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MELCOR Activities at KTH

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Outline

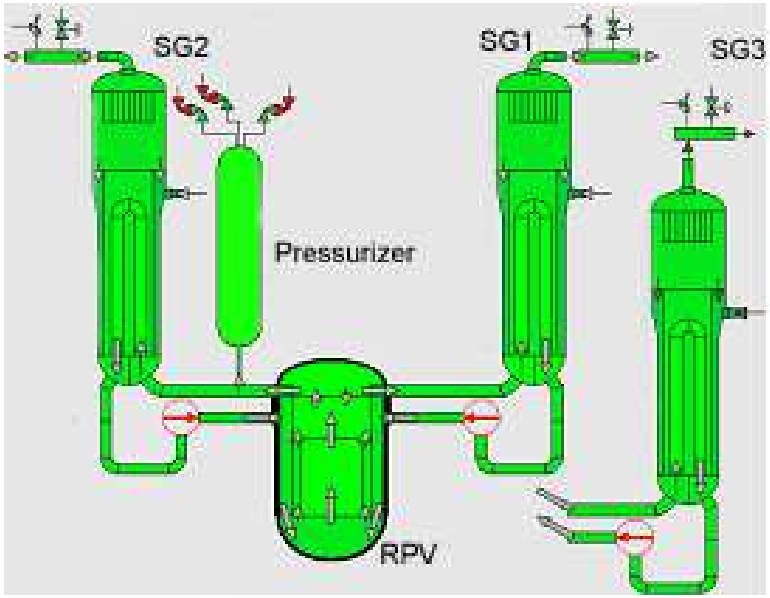
- Background
- Applications of MELCOR
  - Power uprate
  - DBC safety analysis
  - Efficiency of CRGT cooling – *see ISAMM-2009*
  - Corium progress and ejection (supporting in-vessel and ex-vessel coolability study)
- Bug report
- Outlook

Background

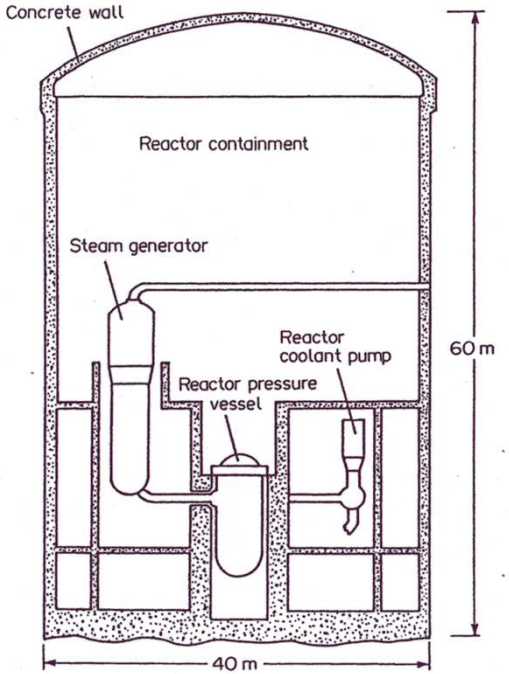
- MELCOR is the reference code for severe accident analysis selected by Swedish Nuclear Authority (SSM).
- As a part of technical support to SSM, KTH started MECLOR work for severe accident risk assessment in 2006.
- So far KTH is the only active user of the MELCOR code in Sweden.
- The current focus of the MELCOR activities at KTH is to perform safety analysis related to the power uprate of Swedish NPPs, including both PWRs and BWRs.
- The code was also used for other purposes, including analysis of design-base incident, quantification of in-vessel melt conditions and assessment of SAM measures (e.g., CRGT cooling).

Application - 1

- ***MELCOR analysis for SA scenarios of Ringhals-3 PWR***
  - Ringhals-3 is a three-loop Westinghouse pressurized water reactor (PWR) with the original capacity of 2775 MWth.
  - The reactor is currently under the power-uprating application for 3152 MWth operation, with 13.5% power elevation.



