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MELCOR SBO analyses for a 2-loop PWR : ISGTR with FP mitigation by SG secondary re-fill

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EMUG, KTH Stockholm, May 2013

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outline

- long-term SBO project and ISGTR
- mitigation with SG secondary re-fill for ISGTR
- FP releases to environment
- first results with ARTIST data applied

  compared with MELCOR SPARC predictions
- summary

SwissNuclear project

- **long-term SBO for generic PWR** with MELCOR 1.8.6

foccusing on RCS and in-vessel behavior **with and without mitigative AM,**
simulated AM measures based mostly on discussions with the SwissNuclear

- **SG refill** was indentified **as the desirable AM,** at different stages
- **parametric approach** adopted: no thermally-induced RCS failures for the base-line SBO and corresponding mitigated scenarios, rapid manual depressurization and **rapid re-fill of one of the SGs** with FIW
- **next step was** to assess parametrically the counterpart sequences: **thermally-induced SGTR (ISGTR)** **and HL/SL failure,** with (and without) **the same mitigative measures**

relatively detailed MELCOR model

in particular, detailed model for the natural circulation counter-current flow in HL and SG

- more than 100 CVs and more than 150 FLs in the plant input deck
- core noding: 10 axial levels x 4 radial rings (17 CVs for RPV, 9 of them in core)

also, simple containment model together with a multi-cavity model for MCCI calculations is in the input

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ISGTR and FP retention simulations

- **for ISGTR: the main emphasis on FP retention in ”early” phase**
- **our aim was to have the SG re-fill at least in 2 different times, looking at the impact of the time shift**
- **where applicable, we wanted to use the experimental data on aerosol pool scrubbing in SG secondary based on ARTIST**

thermally-induced SG tube rupture calculated in MELCOR using **counter-current natural circulation model**

-- based on Westinghouse 1/7th scale SG experiments and on full-scale CFD

- HL/SL failure mode simulated as well in our analyses
- timings of the 2 failure modes close to each other, sometimes rather sensitive even to small changes in the input and, first of all, to model assumptions

SBO counter-current natural circulation and ISGTR

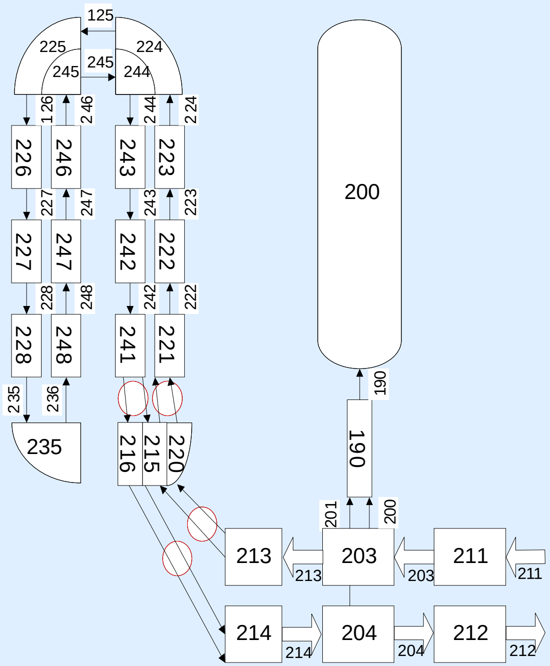
- **detailed MELCOR model**
  for HL counter-current flow natural circulation
  (with CL loop seal plugged)
  - heat transfer to HL, surge line and SG tubes
  - mixing of hot and cold gas in SG inlet plenum
  - recirculation through SG U-tubes
- **pairs of FLs to simulate counter-current flow**
  and SG inlet plenum mixing
- **constant mixing parameters assumed** in MELCOR model (input), **also after tube breach**

- Larson-Miller for thermally-induced single tube rupture, just above the tube sheet, with pre-existing flaws assumed (a stress multiplier in the modeled time-fraction damage integral),

calculated SG tube failure (with SRV1 stuck-open):
~6hr into the accident

assumptions (required input):

