# An attempt to model the heat conduction in concrete during CCI: Simulation of the CCI-2 test with CORCON in MELCOR

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# modeling of the CCI experiments of the OECD-MCCI project

part of activities for the OECD-**MCCI** project (**M**elt **C**oolability and **C**oncrete **I**nteraction, 2002-2006), experiments carried out in ANL

experimental data somehow proprietary (this work hasn't been presented to any MELCOR group before, only to the OECD MCCI Seminar) but it's not the case any longer

one of the 2 main parts of OECD-MCCI were the **large 2D CCI tests**

looking at the 2D profile of the concrete erosion (axial-to-radial ablation depth ratio)

- about 400kg of prototypical PWR corium (+8% concrete decomposition products), fully-oxidized (i.e. homogeneous); at ∼2000°C, internally heated DEH; in a rectangular cavity 50 x 50 cm, with the bottom part and 2 sidewalls made of concrete, the other 2 sidewalls non-ablative MgO, two types of concrete studied: siliceous and LCS

—for the heat conduction simulations, we chose the ANL **CCI-2 experiment (LCS concrete)** because many modeling activities had been aimed at that before and we also had our own detailed simulations of this test

# heat conduction in concrete during CCI

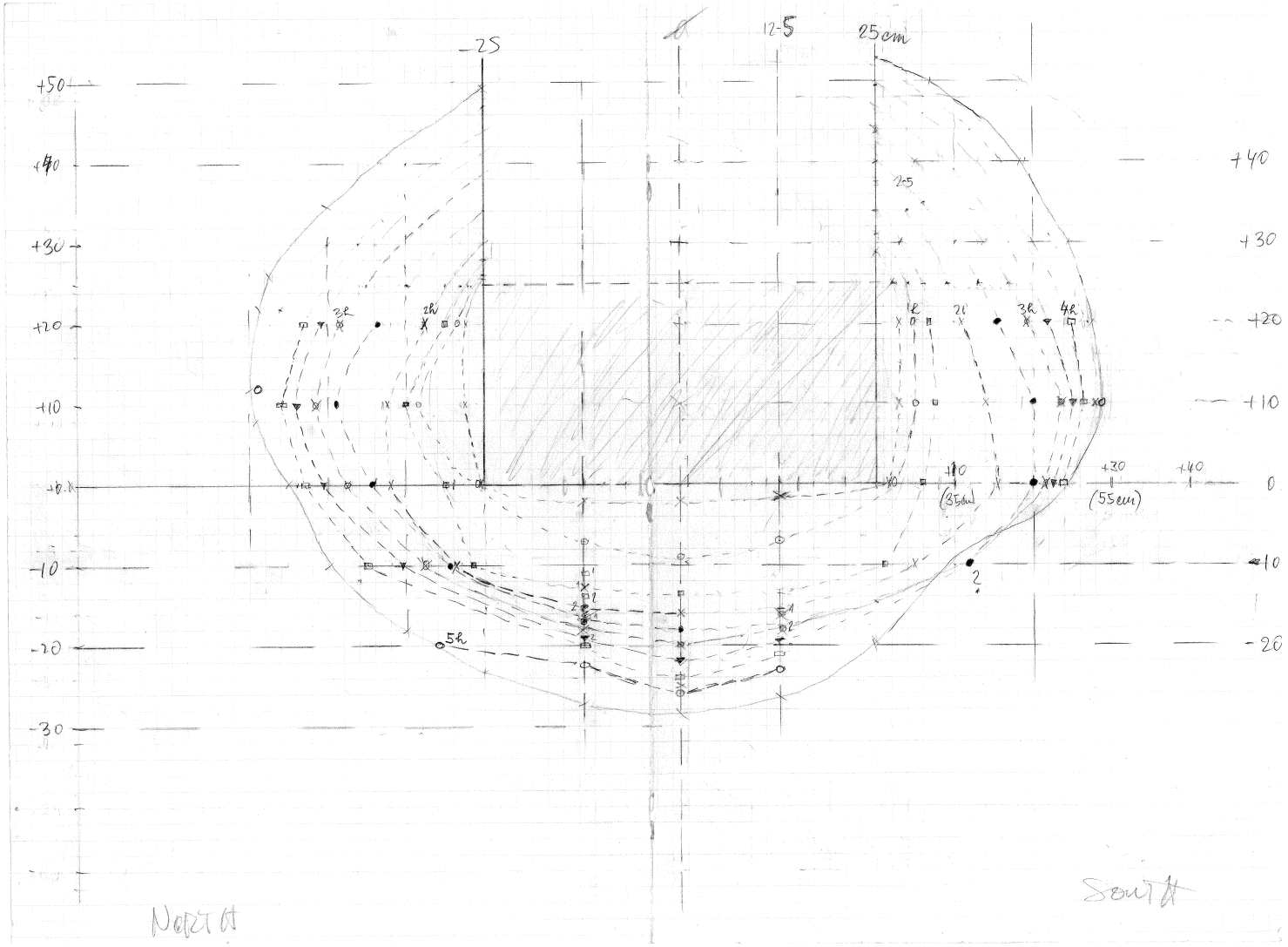
thermal conductivity of concrete is very low $\Rightarrow$ most of the CCI codes do not model conduction of heat in ablated concrete

