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Severe Accident Analyses for Shutdown Modes and Spent Fuel Pools to Support PSA Level 2 Activities

Content

- Introduction
- Shutdown Mode Analyses
- Spent Fuel Pool Analyses
- Conclusions

Introduction

- On the field of Level 2 PSA, two projects are being performed to study the plant behavior during shutdown modes and inside spent fuel pools of PWR and BWR under severe accident conditions.
- Severe accident analyses are a main part in order to support the probabilistic parts of these projects.
- Deterministic analyses of severe accident sequences during shutdown modes and external hazards are financially supported by German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Office for Radiation Protection (BfS).
- Severe accident analyses of spent fuel pools of generic PWR and BWR are being performed on behalf of German Federal Ministry of Economics and Technology (BMWt).
- First results of selected MELCOR analyses done for the two projects mentioned above are presented.

Shutdown Mode Analyses

- BMU/BfS financially supports a project regarding analyses of severe accident sequences during shutdown modes and in consequence of external hazards for both PWR and BWR.
- Little experience with severe accident analyses for these events, because up to now no consideration in PSA Level 2 studies is demanded.
- Gain of related knowledge regarding the progression of severe accidents in shutdown modes and in consequence of external hazards events.
- These results can be used for supporting future Level 2 PSA studies.
- First preliminary MELCOR results for a selected scenario of a generic PWR will be presented.

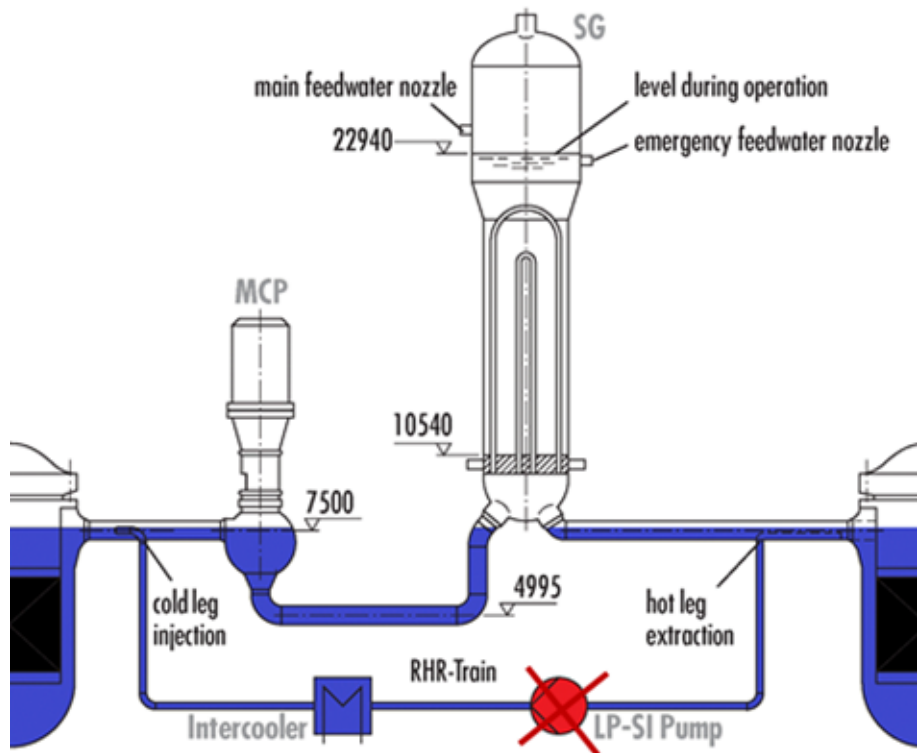
Shutdown Mode Analyses

- 11 relevant scenarios has been identified for the shutdown modes of a PWR and 5 representatives will be calculated. Preliminary results of a selected scenario for PWR:

Failure of Decay Heat Removal, mid-loop operation, RPV open	
Initial event:	Failure of 3 RHR pumps by CCF and 1 RHR pump due to maintenance; additional failure of one emergency RHR pump
Water level in primary circuit:	Mid-loop
State of RPV lid:	removed
Time after shutdown (begin of operational mode):	40 hours
Decay heat (beginning of scenario):	17.75 MW
Miscellaneous actions:	Accumulator injection (6 of 8) at the beginning of the scenario

