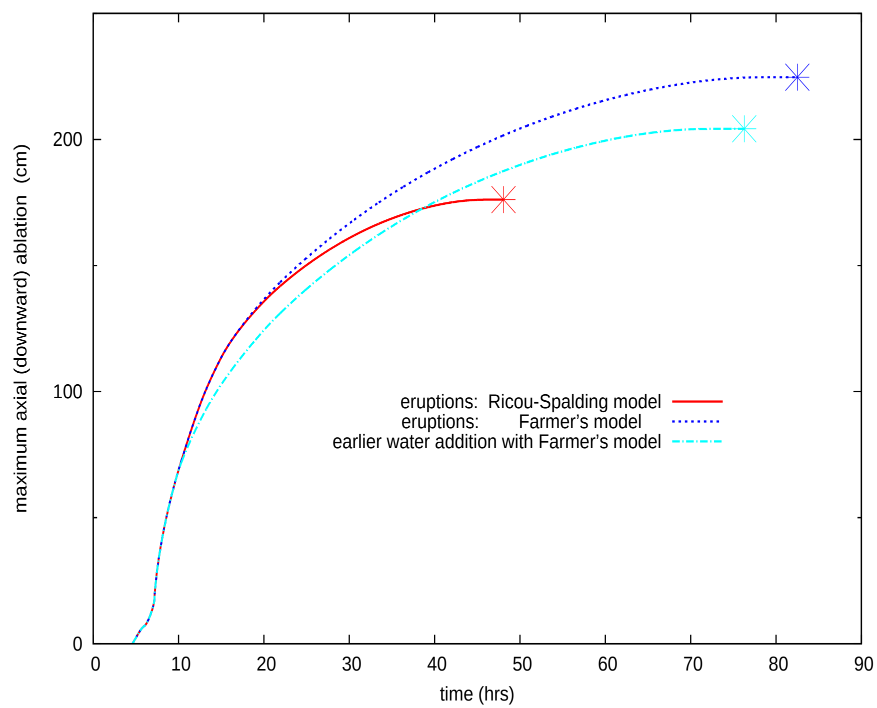


Sensitivity calculations: modeling of melt eruptions

CORQUENCH melt entrainment: $\dot{m}_{me} = (K_e \cdot j_g) \cdot \rho_m \cdot A_m$

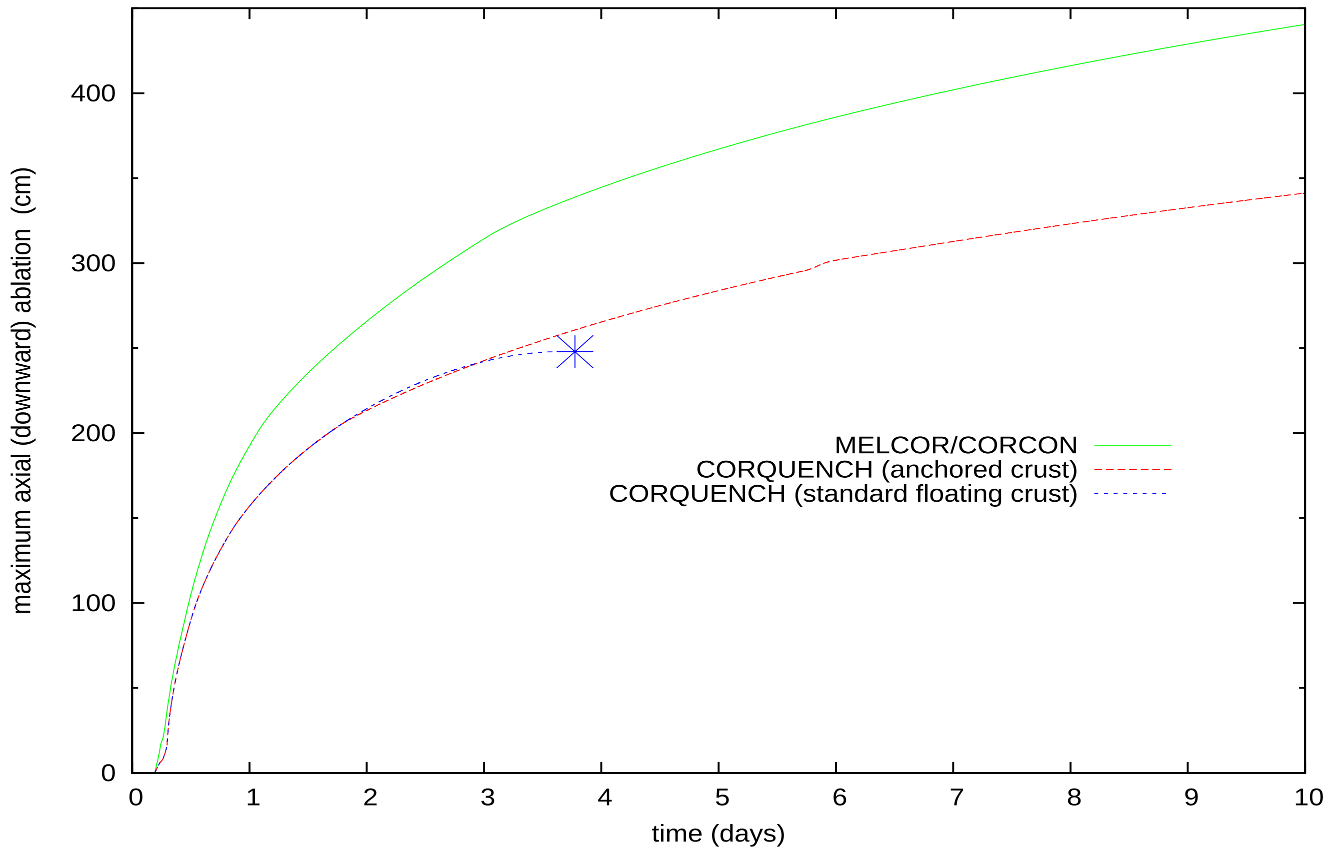
different models for melt entrainment coeff can be used,
Ricou-Spalding, Farmer's (used in base_case), user defined const.