however, at an accident, the amount of relatively cold mass of cavity concrete is big and there is a potential to remove at least some energy from the melt via conduction

also, the neglected conduction of heat in concrete could be the reason why none of the codes used in the analytical exercise on the CCI-2 test was able to predict the initial phase of the test ($\sim$ 1hour)

—to assess the impact of this phenomenon we utilized the capabilities of the MELCOR code (as a driver to CORCON) trying to get a rough estimate of the amount of energy transferred from the pool by conduction in concrete in the course of CCI

# CCI–2 geometrical data —our (artistic) estimate based on experimental data points



## eroded concrete volumes in the course of CCI–2 test —estimate

(based on the evaluations of the data from the graph)

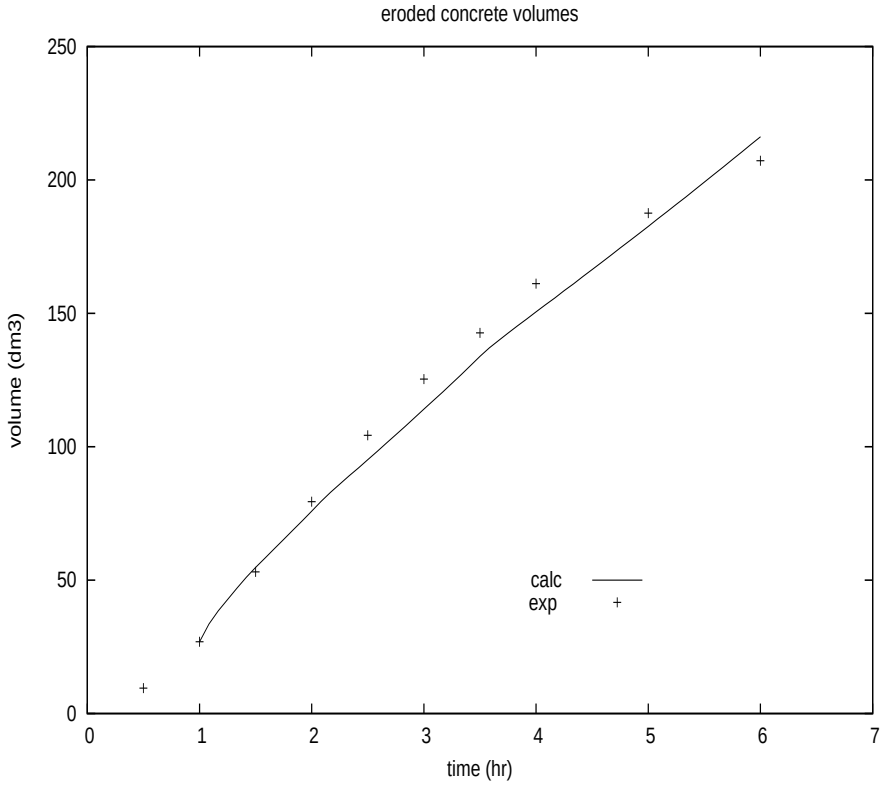
| | 0.5hr | 1.0hr | 1.5hr | 2.0hr | 2.5hr | 3.0hr |
|---|---|---|---|---|---|---|
| total eroded concrete volume (L) —our estimate from the experimental data | 9.5 | 26.9 | 53.1 | 79.4 | 104.3 | 125.4 |
| | 3.5hr | 4.0hr | 4.5hr | 5.0hr | 5.5hr | 6.0hr |
| total eroded concrete volume (L) —our estimate from the experimental data | 142.7 | 161.2 | | 187.6 | | 207.2 |