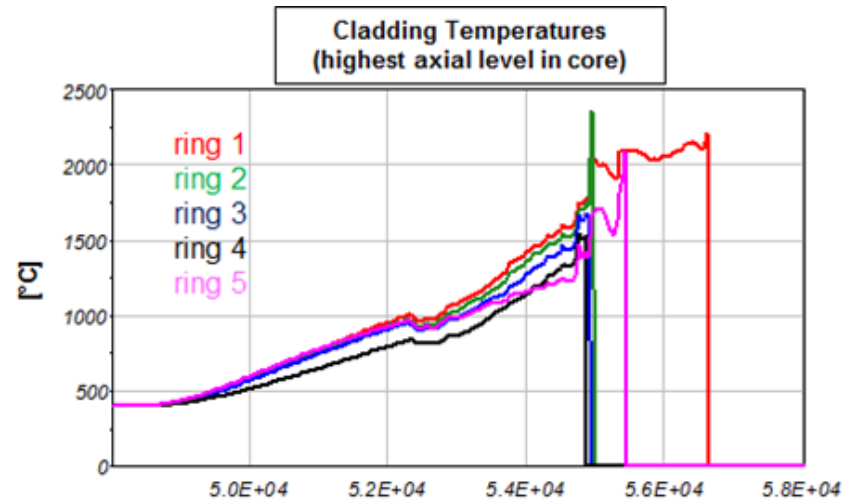
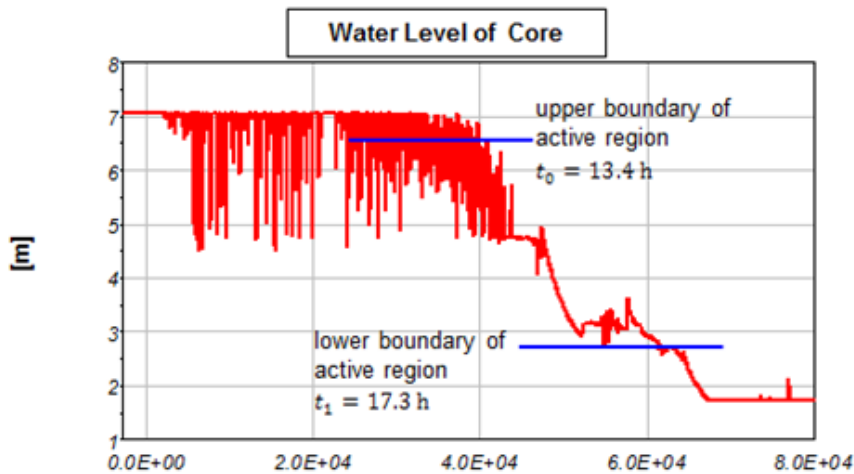
Shutdown Mode Analyses