Sensitivity calculations: worst case by CORQUENCH

ANCHORED CRUST
with late water addition (30hrs into the accident)



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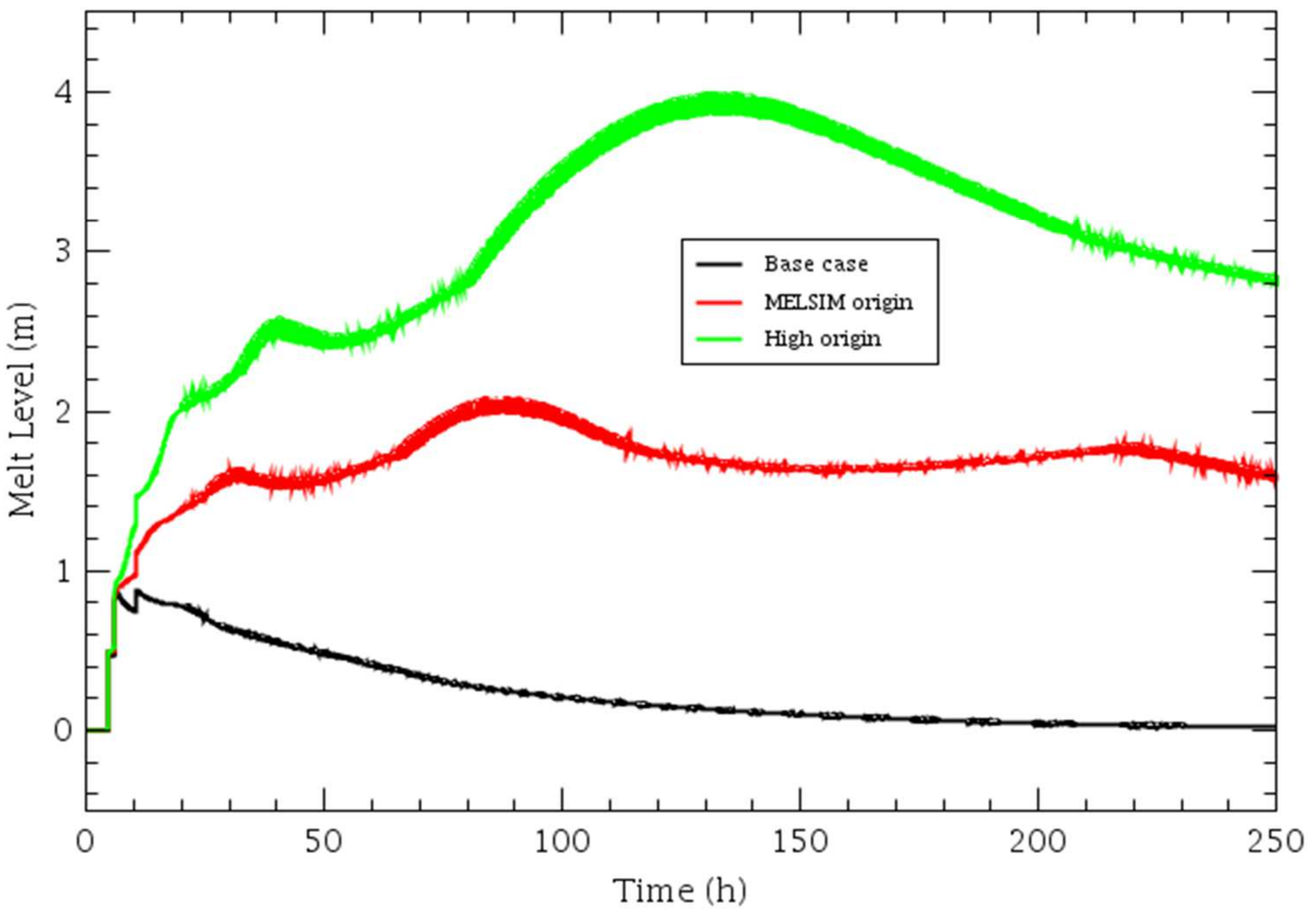
Conclusions

- MELCOR and CORQUENCH analyses of various long-term SBO scenarios were done in support of understanding the MCCI progression in KONVOI PWR containment cavity
- basemat melt-through at this type of cavity doesn't seem to be a question of a short time: for the base case SBO scenario, MELCOR/CORCON calculations show it would take at least 3 months (2000hrs)
- as inherent to MELCOR/CORCON, no "melt arrest" is predicted in any of the cases, not even with the water atop the melt
- in contrast, CORQUENCH calculations show quenching of the melt in cavity, i.e. stop of the MCCI progression, in most cases analyzed
  - in base case scenario, melt arrest calculated   at ~63hr, with less than a half of the total basemat thickness eroded
- sensitivity analyses with CORQUENCH support the assumed picture: putting water atop the melt (as a part of long-term AM) makes the quenching of the melt highly likely