- recirculation ratio
- Hot-to-Cold tube split



re-fill of SG1 secondary with fire water at ISGTR

parametric approach: timings of SG refill based on preliminary simulations

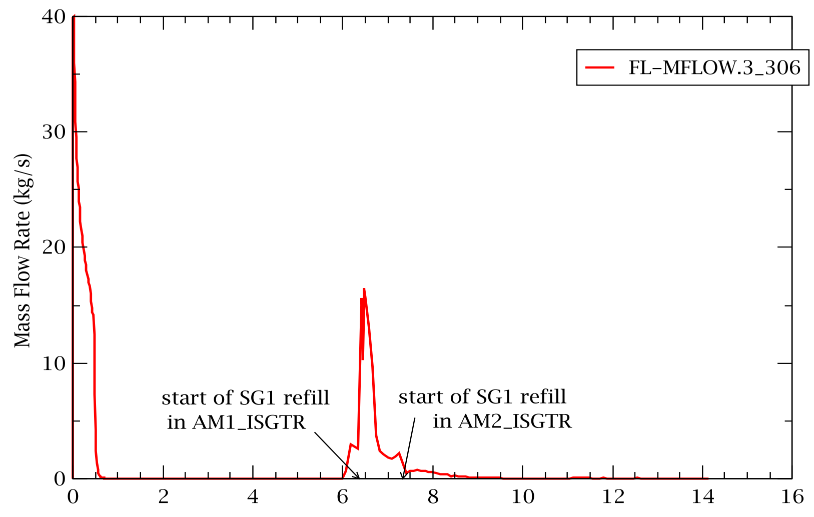
with

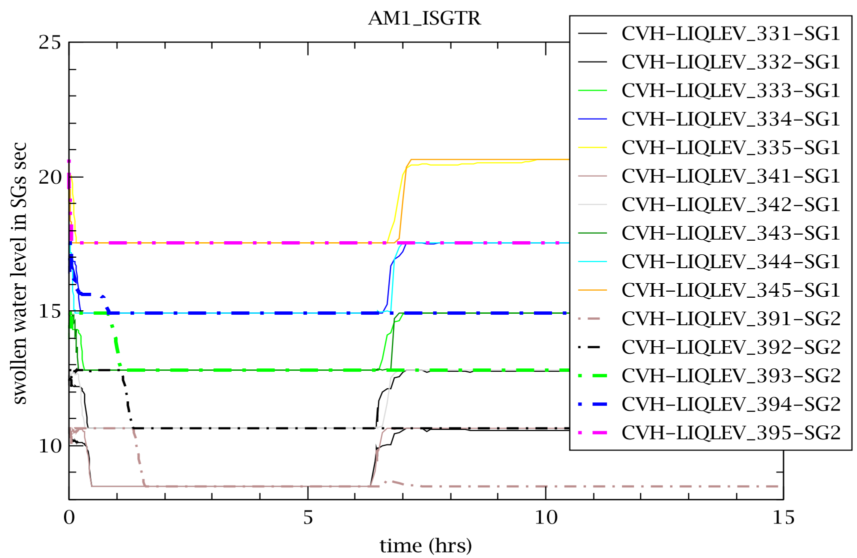
- "early" refill, **AM1_ISGTR** sequence,
  to see an effect of the mitigation on bypass FP releases to environment
  and, in particular, look at **aerosol scrubbing, various ways**

and then

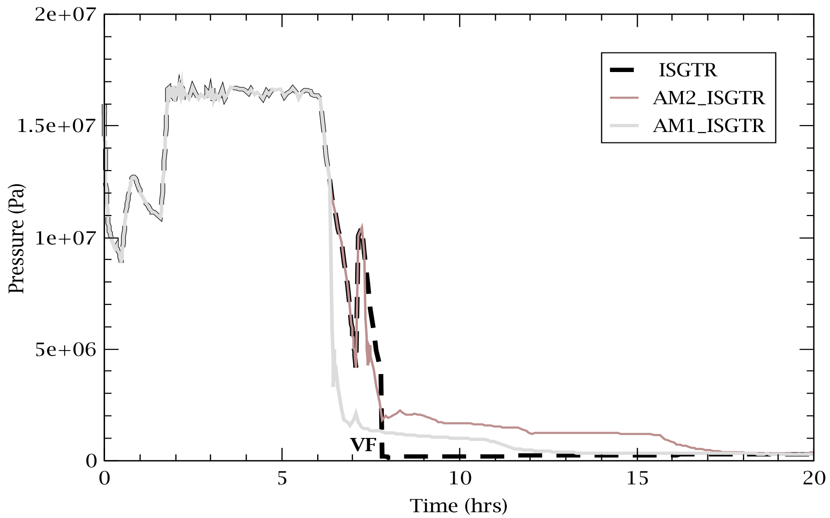
- ~1 hour later, **AM2_ISGTR** sequence (shortly after the complete core degradation)
  to see whether the RPV could be saved
  (though most of the radioactivity has been released already)

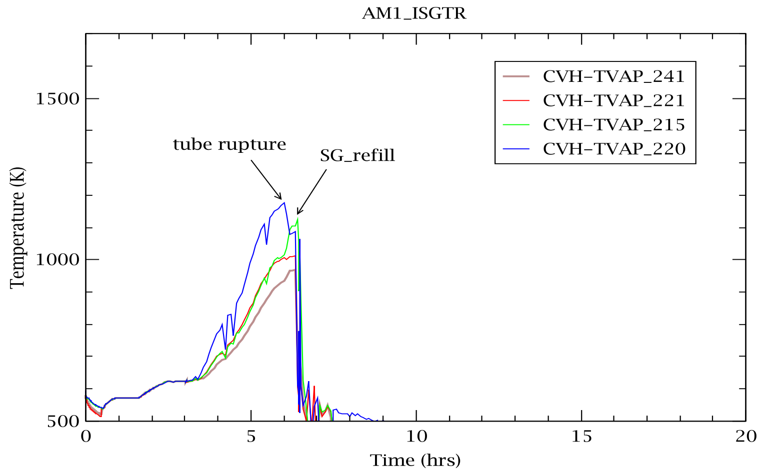
both mitigated scenarios recovered after RCS pressure decrease followed by accumulator injection