Failure of RHR, “Mid-loop” Operation, RPV Open

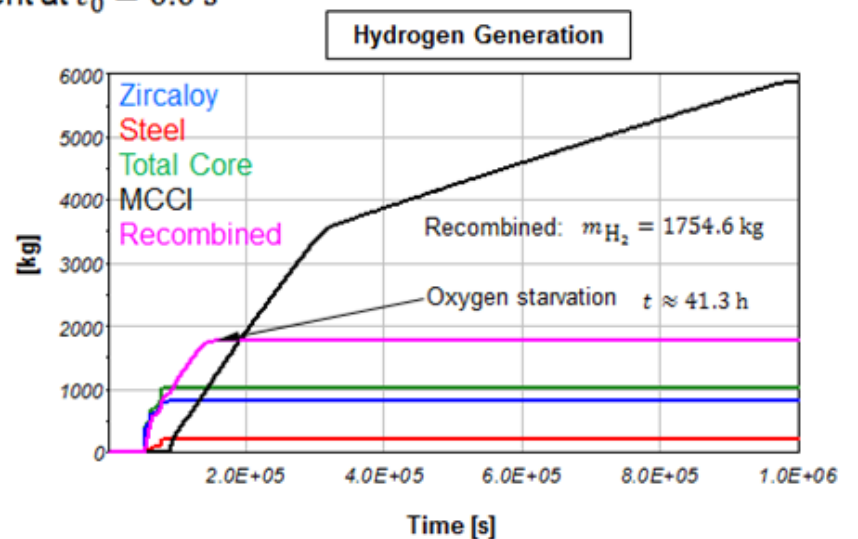
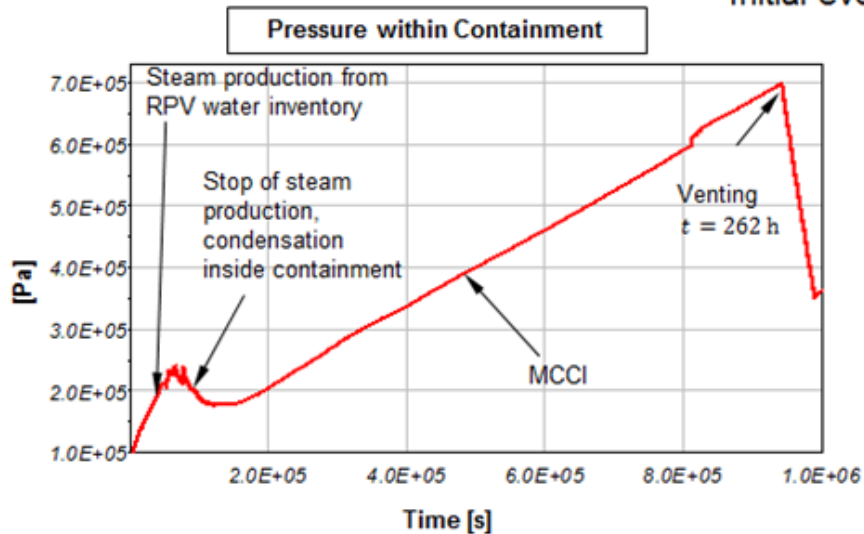


Event	Time
Shutdown	-40:00 h
Accu injection (assumption)	00:00 h
Begin of core uncover ($L_{RPV} \leq 6,63$ m)	13:23 h
Gap release	14:31 h
Exposure of core ($L_{RPV} \leq 2,73$ m)	17:14 h
Failure of lower core grid	21:25 h
Dry out of lower plenum	22:00 h
Melt ejection into cavity	25:01 h
Begin of venting ($p_{initiation} = 7.0$ bar)	262:01 h
end of venting ($p_{end} = 3.5$ bar)	275:21 h

Shutdown Mode Analyses



Initial event at $t_0 = 0.0$ s



Spent Fuel Pool Analyses

- Research project financially supported by the BMWi regarding the extension of probabilistic analyses for spent fuel pools (SFP).
- Supporting deterministic analyses of the accident progression inside the SFP are being performed inside the project.
- The accident progression is being analyzed for both PWR and BWR pools by using the integral code MELCOR.
- Development of a basic approach for consideration of SFP within Level 2 PSA, the quantification of event trees, and the identification of possible mitigative accident measures.
- First preliminary MELCOR results for a SBO scenario inside a spent fuel pool of a generic PWR will be presented.