Thank you for your attention

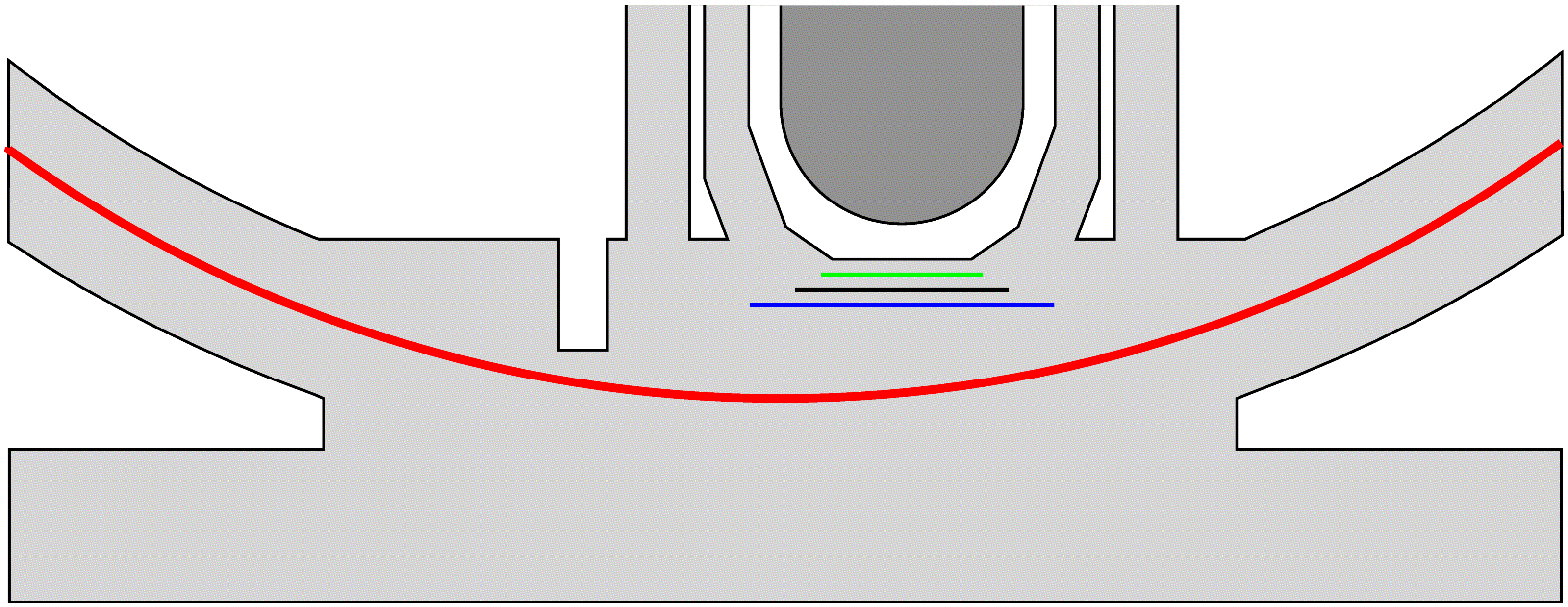
Proper choice of MELCOR/CORCON coordinate system