Primary system and steam generators



Containment (~52000m^3)

Application - 1

- ***MELCOR analysis for SA scenarios of Ringhals-3 PWR***

  - The objective is to perform severe accident analysis using MELCOR code for ***the same scenarios as*** in MAPP4 calculation.
  - For the purpose of comparison, the MELCOR modeling (e.g. nodalization, initiating events, engineering safety features) was set as close to the MAAP4 input as possible.
  - The severe accident scenarios were calculated for the new capacity of 3152 MWth as well as the original capacity of 2775 MWth.
  - For sensitivity study, scenarios with penetration failure and vessel failure were considered, respectively.
  - Default values were accepted for most parameters in MELCOR input.
  - MELCOR 1.8.5 was employed.

Application - 1

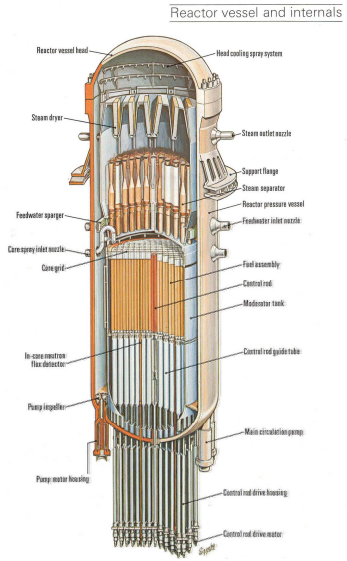
- ***MELCOR analysis for SA scenarios of Ringhals-3 PWR***

Results

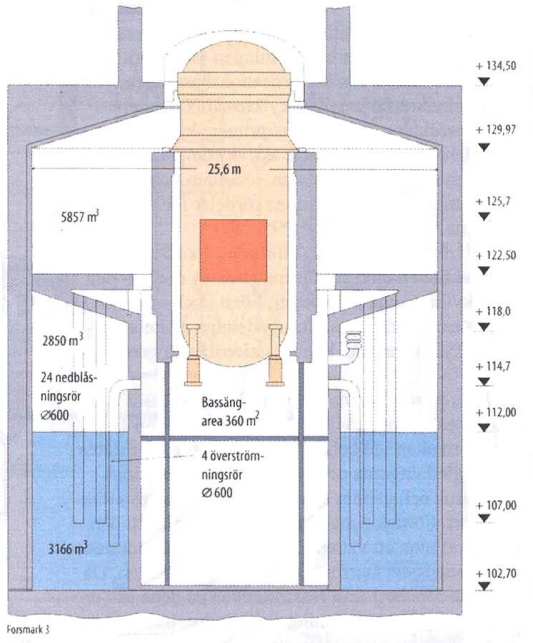
- The time of penetration failure is around 1 hour earlier in MELCOR calculation than in MAAP4 calculation (more clarification needed for modelling of penetration or vessel failure).
- For SBO scenario, the H2 production is around 40% higher in MAAP4 calculation than in MELCOR calculation, while for SBO+LOCA scenario it is 50% higher in MELCOR calculation than in MAAP4 calculation.
- The fission product release is similar in the MELCOR and MAAP4 calculation.

Application - 2

- ***MELCOR analysis for SA scenarios of Oskarshamn-3 BWR***
  - Oskarshamn-3 is a boiling water reactor (BWR) supplied by the Swedish firm ASEA-ATOM (nowadays Westinghouse Atom AB), with the original capacity of 3020 MWth. Later it was uprated to 3300 MWth (the present operation).
  - The reactor is currently under the power-uprating application for 3900 MWth operation, with 29% power elevation.



Reactor



Containment (~9000m^3)

Application - 2

➢ ***MELCOR analysis for SA scenarios of Oskarshamn-3 BWR***

- The severe accident scenarios were calculated for the new capacity of 3900 MWth as well as the original capacity of 3300 MWth.
- Default values were accepted for most parameters in MELCOR input.
- MELCOR 1.8.5 was employed.

Application - 2

- ***MELCOR analysis for SA scenarios of Oskarshamn-3 BWR***

Results

- For SBO scenario, the vessel failure time after power uprate (3900 MWth) is calculated by MELCOR to be earlier than that of the current operation (3300 MWth) - 3.2 hrs *vs*. 4.2 hrs.
- For SBO scenario, the H2 production is around 455 kg.
- There is no dramatic change in total fission product release from 3300 MWth to 3900 MWth operations.