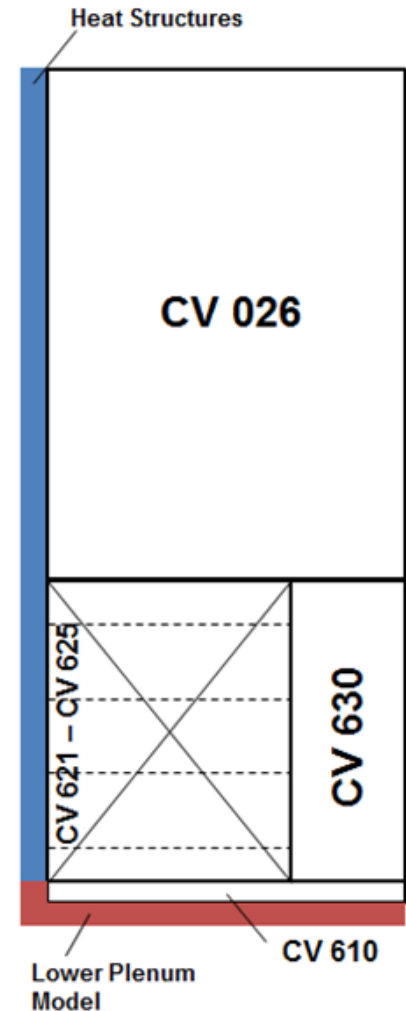
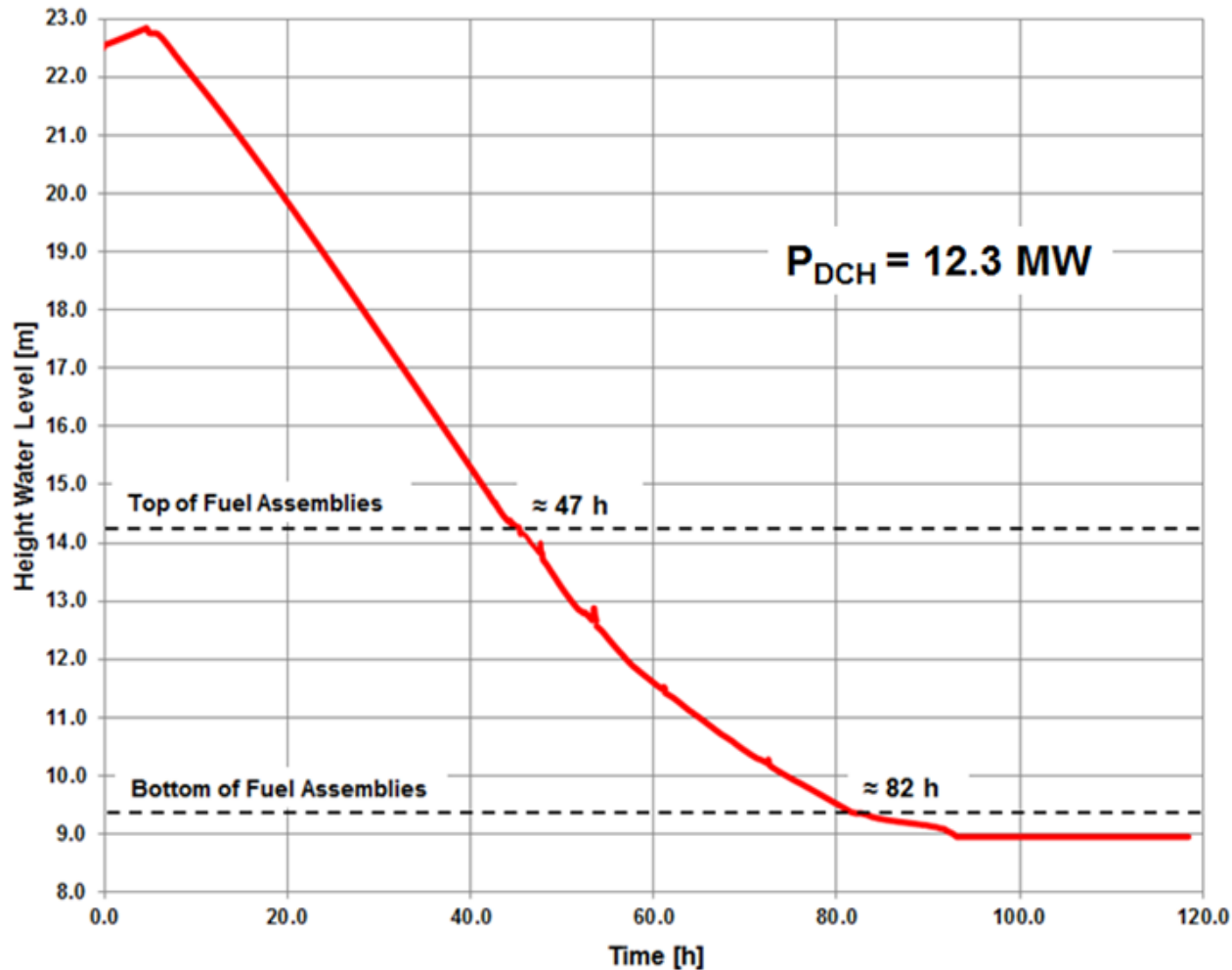
Spent Fuel Pool Analyses

- Preliminary results of a MELCOR 1.8.6 analysis of a “Station Black-out” event are shown for PWR.
- Characteristics of the modeling:
 - typical dimensions of a PWR spent fuel pool ($A = 98.2 \text{ m}^2$, height water column = 13.55 m),
 - water volume ($\approx 1400 \text{ m}^3$) is being depicted by eight control volumes,
 - one core inside the pool ($\approx 12.3 \text{ MW}$), pool separated from flooding compartment, and containment closed,
 - inventory of radionuclides like power operation mode, time offset for decay heat of 124 h,
 - temperature criterion for the failure of the steel liner at the bottom of the pool, cavity model is switched on with the failure of the liner.