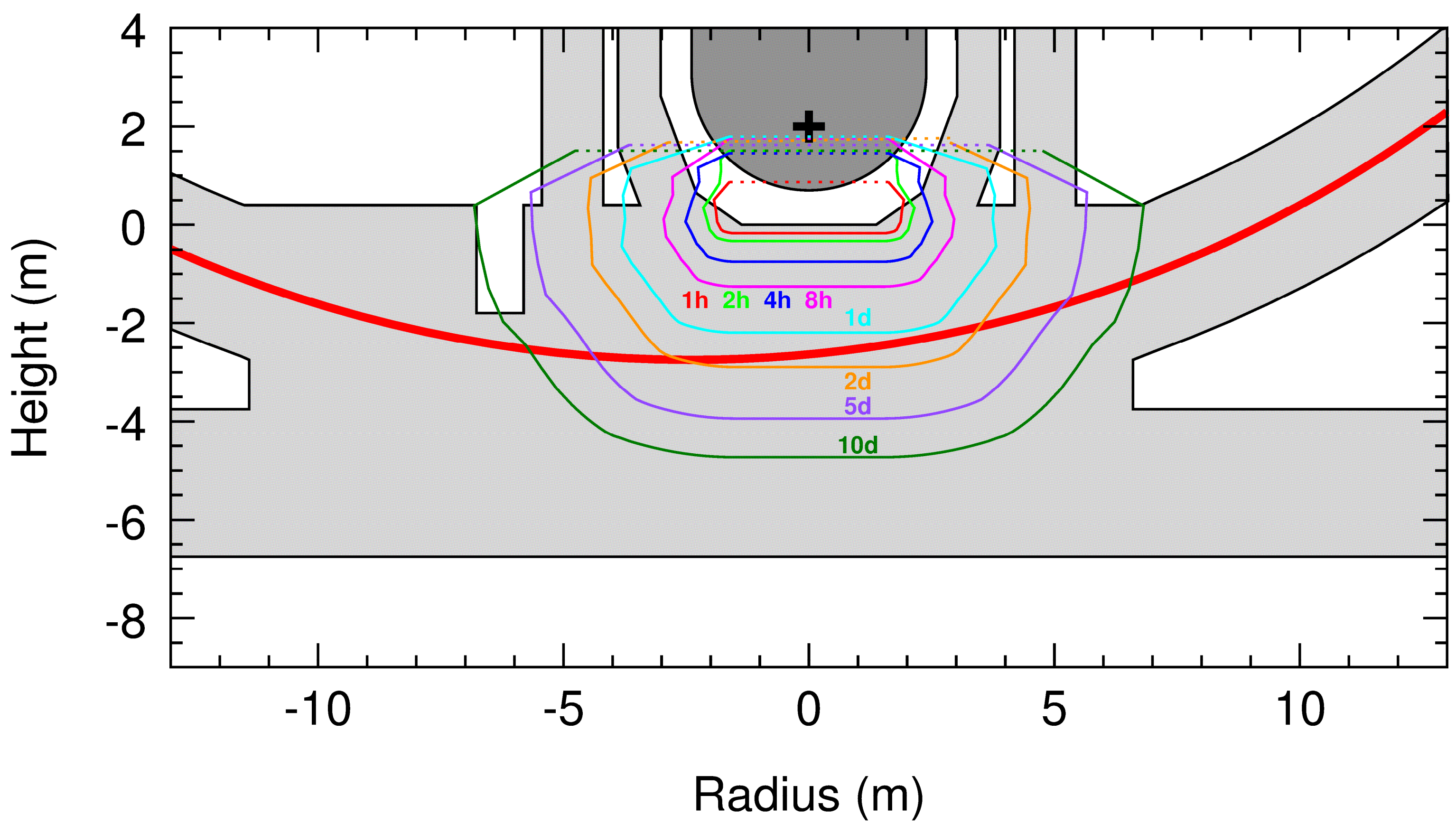
Cavity model

Small case	R=1.6 m	A=8.0 m^2
Base case	R=2.1 m	A=13.9 m^2
Large case	R=3.0 m	A=28.3 m^2

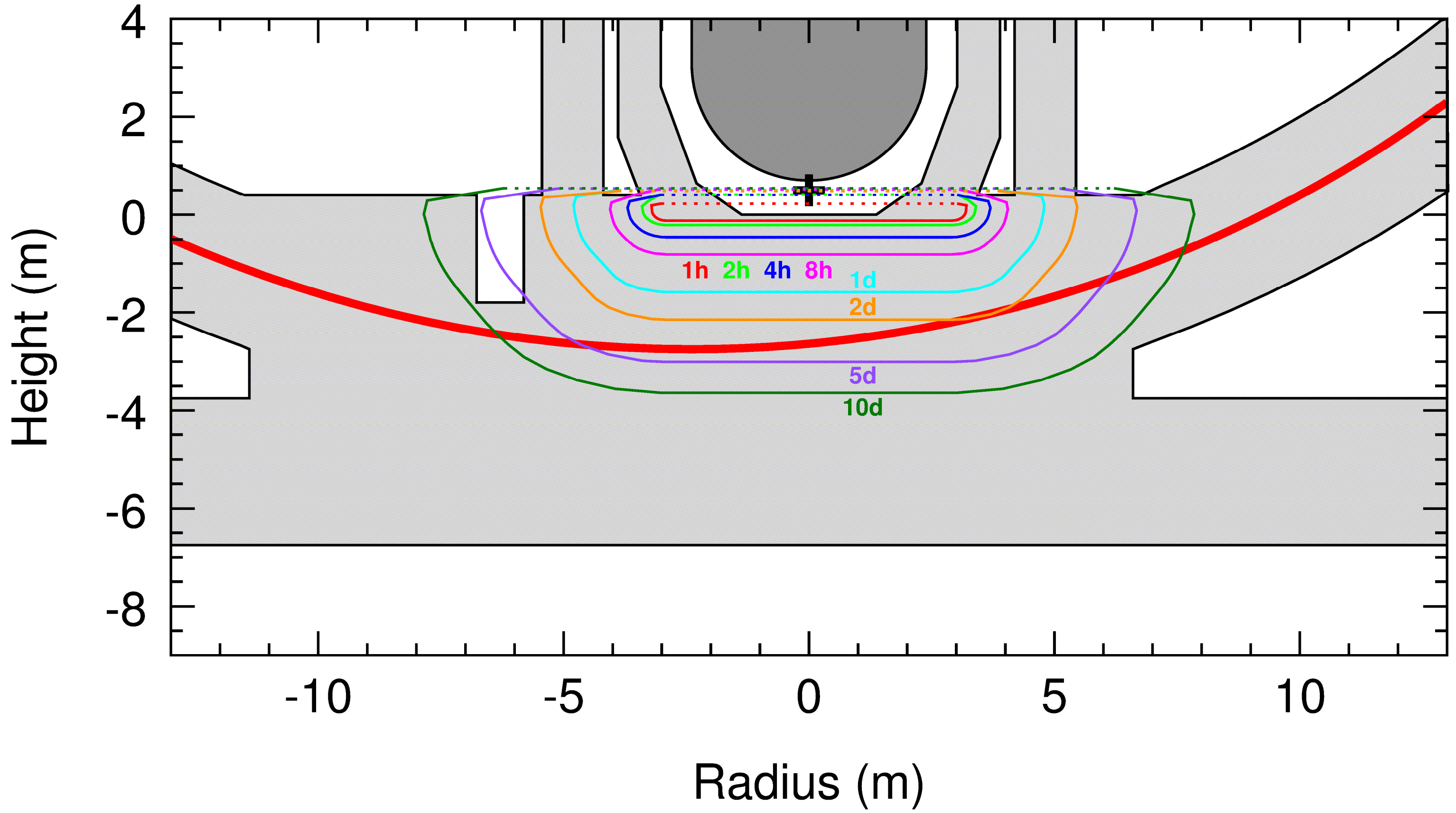
1 cylindrical cavity instead of 7 cavities
no complicated flow paths