Application - 3

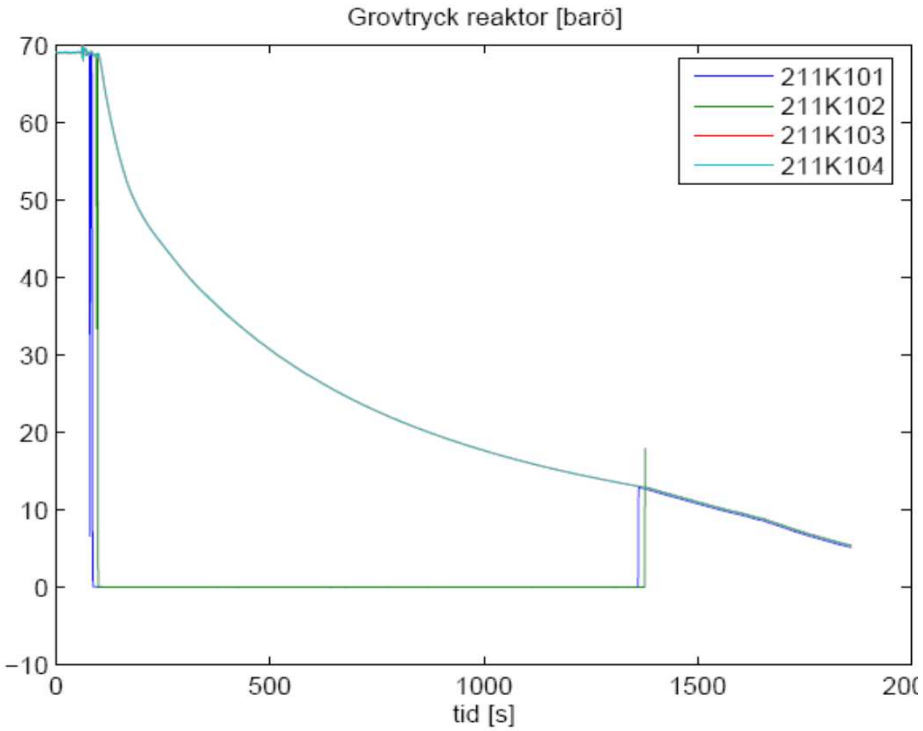
- ***MELCOR calculation for the SBO event of Forsmark-1 BWR***
  - Forsmark 1 is a boiling water reactor with the capacity of 2928 MWth (1016 MWe net power). The safety systems in Forsmark 1 are fourfold redundant, with four subdivisions (subs A, B, C and D) physically separated and encompassing electronic, electrical and mechanical equipment.
  - On the 25th of July 2006 at around 13:15, Forsmark-1 experienced a Station Blackout (SBO) event, initiated by a short circuit in the offsite 400 kV switchyard. Due to voltage and frequency fluctuations that followed, together with additional component failures, 2 of its 4 auxiliary diesel generators did not start, and consequently half of its four subs were out of action, i.e. subs C&D were functioning while subs A&B failed. The loss of power in subs A&B resulted in reactor shutdown and safety systems intervention in an abnormal way. After 23 minutes the operators managed to start the two failed diesel generators manually, and after 35 minutes the subs were reset and the reactor was back to normal shutdown conditions.
  - MELCOR 1.8.5 was used to calculate the event.