Used data doesn't completely match the real plant conditions!

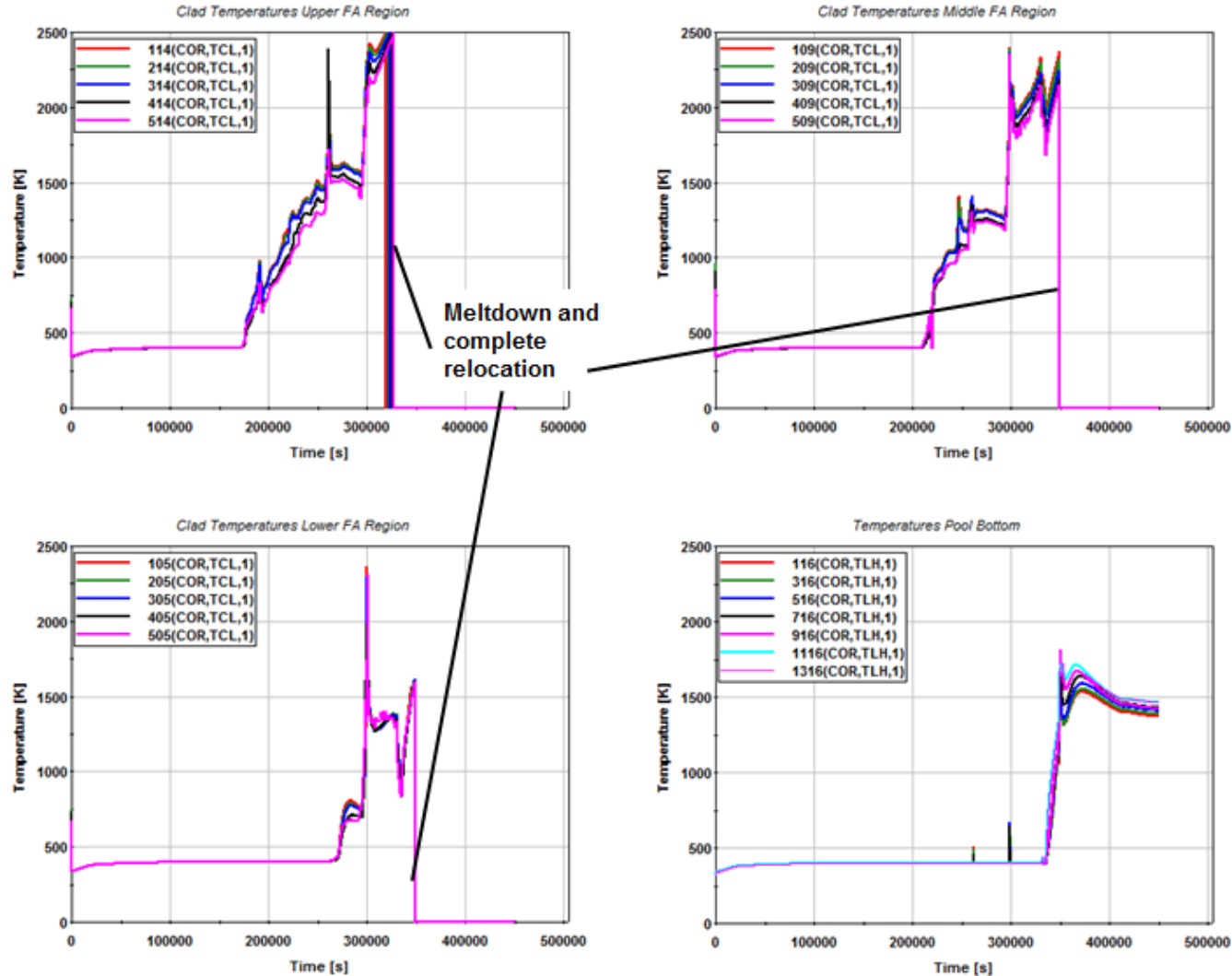
Spent Fuel Pool Analyses

- Calculated Water Level inside SFP for PWR



Spent Fuel Pool Analyses

- Calculated Temperatures inside SFP of PWR

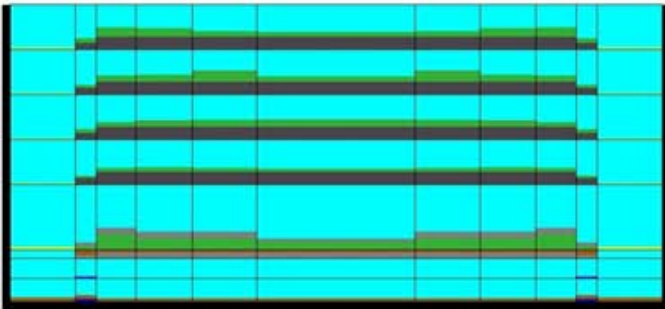


Spent Fuel Pool Analyses

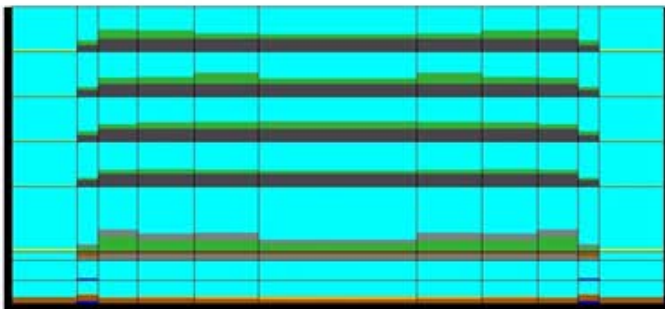
- Calculated mass distribution inside the lower meshes of the SFP of PWR