Volume of ablated concrete was for us the first parameter to lean against when comparing predictions of the code with the experimental results

Otherwise, it is a problem to say whether CORCON (simulating only cylindrical geometries of real plant cavities) is doing well for an experiment in a rectangular cavity and with only 2 ablative sidewalls

# CCI–2: orig CORCON calculation (MCCI exercise) starting at 1hr

with equivalent cylindrical cavity of r=28cm, all the defauts in the code used + slag film model, starting with the right amount of ablated concrete in the melt at 1h, init temperature was input: 2073K



## some details on the proposed way of heat conduction modeling

How to model the first hour of CCI-2 : trying heat conduction in concrete

We utilized the capabilities of MELCOR, as a driver to CORCON, to model the heat transfer in independent MELCOR heat structures. Based on CORCON evaluations, changing boundary conditions and changing init temperature distributions in HSs were used for restart runs of the MELCOR code

- about 50 equivalent rectangular HSs were used in the simulations with changing lengths; in each restart, different HS (automatically selected based on CORCON) was used for the conduction calculation
- conduction in a given HS was driven by input (constant) boundary temperature —temperature of ablation for LCS
- MELCOR was being restarted automatically in small steps (intervals) and the heat going to the selected HS during the interval was subtracted from the heating of the melt

# CCI modeling by CORCON in MELCOR

All the defaults in the code were used in calculations (also emissivities and concrete properties for LCS); slag film model used on both the bottom and the sidewalls (in all the simulations of CCI–2 we found no big differences in results using slag film model versus gas film model)

- forced mixing of the melt (one mixed layer) used
- some boundary conditions calculated by MELCOR; particularly temperatures above the melt were input using time-specified conditions in the atmosphere of MELCOR control volume

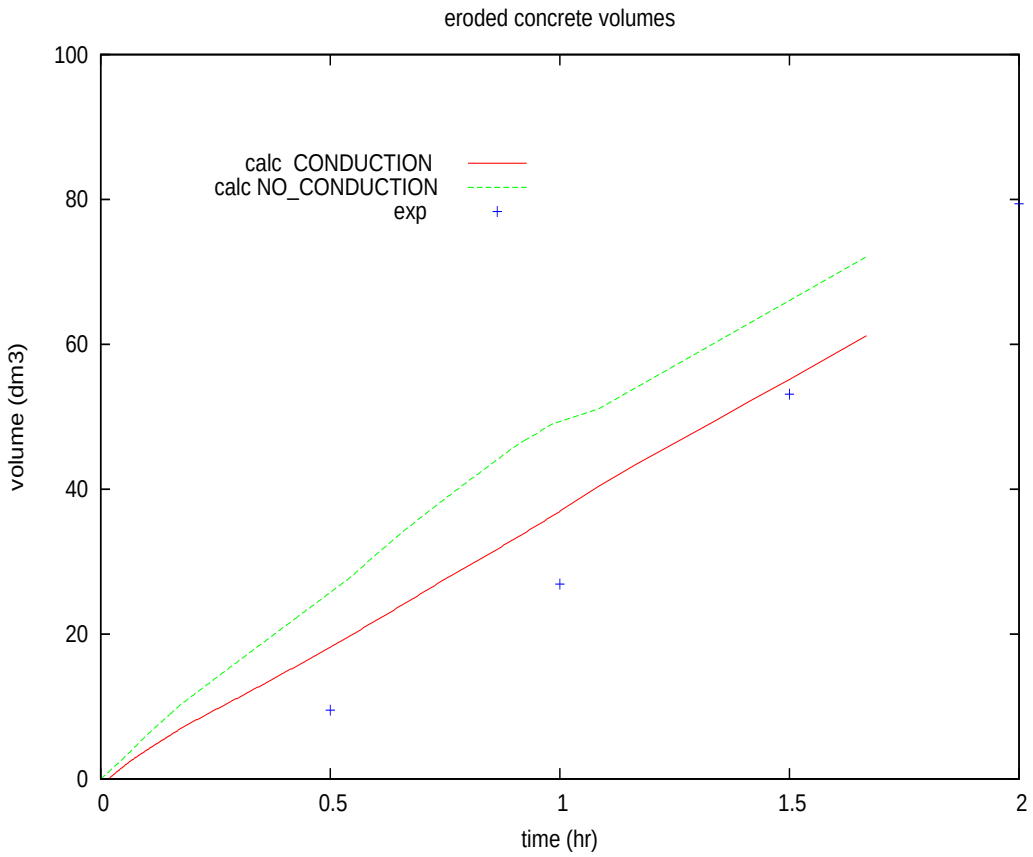
For the calculations simulating the heat conduction to concrete