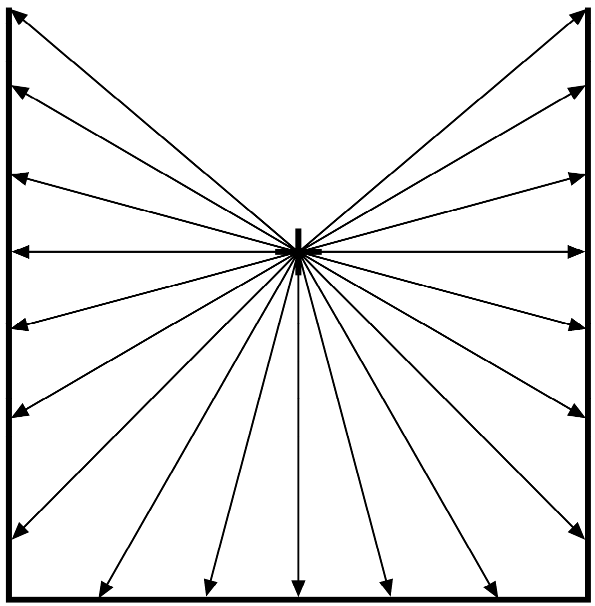
Small case

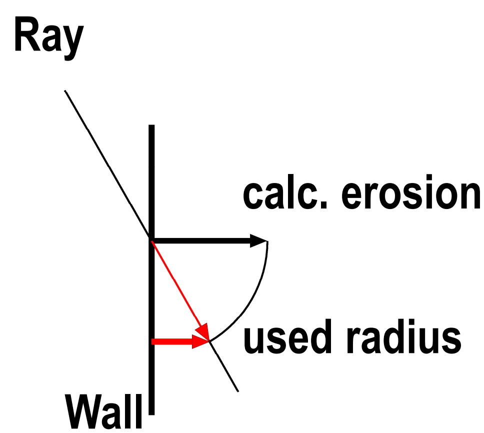


Large case



Secret of CORCON (Origin of Rays)

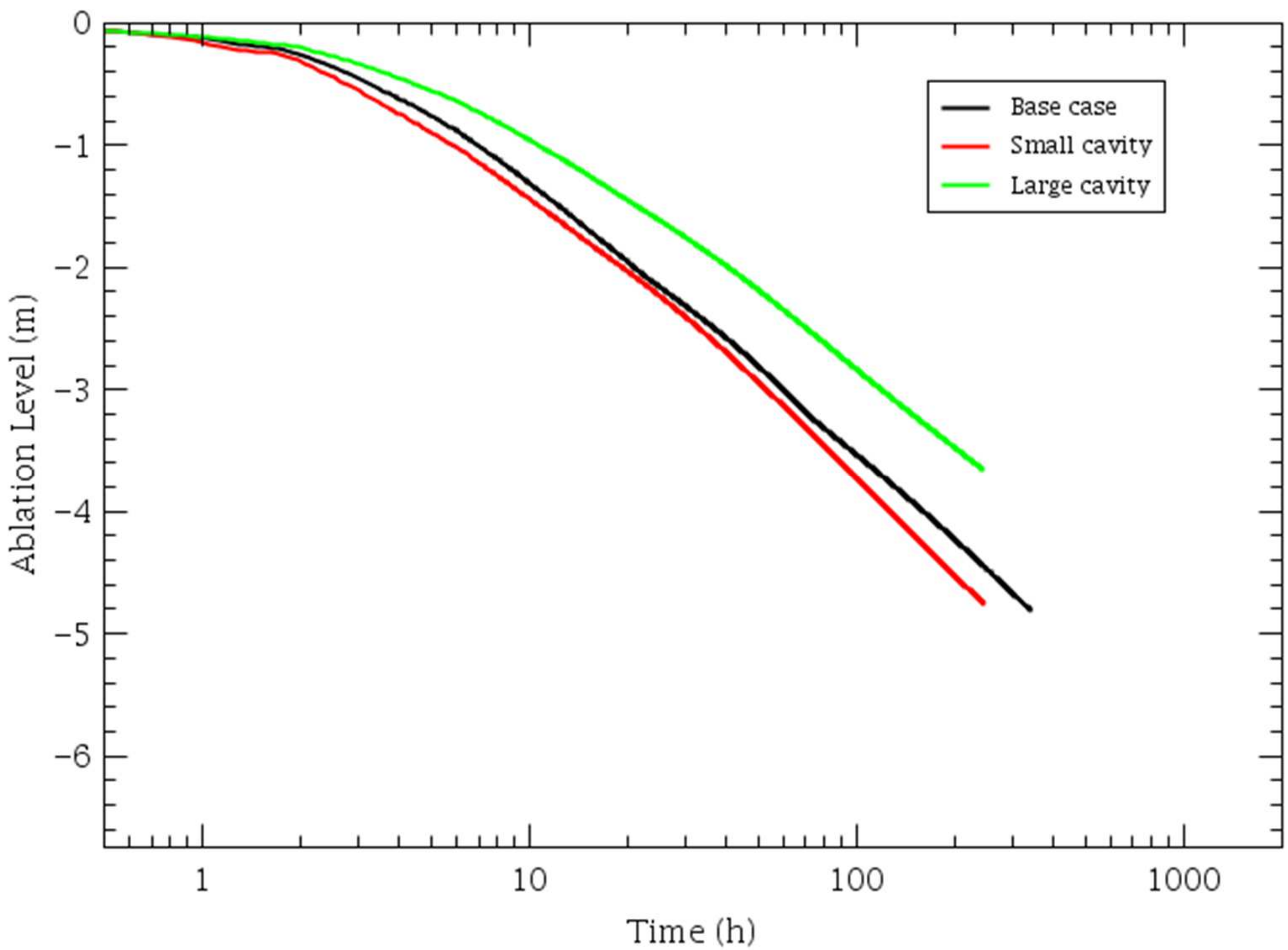




A high origin of the rays lead to reduction of the radius increase and therefore to an increase of the melt level.