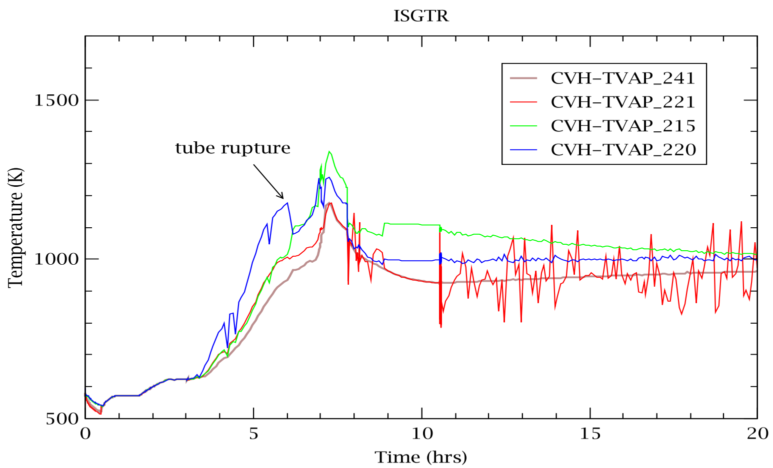


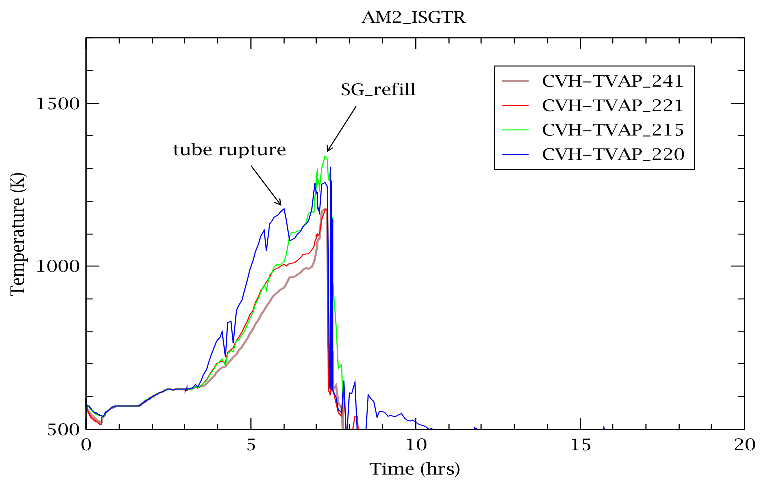


ISGTR progression and mitigated scenarios

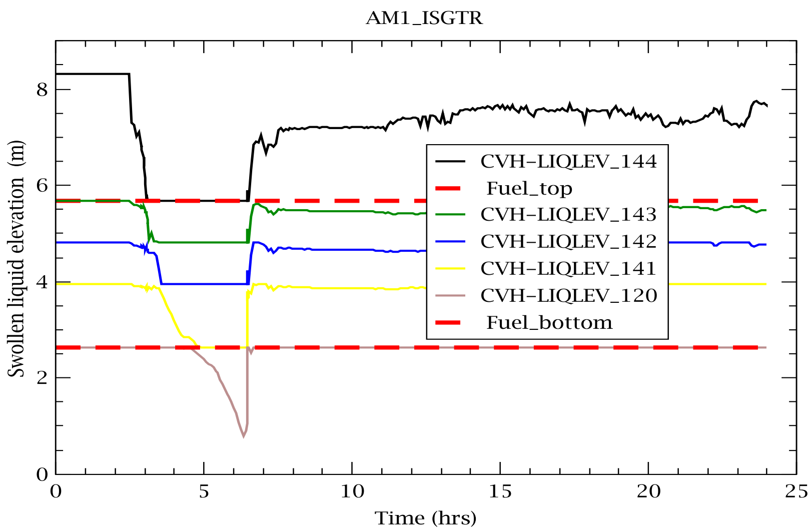


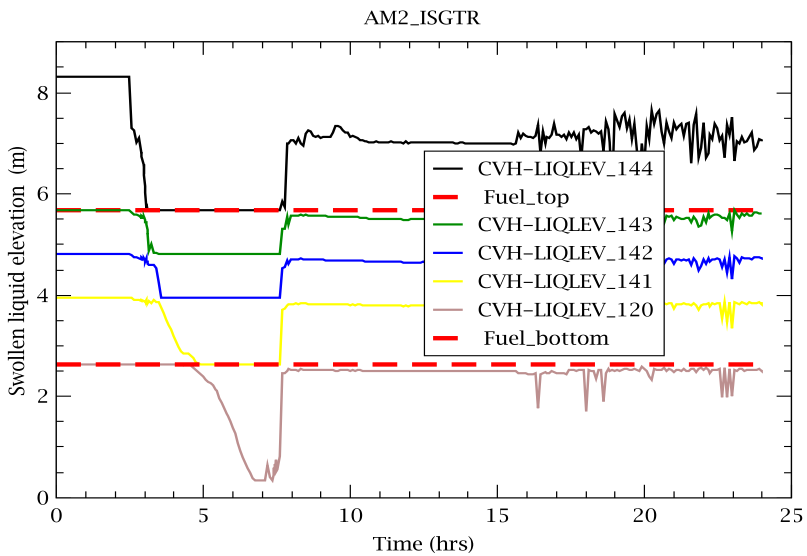






water levels in RPV





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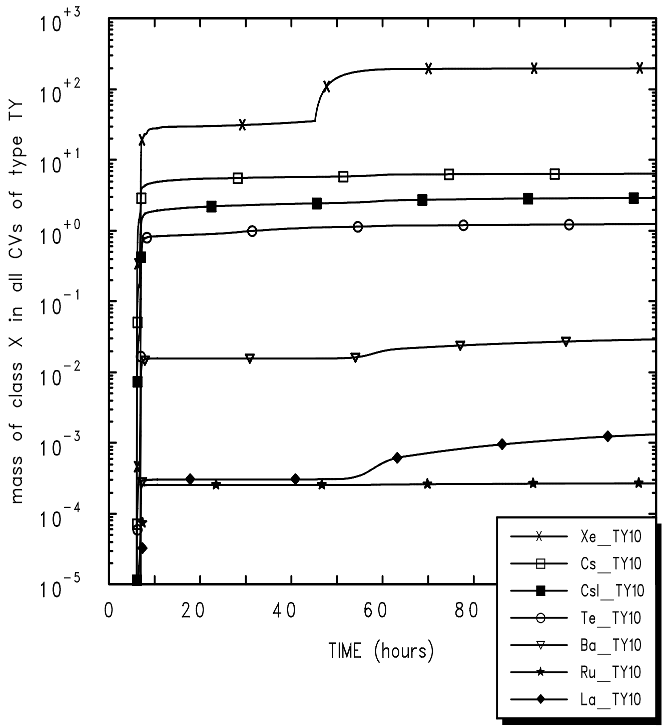
FP releases to environment

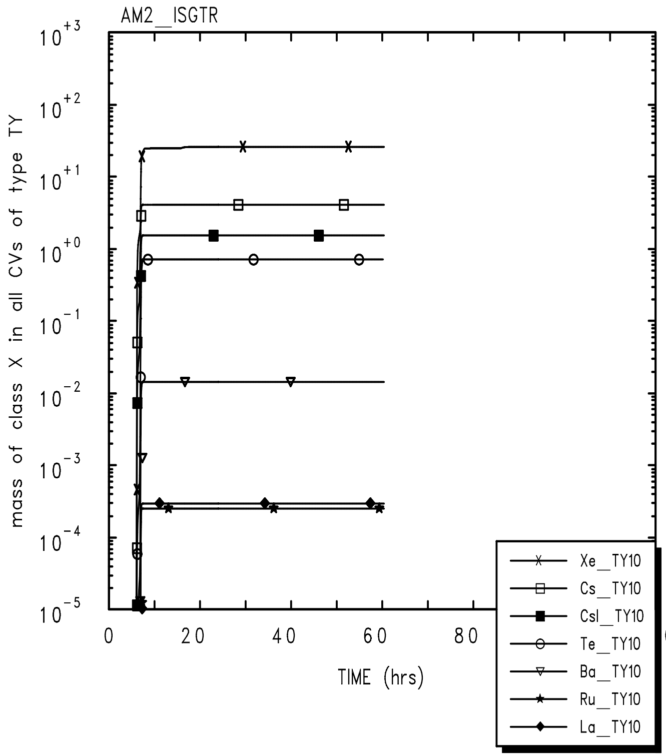
very small differences in environmental releases for "late" SG re-fill compared to unmitigated ISGTR sequence

(before the containment venting in the unmitigated sequence, at ~45hrs)