• a lot of UNIX programming was needed because most of the CORCON variables we wanted for MELCOR restarts are only in printed (text) output files, not in binary file for restart

• also, many output variables —first of all these ablated concrete volumes— had to be recalculated from data in the text output files; they are not normally available in MELCOR

# CCI–2 by CORCON: eroded concrete volume in the first hour

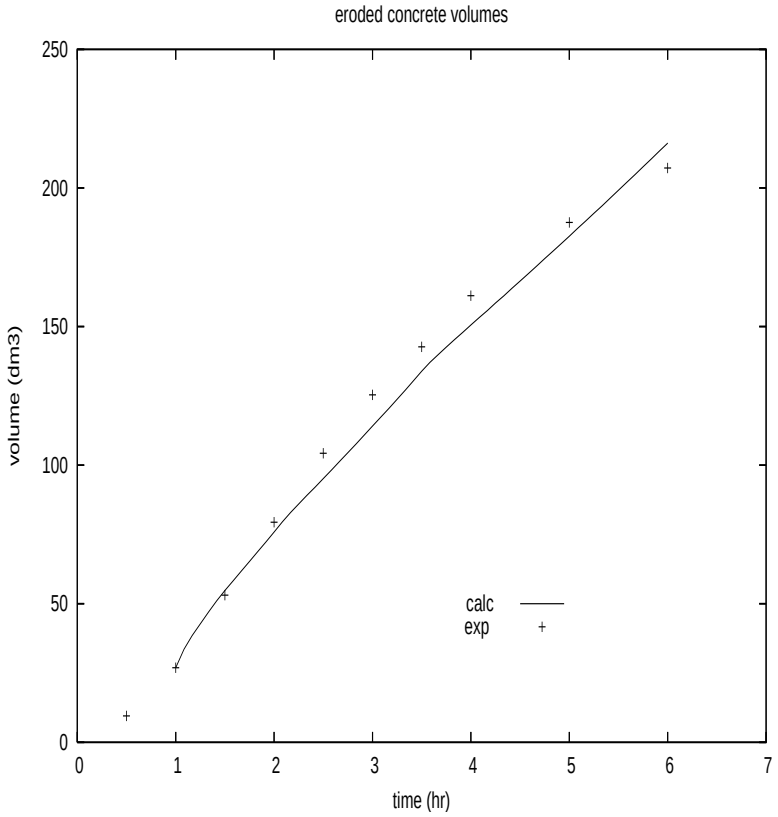
comparison of the calculations starting at 0.0 with and without heat conduction modeling (up to ∼1.5hr —beginning of the experiment)



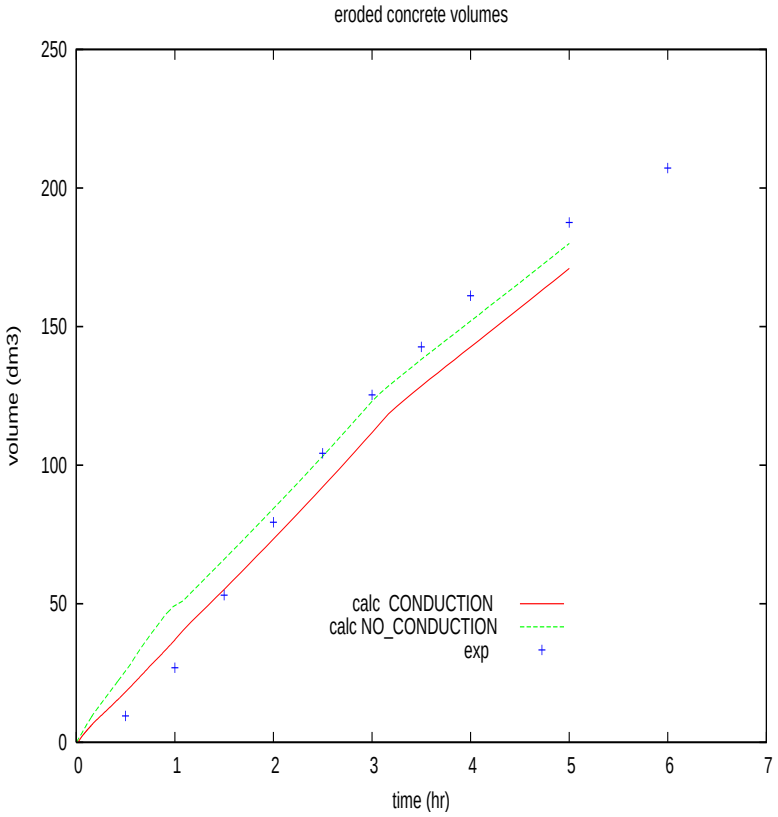
# CCI–2 by CORCON: eroded concrete volume