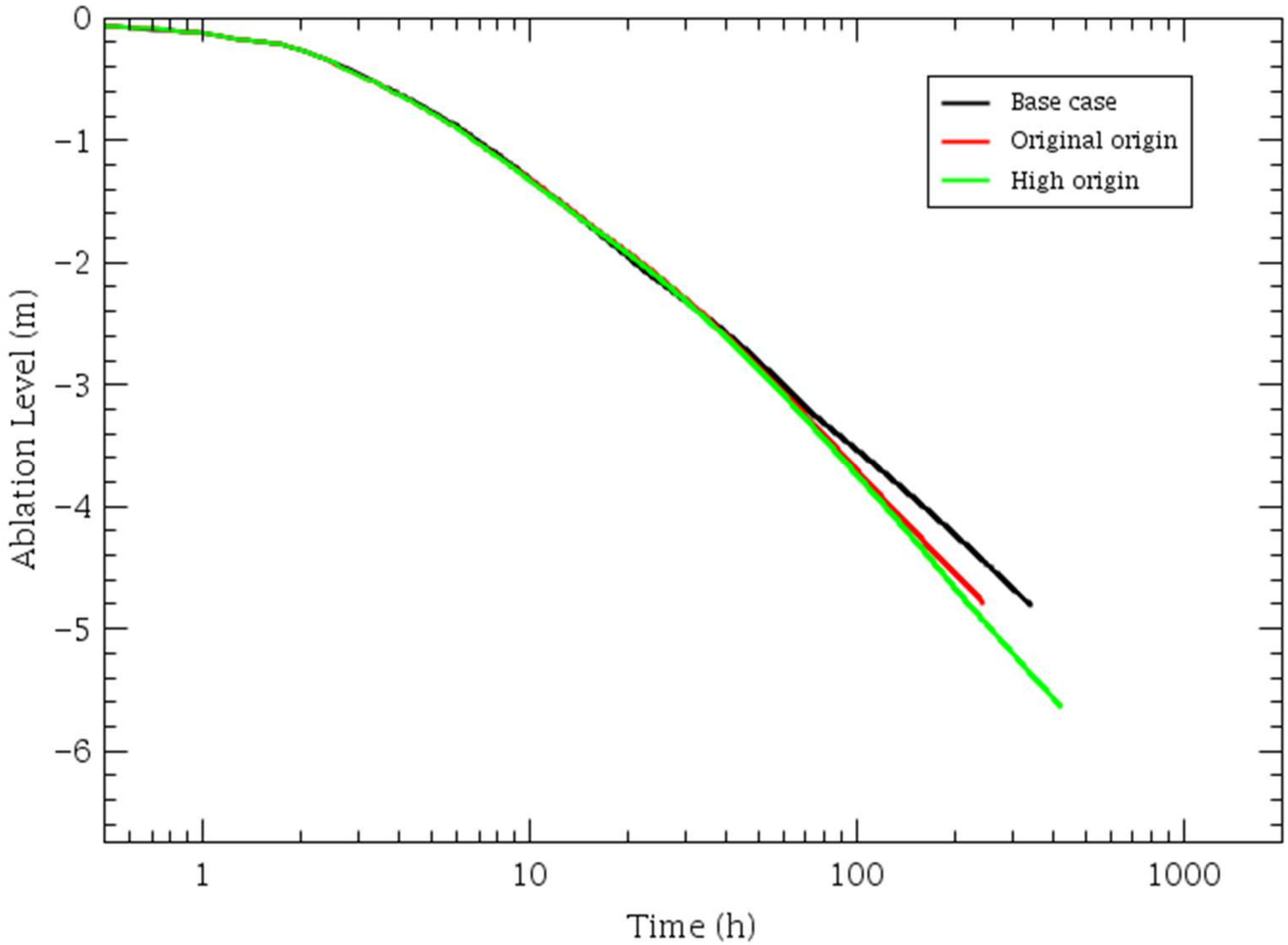
MELCOR manual:	Origin of rays should be in the centre of the cavity
PSI rule:	Origin of rays should be at the expected melt surface

Cavity size



0
−1
−2
−3
−4
−5
−6
Ablation Level (m)
1
10
100
1000
Time (h)
Base case
Small cavity
Large cavity