unmitigated ISGTR



AM2_ISGTR



modeling of FP mitigation

comparison of the unmitigated sequence and the mitigated AM1_ISGTR releases

first

- **with MELCOR defaults in the mitigated scenario, i.e. no aerosol scrubbing in the water on the secondary side**

and then

- **use the available model of aerosol scrubbing, SPARC, on the secondary side of the flooded SG**

and also

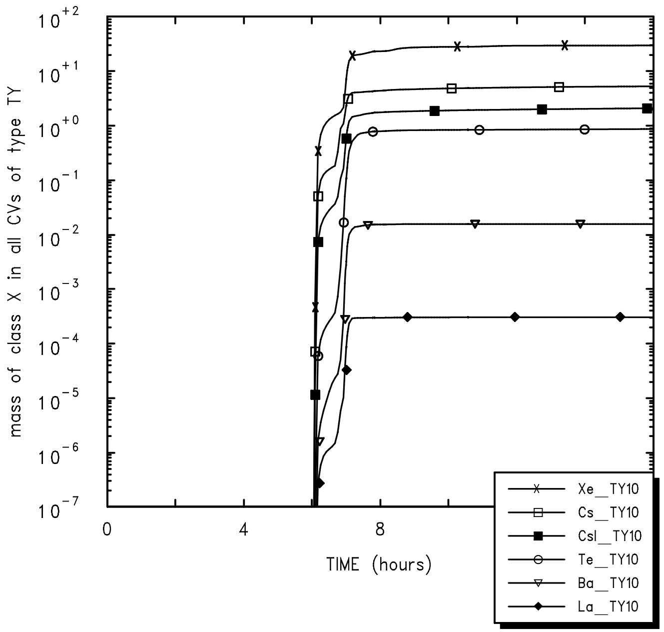
- **instead of SPARC, use the experimental data from the international ARTIST project -our main interest: we were anxious to know how it compares with models**