for the whole duration of the experiment the results are not so convincing; calc average layer temperature is always distinctly lower than experiment

original calculation beginning at 1h

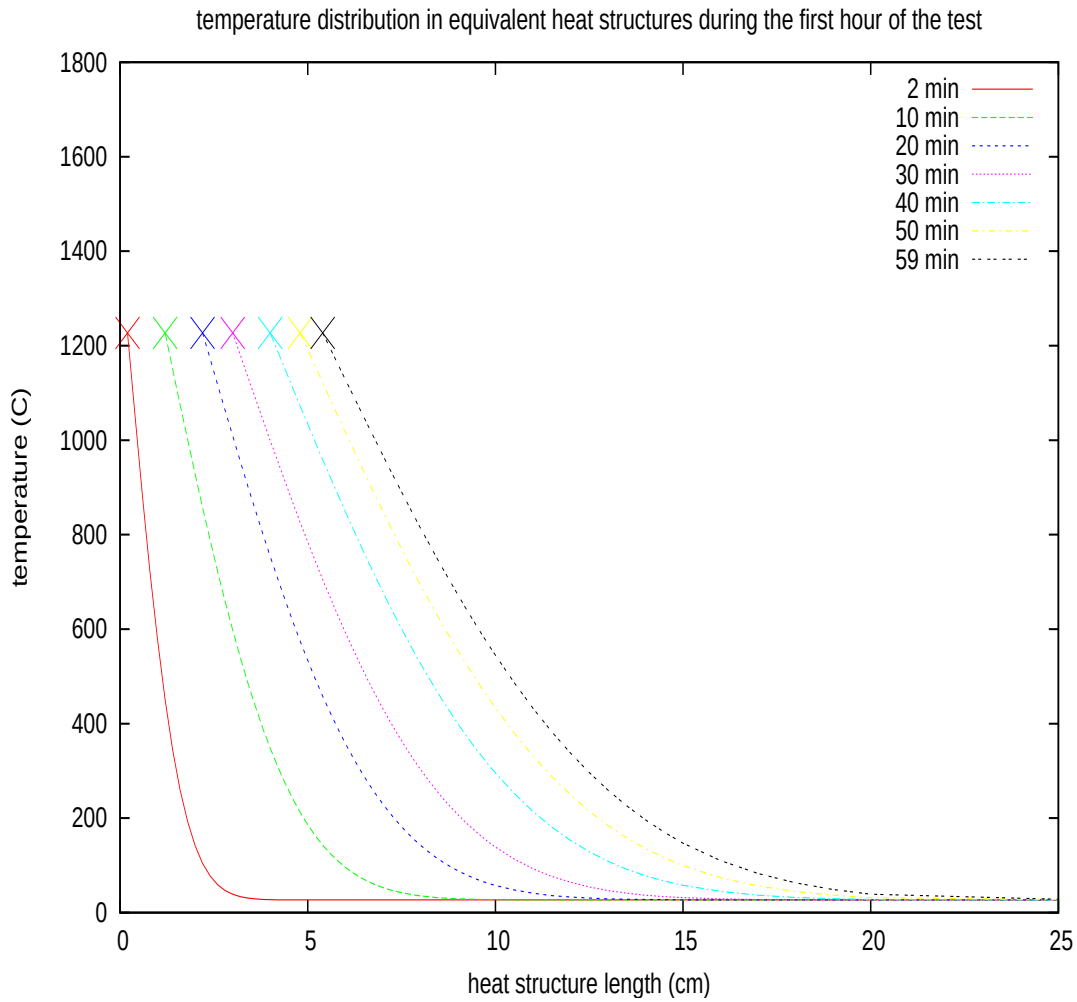



new calculations (heat conduction) from 0.0