Influence of origin



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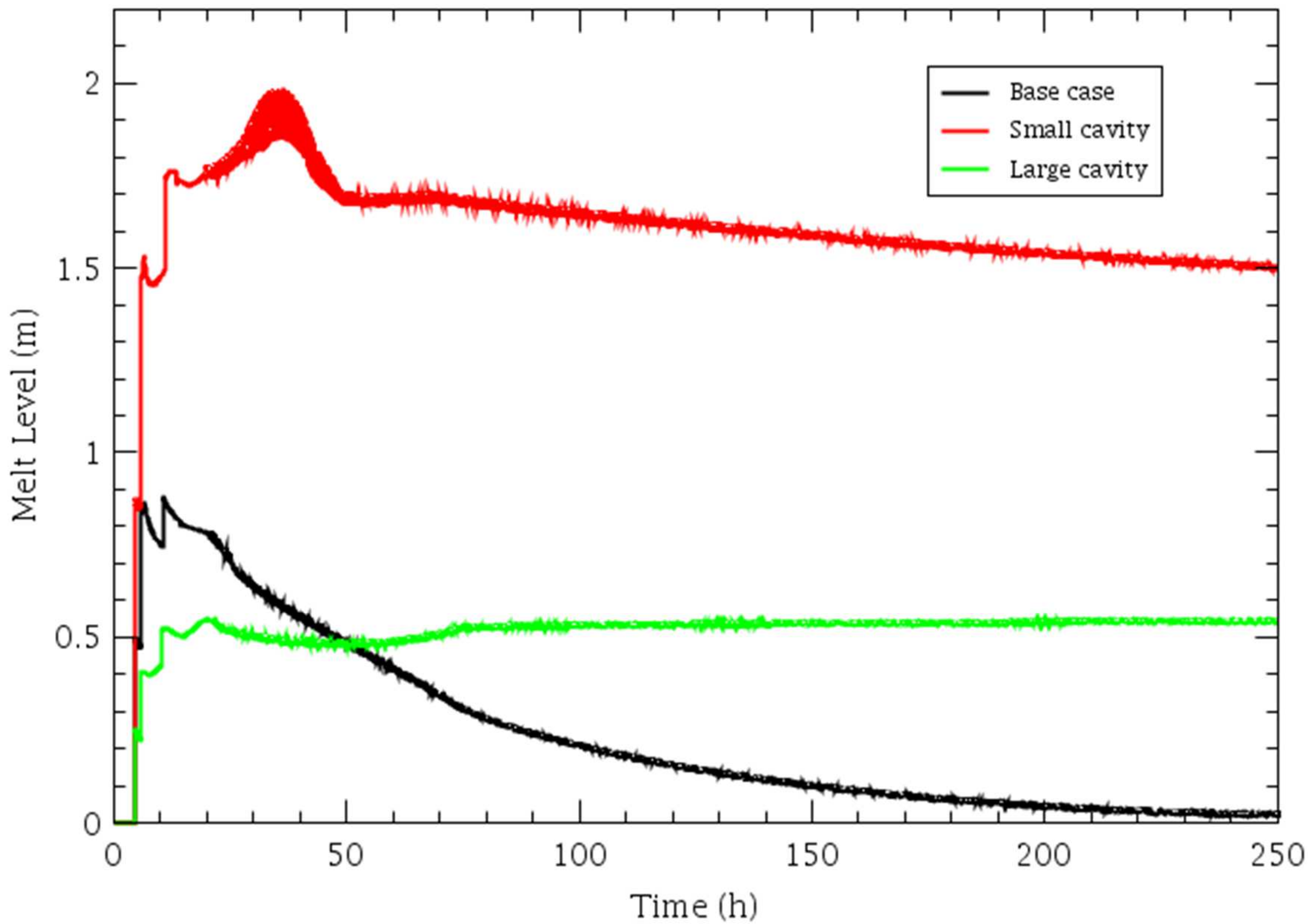
Cavity size