Application - 3

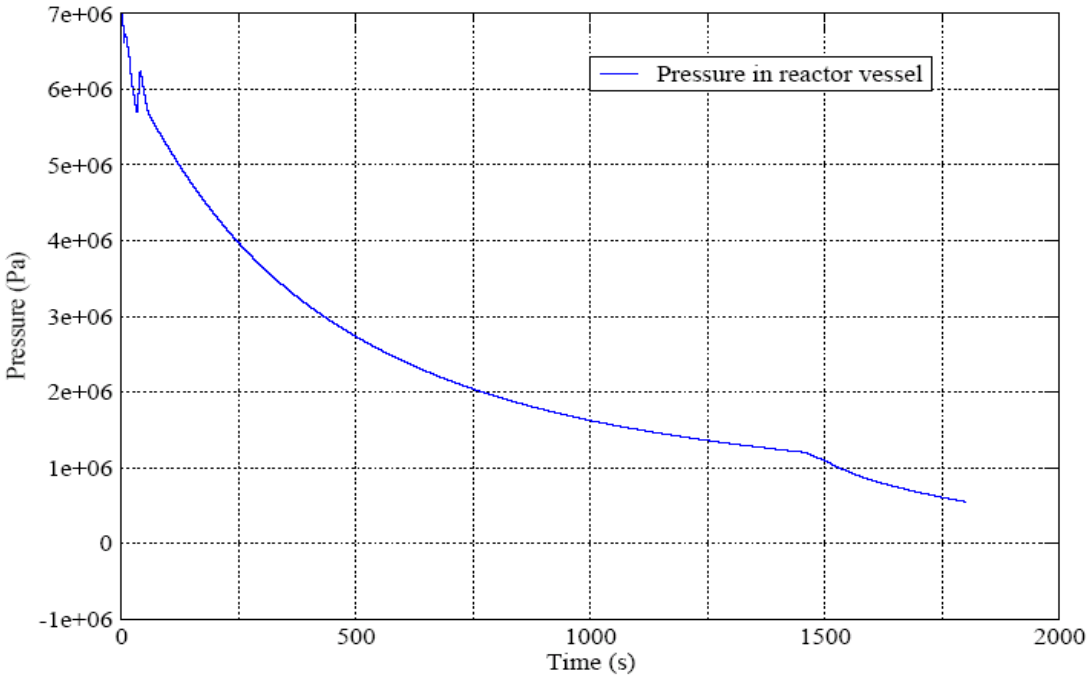
- ***The objectives of the calculation are to***
  - Evaluate MELCOR capability to analyze such an event, i.e. is the code able to reproduce the transient?
  - Understand the reactor and safety systems response during the event, i.e. how did the parameters (e.g. water level, pressure) behave like that?
  - Examine the safety margin during the event, i.e. to answer questions “if the reactor is still safe with the 2 subs in place”, “what is the consequence if all subs unavailable”, and so forth.