# predicted temperatures in equivalent concrete HSs during CCI-2

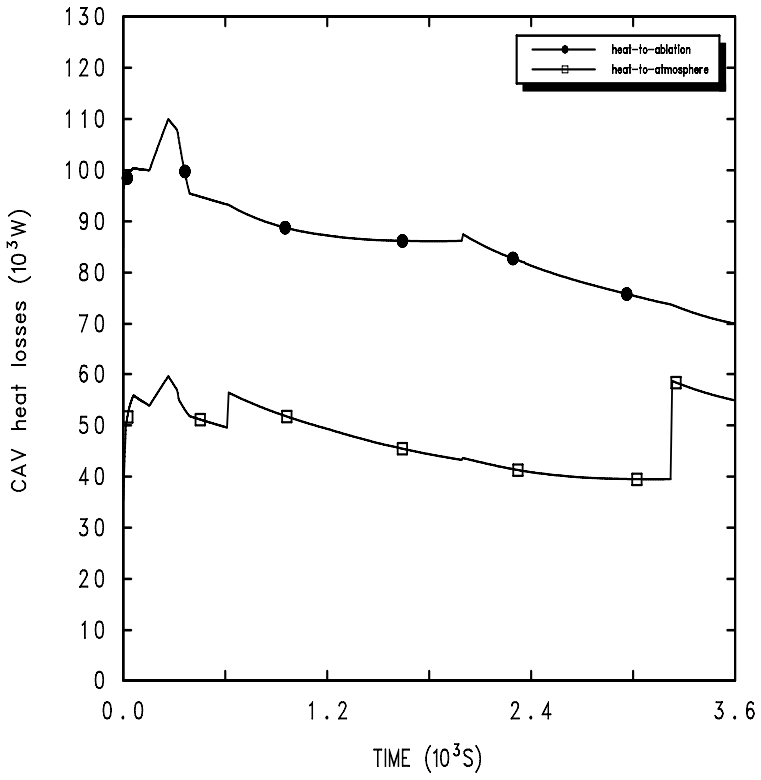
ablation temperature of CCI-2 LCS concrete: 1500K (CORCON default)



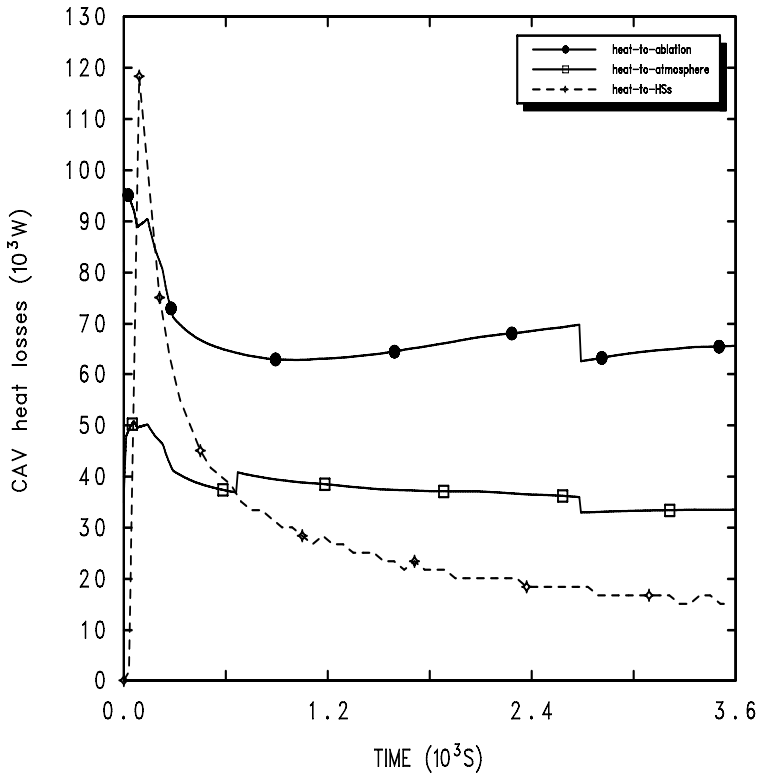
# CCI–2 by CORCON: total heat fluxes during the first hour