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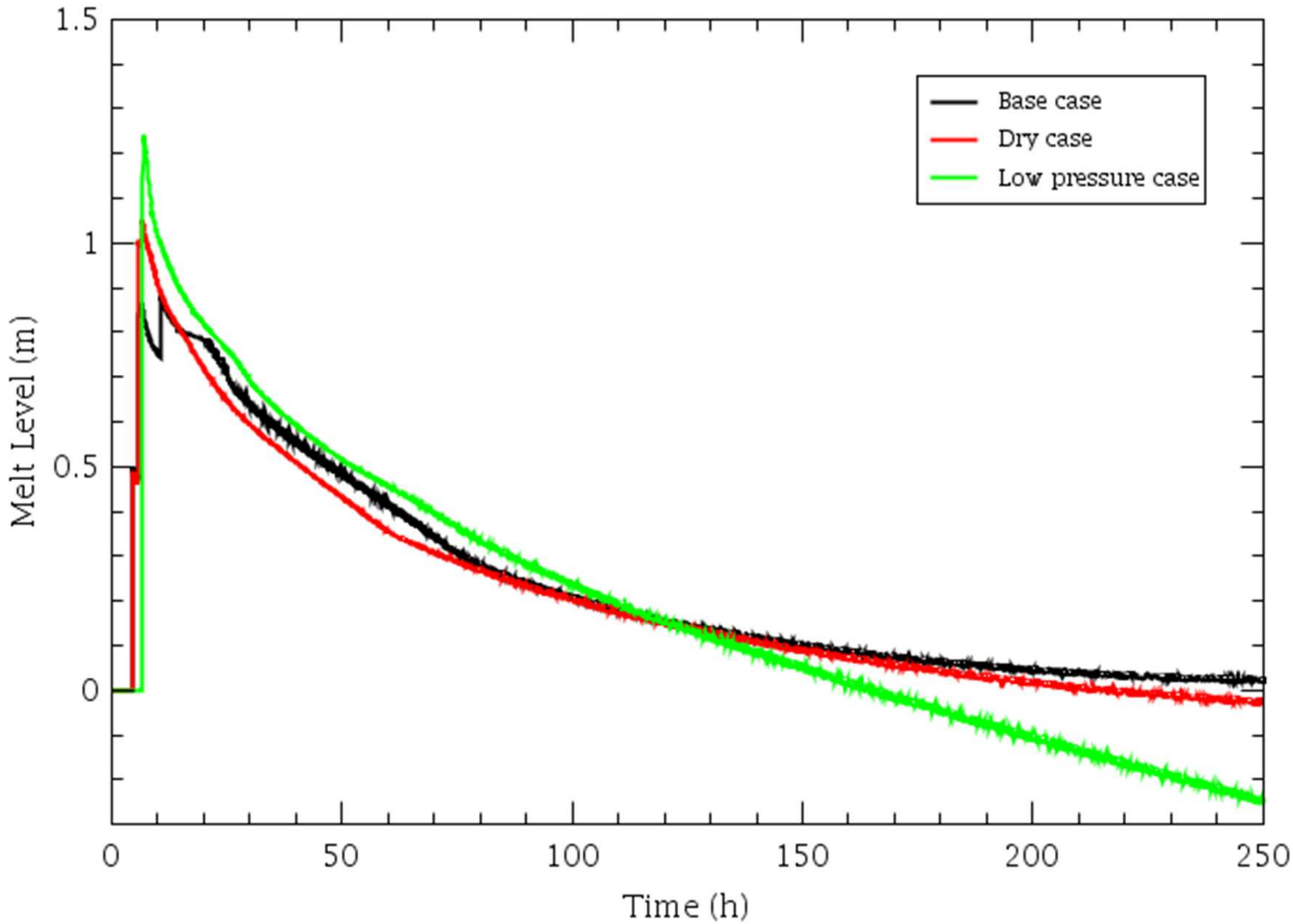
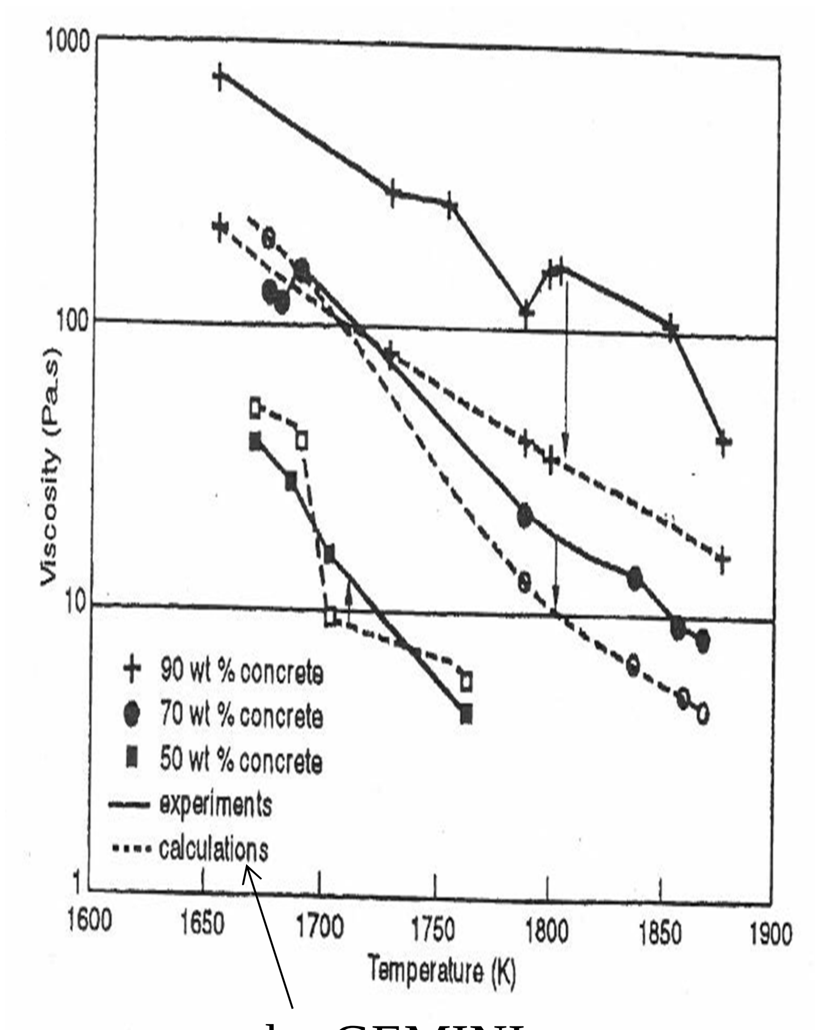
Sensitivity with different sequence progression



Why to use the simpler model

- The melt level does not support melt spreading to cavities outside the biological shield
- The increase in viscosity with increasing take up of concrete into the melt mixture would not allow significant spreading after the ventilation channels are reached (after melt-through of ~50cm of concrete above the channels), certainly not significant spreading upwards
- The estimate of the overall energy and mass balances from MCCI likely much more reasonable with the simpler model
- Chosen approach conservative anyway, that is, with respect to axial (downward) melt-through

Example of corium-concrete mixture viscosities



by GEMINI
(for SIL concrete)

- **viscosities calculated by codes -also CORCON and CORQUENCH- usually lower than experimental**
- **difficult to estimate VOLUMETRIC SOLID FRACTION in the melt which has crucial impact on viscosity (typically for fractions >40%)**
- **for reliable estimates specialized chemical equilibria calculations needed, for multiphase, multicomponent system in question -example of a tool which can be used for such calculations is French code GEMINI**