Application - 3

- ***Forsmark-1 2006 event – The pressure***



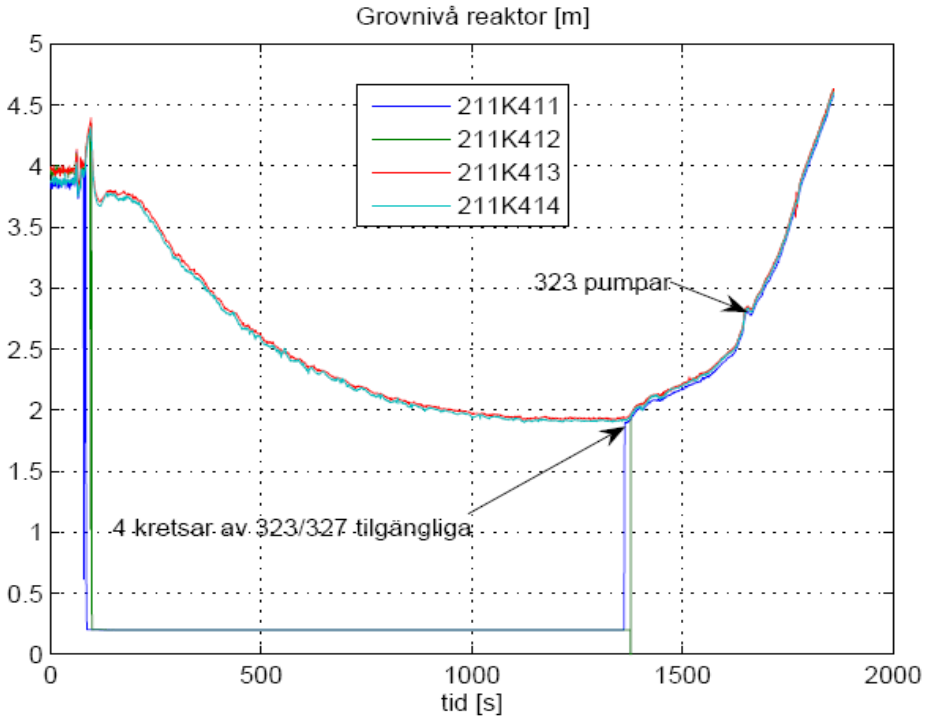
Plant recording data



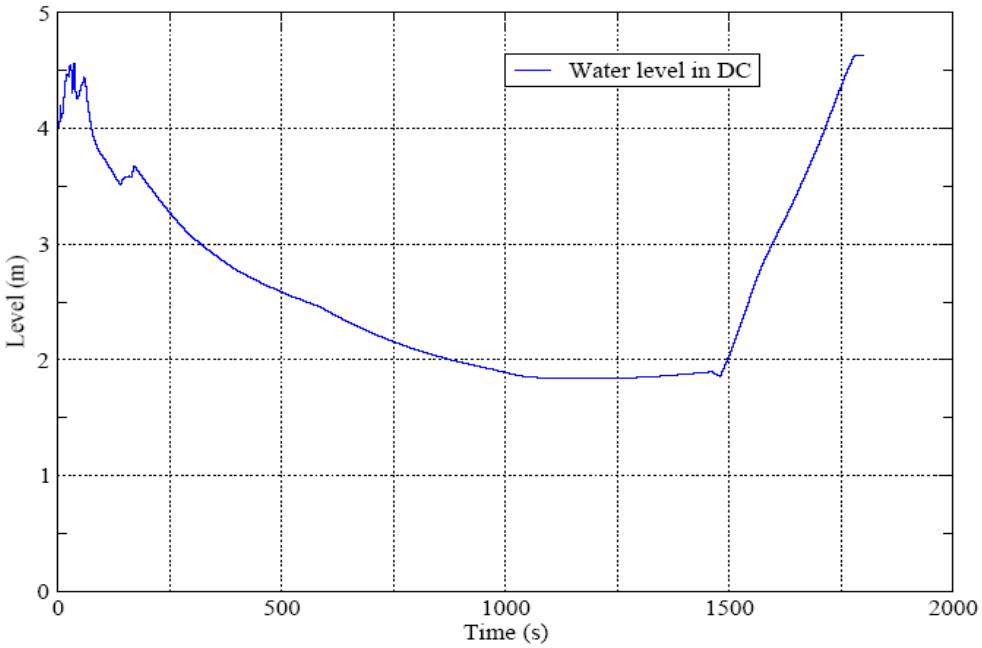
MELCOR calculation

Application - 3

- ***Forsmark-1 2006 event – The water level***



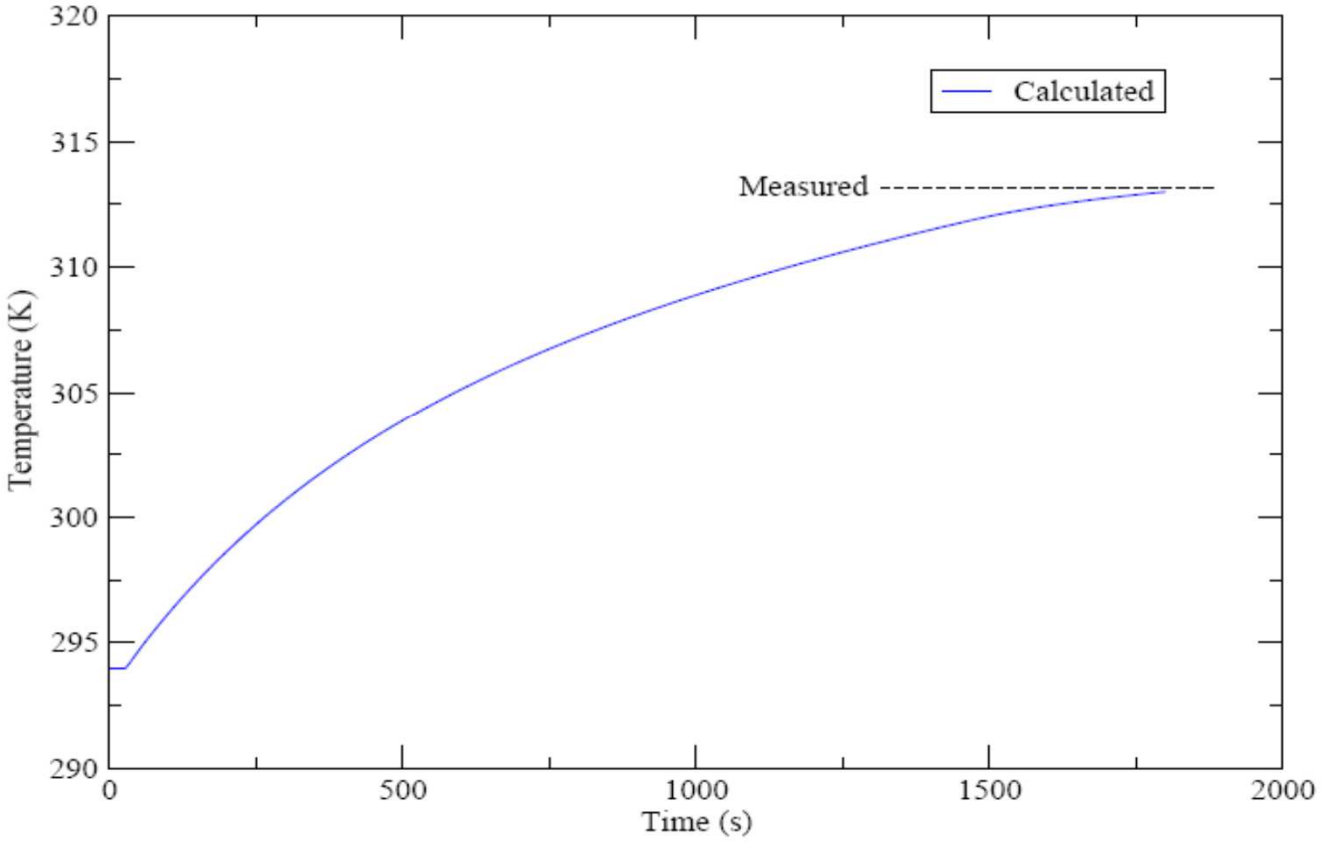
Plant recording data



MELCOR calculation

Application - 3

- ***Forsmark-1 2006 event – The temperature in condensation pool***



Measured temperature of the condensation pool is 40 °C (313.25 °K) at 25 minutes

Application - 3

- ***MELCOR calculation for the 2006 event of Forsmark-1 BWR***

Conclusions

- The reactor system behavior (thermal-hydraulics) during the 2006 event of Forsmark-1 can be well calculated (reproduced) by MELCOR 1.8.5.
- The results of the MELCOR calculation also have a good agreement with the prediction of RELAP5.
- In the event, the reactor core remains well covered, even if the operator failed to recover subs A & B at 23 minutes.