mitigation of FP releases at AM1 ISGTR

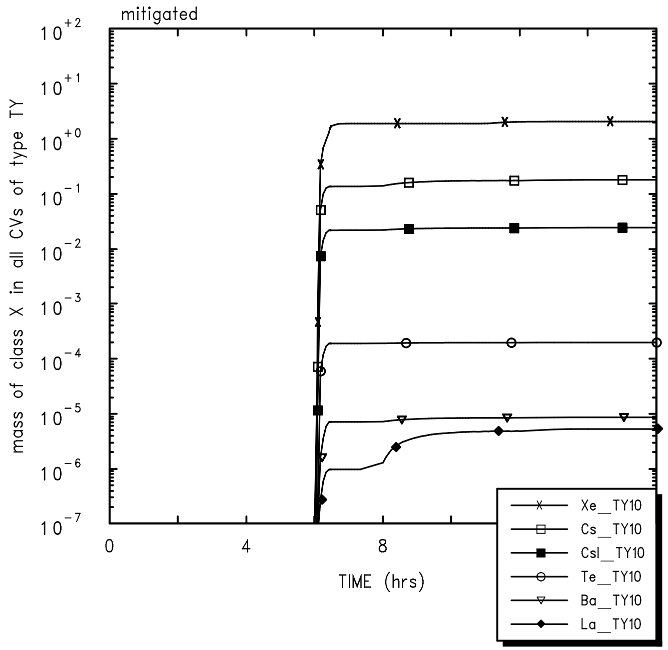
-using only defaults in MELCOR

distinct differences between mitigated and unmitigated sequence where mitigated releases were calculated with all the defaults in the code, i.e. also without any scrubbing of aerosols (!?) in sec of SG1

unmitigated ISGTR



AM1_ISGTR



using ARTIST data

for the mitigated ISGTR (AM1_ISGTR)

- one **part of the international ARTIST Project** provided experimental data on **"Decontamination Factors (DF) for aerosols during SGTR incidents under flooded conditions in SG secondary"**

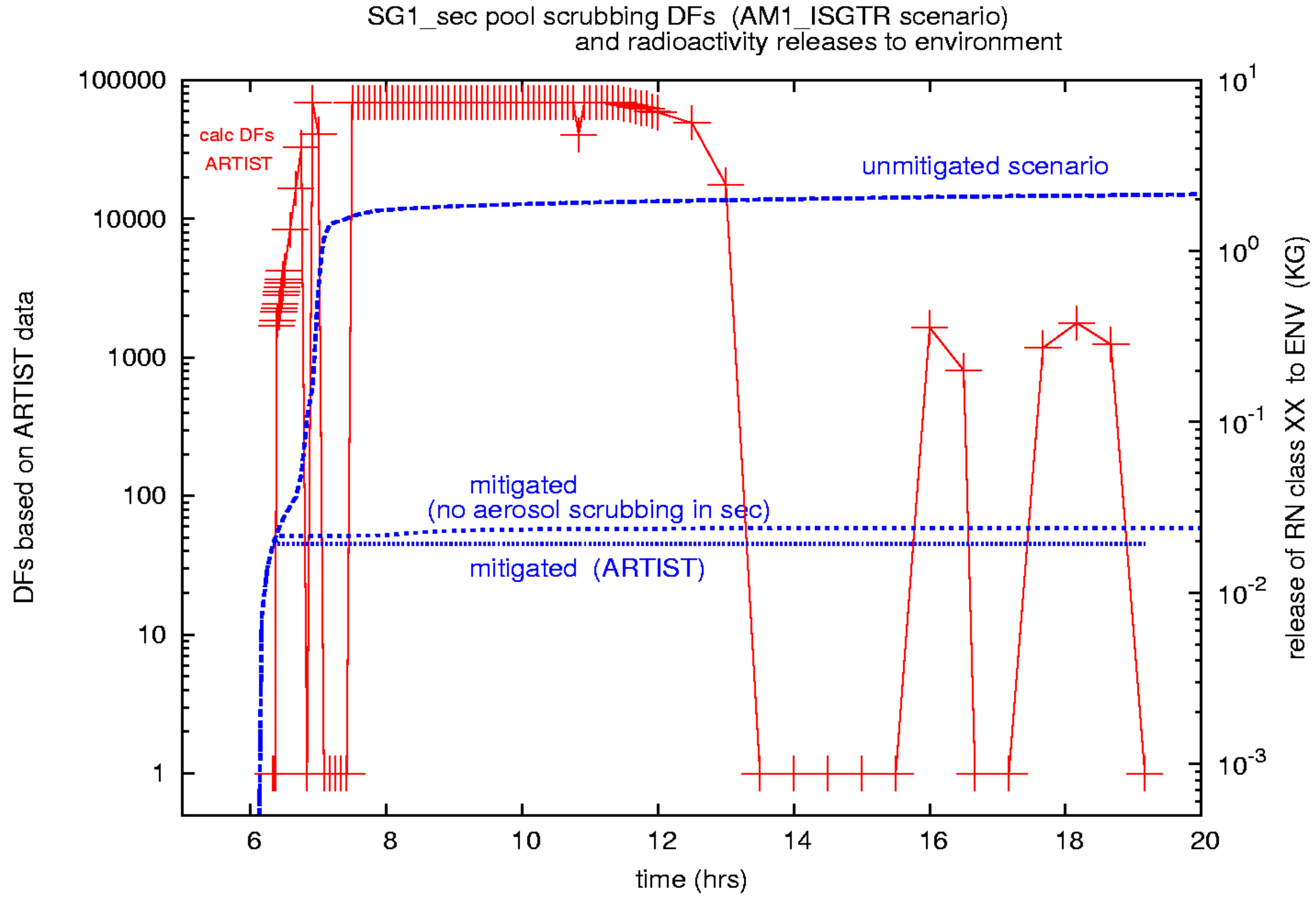
- for our work we wanted to **use (recalculate) the ARTIST DFs for a "real" (postulated) SGTR scenario,** mitigated by SG re-fill, and compare the FP retention with predictions of the available models, here: SPARC as implemented in MELCOR (with all the defaults used)