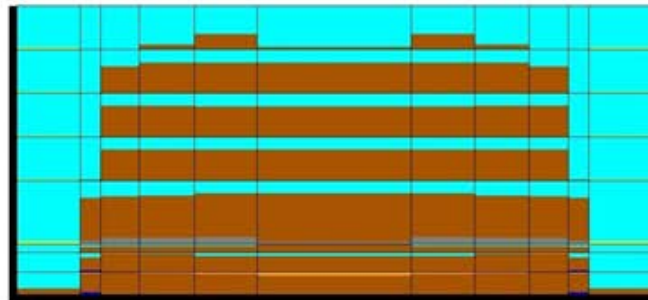
t = 330.000 s = 91,7 h



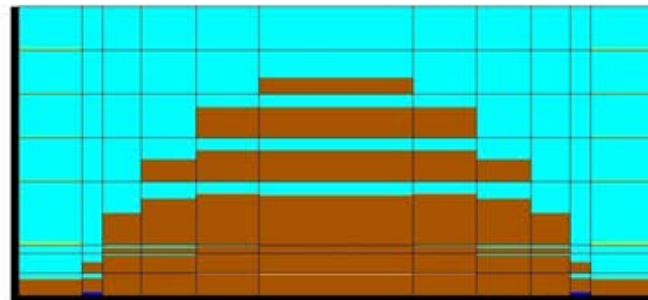
t = 348.008 s = 96,7 h



t = 348.012 s = 96,7 h



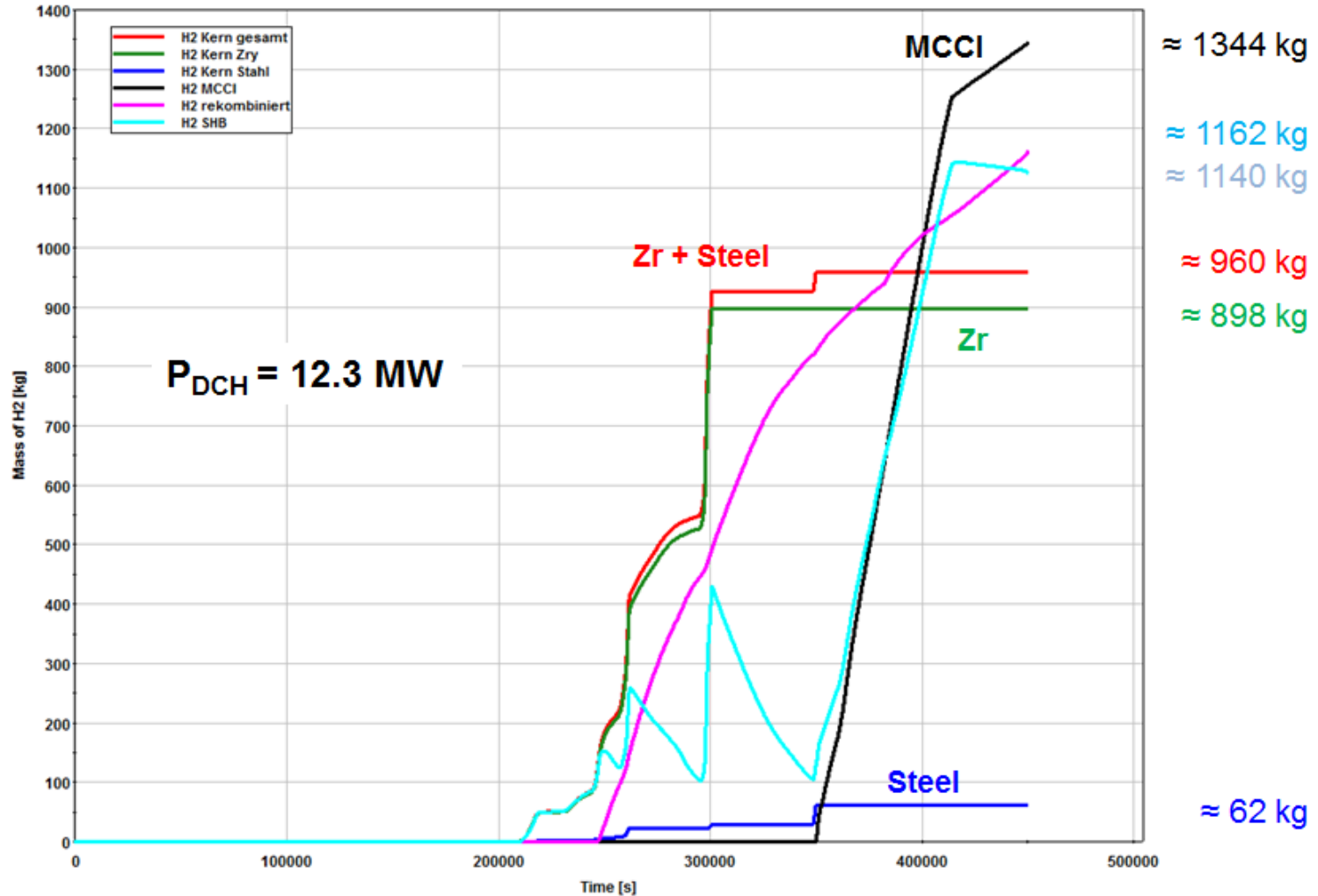
t = 349.507 s = 97,1 h



- First relocation to pool bottom at 83 h,
- Failure of steel liner at 97.1 h \Rightarrow Start of transfer into cavity
- End of transfer into cavity at 97.9 h (about 192 tons)