Bug report - 1

- ***MELCOR 1.8.5***

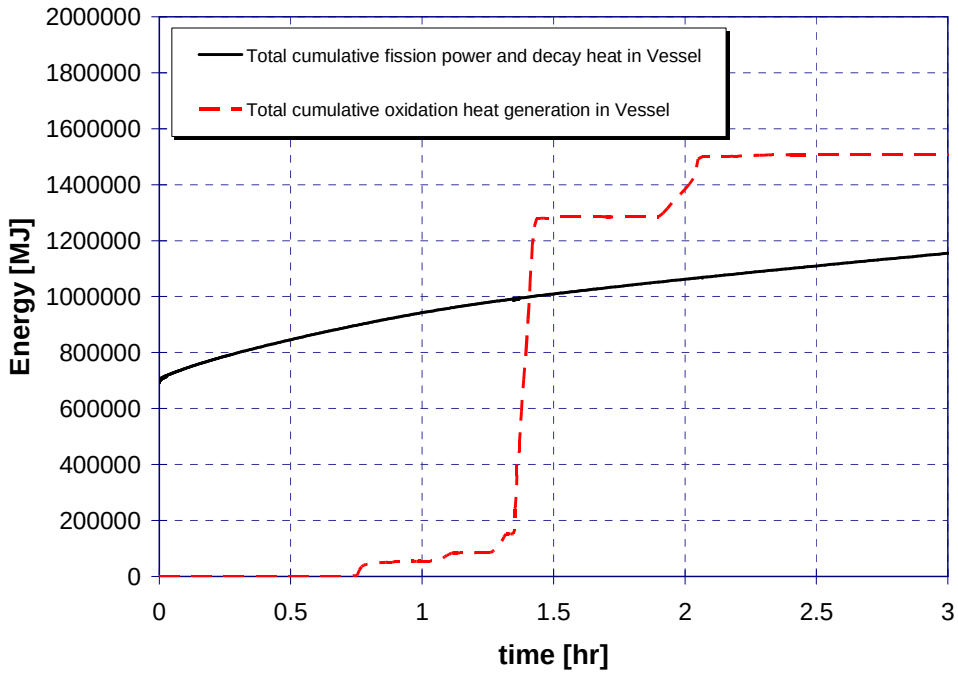
Plotting parameter: COR-EMWR-TOT

Total cumulative oxidation heat generated in the core (COR-EMWR-TOT) is ~1500 GJ (as shown right),

*which is much higher than that when all Zr (52680 kg) was oxidized (52680kg * 6500 kJ = 342 GJ).*

Actually, only a small portion of Zr was oxidized, if I check the melt compositions.

Why? Is the plot variable COR-EMWR-TOT correct?



Bug report - 2

- ***MELCOR 1.8.5***

Control parameter: COR-MLTFR.n.m.k

This parameter means "Melt fraction of material number m in component number k in cell n" from the definition of CORUserGuide, but I cannot use it as argument in CF.

Why?

Is this a usable parameter?

Bug report - 3

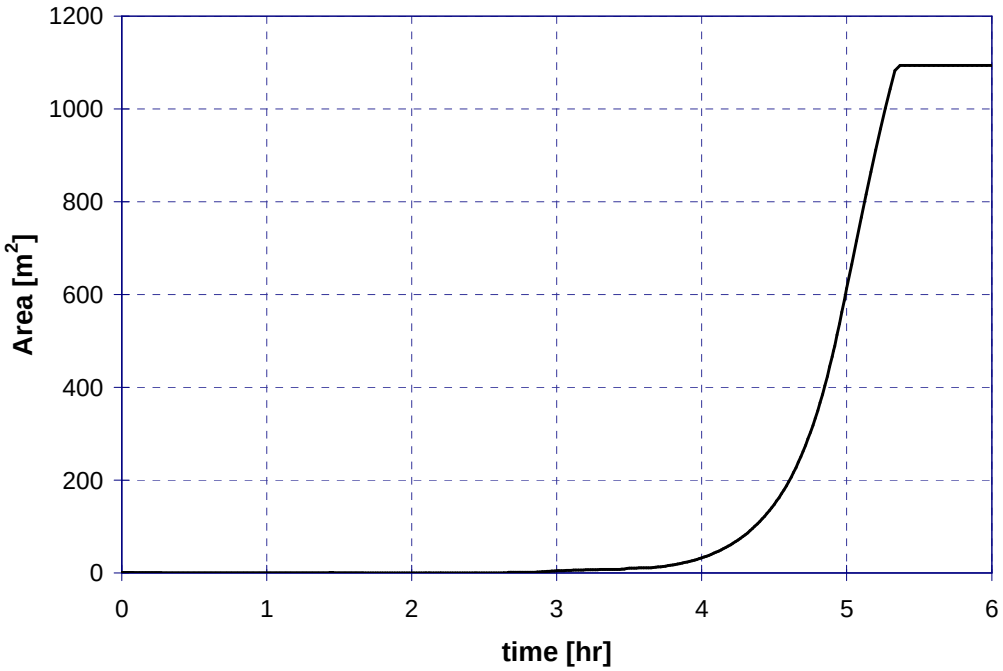
- ***MELCOR 1.8.5***

Control parameter: COR-ABRCH

This parameter means "Total flow area of vessel breach" from the definition of CORUserGuide.

The cross-section area of the vessel is not more than 30 m^2.

The ablation is not physical after 30 m^2 !!!



Outlook

- Update of the input decks of Ringhals-3 and Oskarshamn-3 plants to MELCOR 1.8.6.
- MELCOR 1.8.6 SA analysis for Ringhals-3 and Oskarshamn-3 plants related to their power uprate (comparison with MELCOR 1.8.5 results).
- Development of a new input deck for the Oskarshamn-2 BWR.
- Benchmark exercise of MELCOR simulation for MCCI (*related to SARNET-2 task*).