- **ARTIST aerosol DFs in a flooded bundle of tubes calculated** for a given scenario **as a function of**
  - **atmosphere flow rate (steam + H2 + ...) from primary to water on sec through SG tube break**
  - **submergence**

- in our first simulations, **the calculated DFs were applied ex-post to releases from the ruptured SG, specifically to selected MELCOR RN classes**
  they might also be calculated directly during an accident simulation via some CF logic, e.g. giving retention for modeled MELCOR aerosol binners, and then be somehow recalculated for specific "radioactivity"

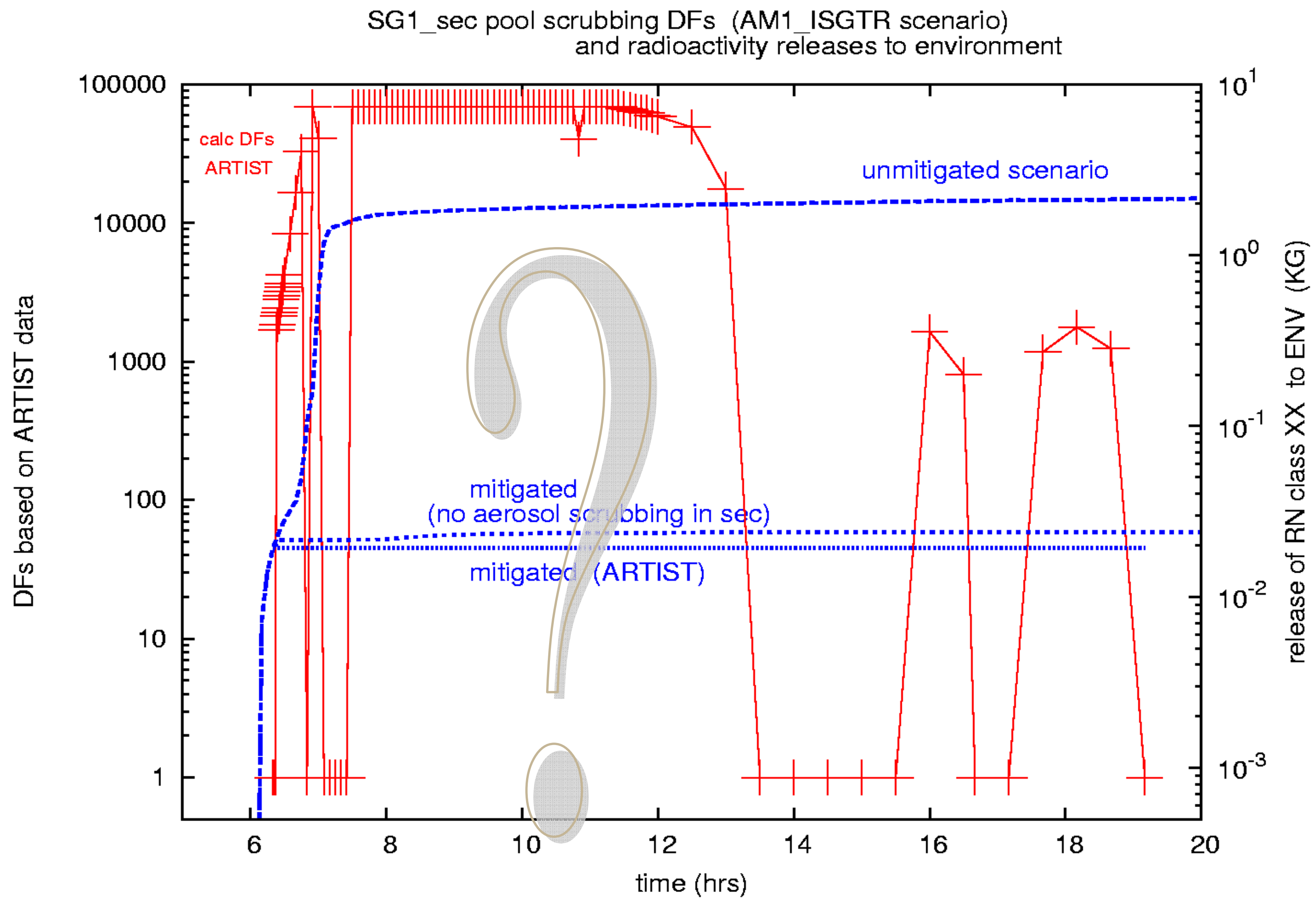
First results:

Calculated mitigation of CsI release to environment



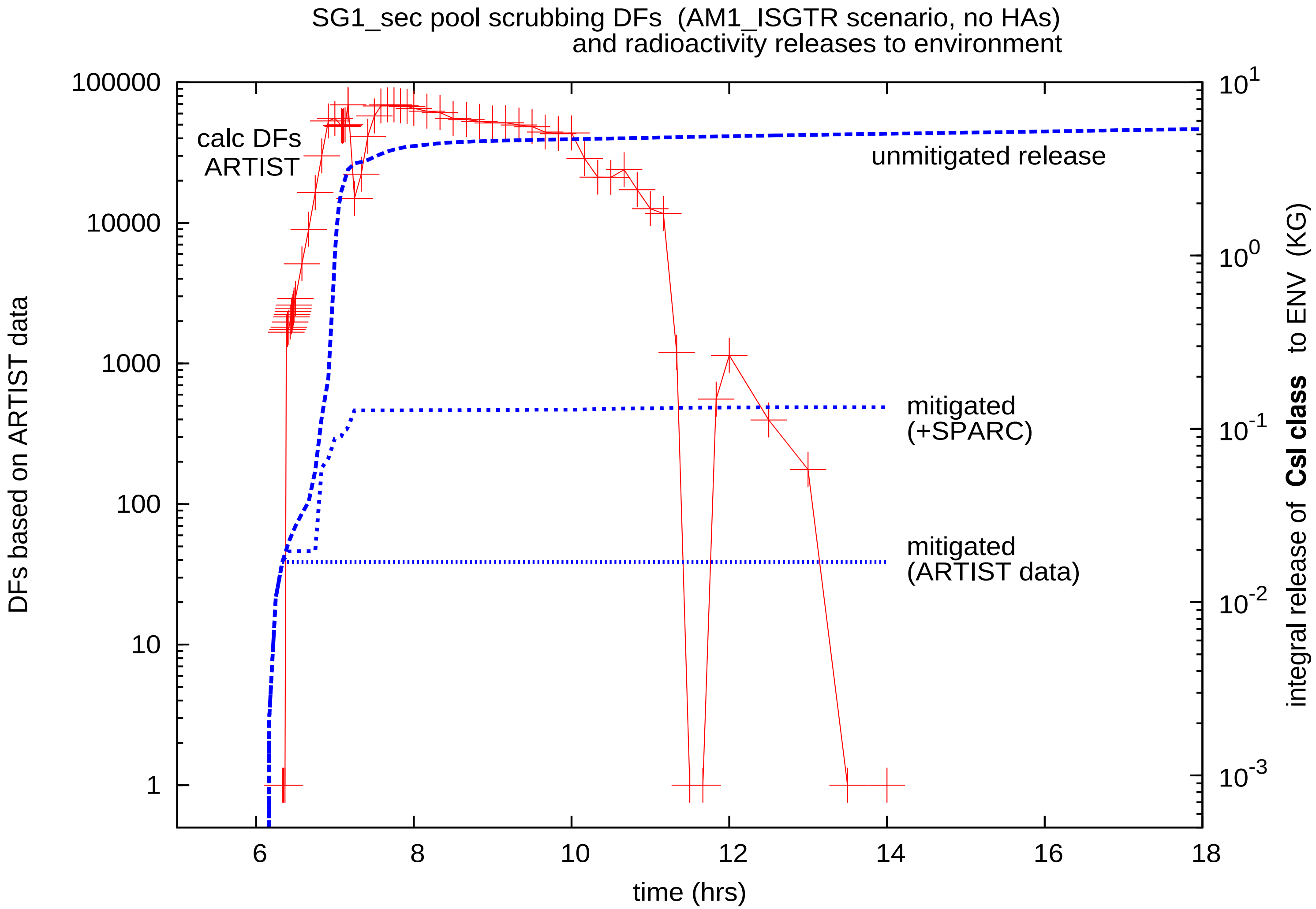
First results:

Calculated mitigation of CsI release to environment



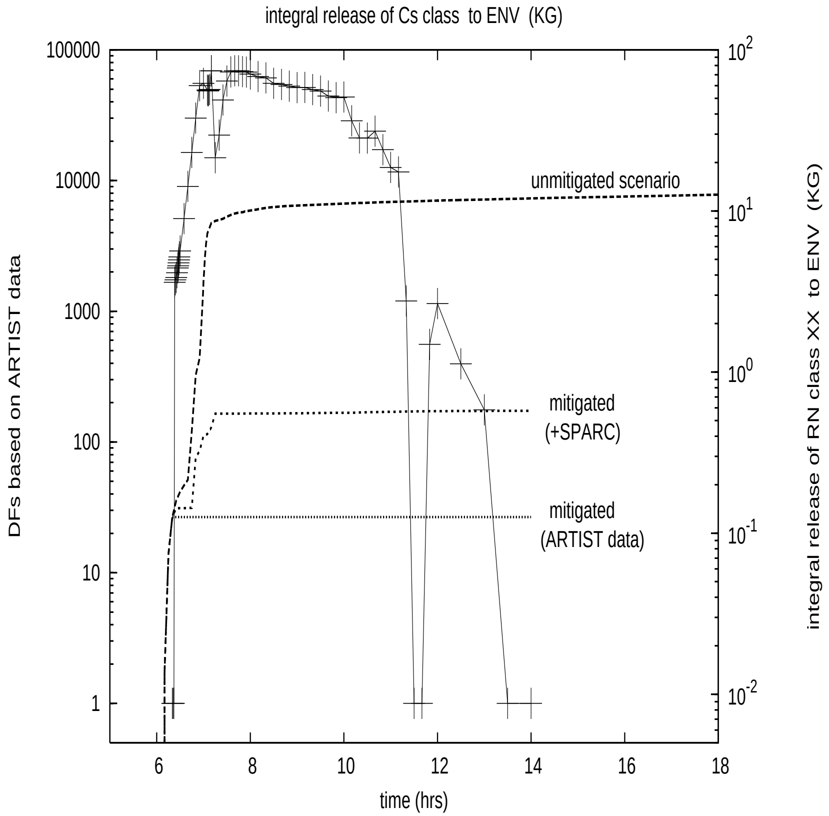
First results:

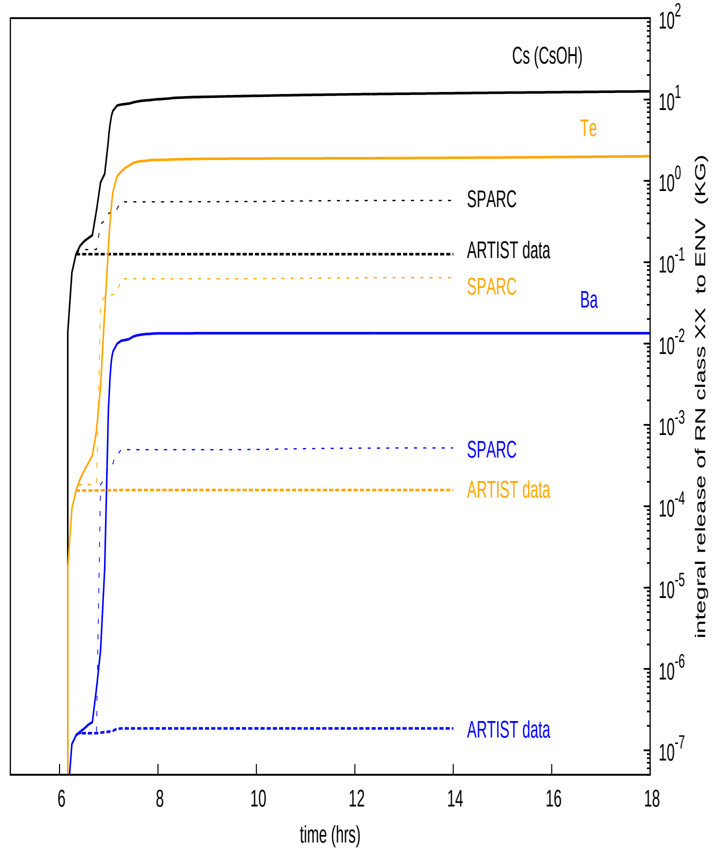
Calculated mitigation of CsI release to environment (without Acc)



mitigation of other RN classes
(AM1_ISGTR, without Acc)

Cs class (CsOH) and Ba and Te classes





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summary

- **MELCOR parametric studies for various black-out scenarios at a 2-loop PWR were carried out within a framework of the project for Swiss NPPs**

- as one part of those: **thermally-induced SGTR simulated, unmitigated and 2 mitigated cases, with SG1 secondary re-fill**

- **"early" re-fill of SG sec seems to be very effective always** (in mitigating the source term), **just by bringing about Acc discharge**

- **first results indicate that experimental (ARTIST) data** on aerosol retention in a flooded bundle of tubes **represent much higher FP decontamination than models (here: SPARC) can predict**

- **the work is on-going, also thanks to financing from SwissNuclear**

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thank you for your attention