energy balances (heat fluxes) without heat of chemical reactions

no heat conduction in concrete



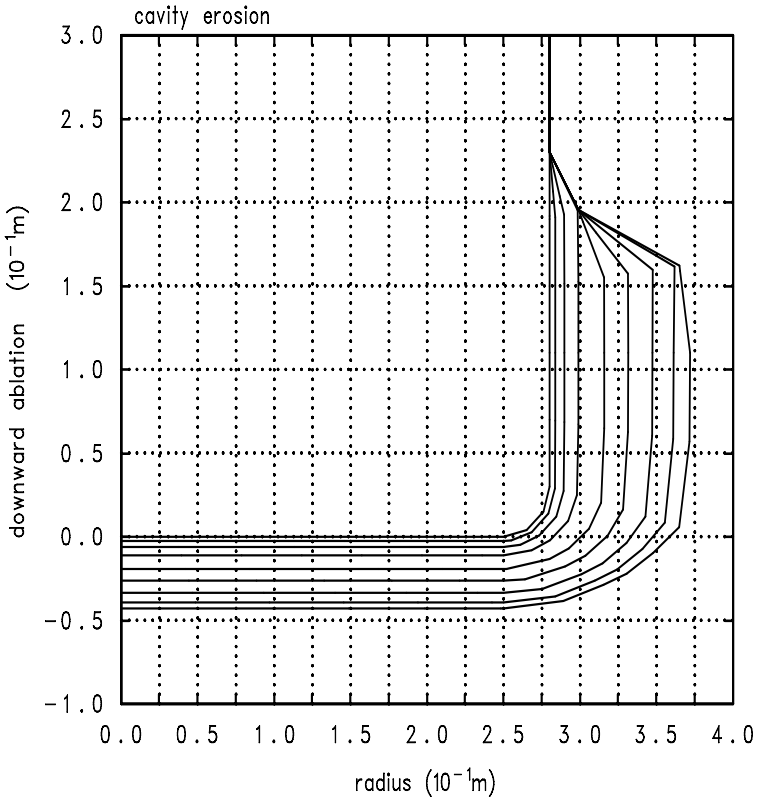

with the heat conduction to concrete



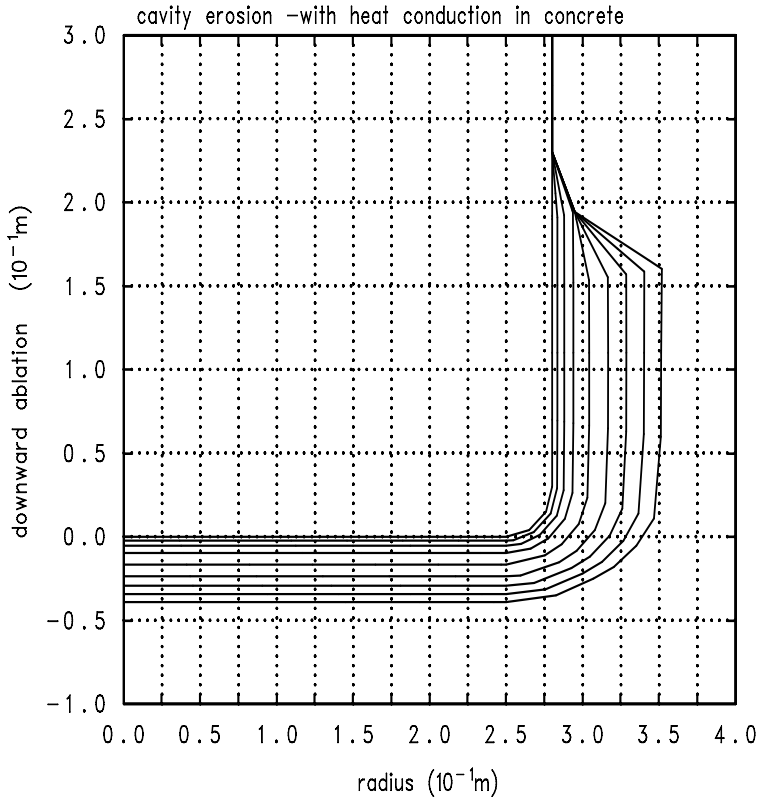
# CCI–2 by CORCON: cavity shapes up to 1 hour