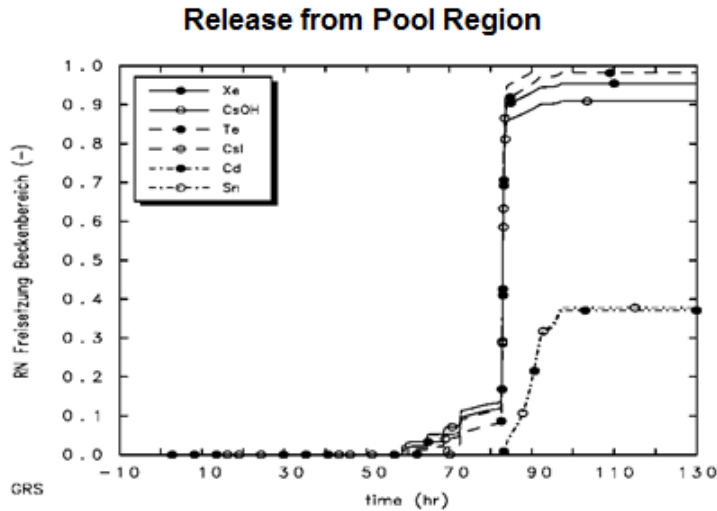
Spent Fuel Pool Analyses

- Calculated hydrogen masses generated and recombined PWR

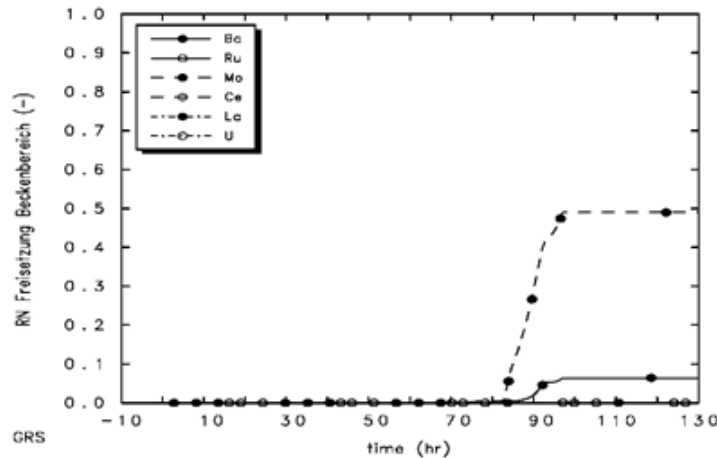
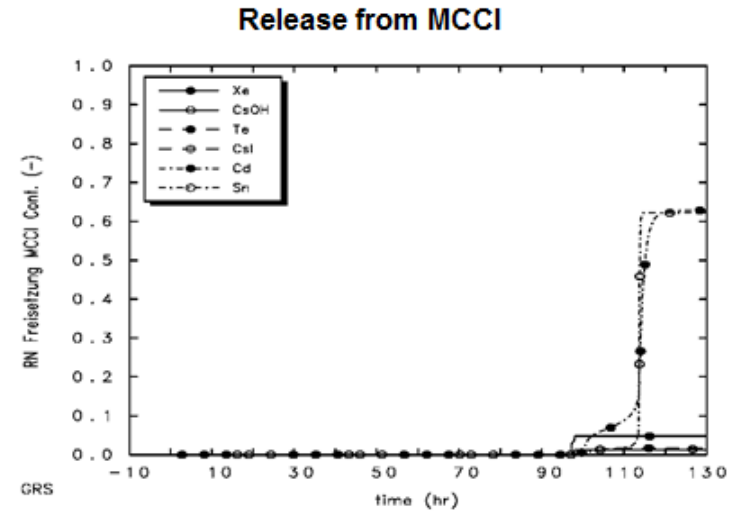


Spent Fuel Pool Analyses

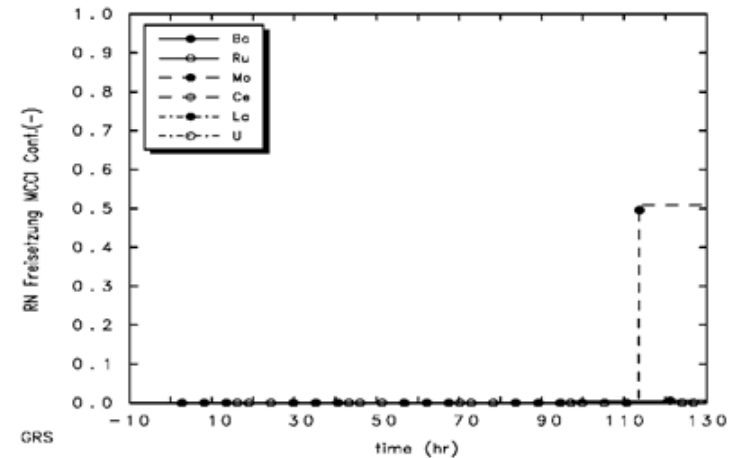
- Calculated release of radionuclides from SFP region and due to MCCI



volatile



non-volatile



Conclusions

- Deterministic integral analyses of the severe accident progression during shutdown modes of a PWR and inside spent fuel pools are being performed in the frame of two projects at GRS.
- First preliminary results of MELCOR calculations of a severe accident sequence during shutdown phase of a PWR and inside a spent fuel pool have been shown.
- It could be shown that the integral code MELCOR is able to calculate the accident progression for both cases.
- From a point of engineering judgment the results seem to be reasonable.
- Both projects are still going on, several adjustments of the input decks will be performed and therefore some improvements of the calculational results can be expected.