ratios of axial to radial erosion depths are not much relevant here

no heat conduction in concrete

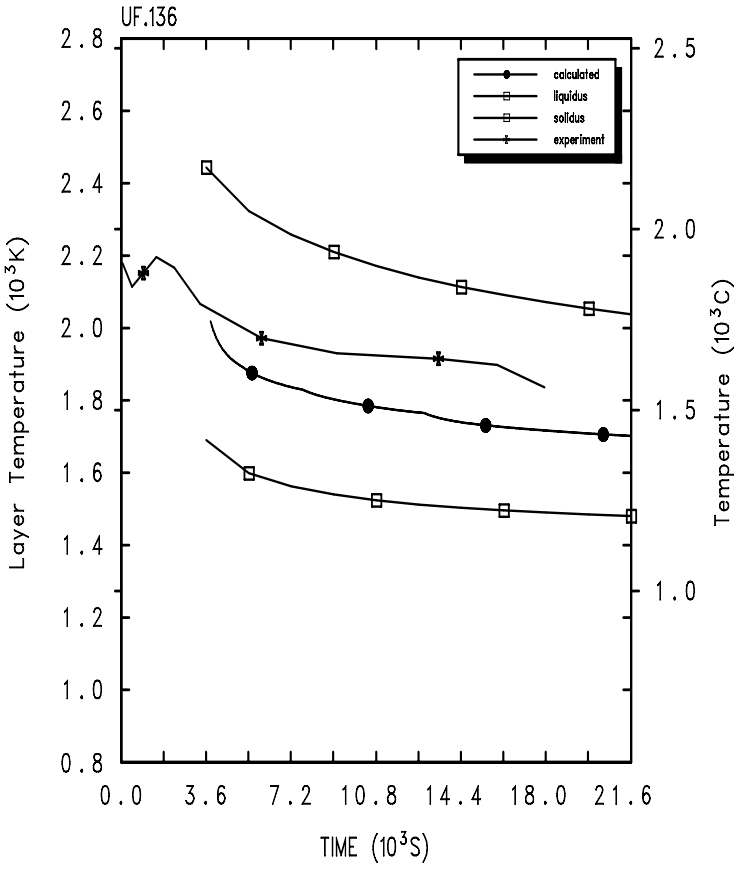


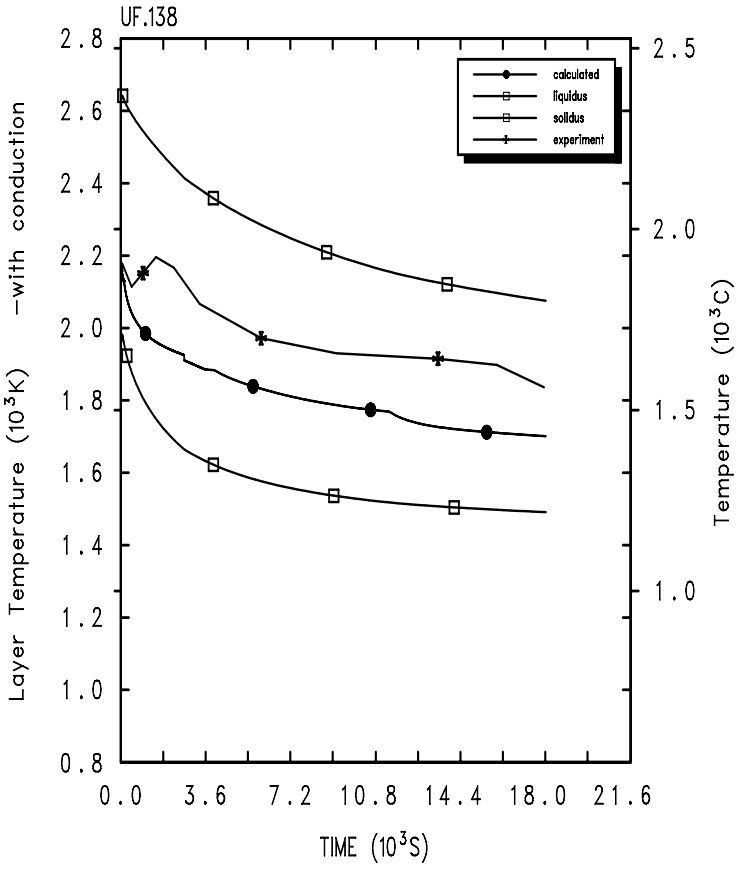

with the heat conduction to concrete



# CCI–2 by CORCON: calculated melt temperatures

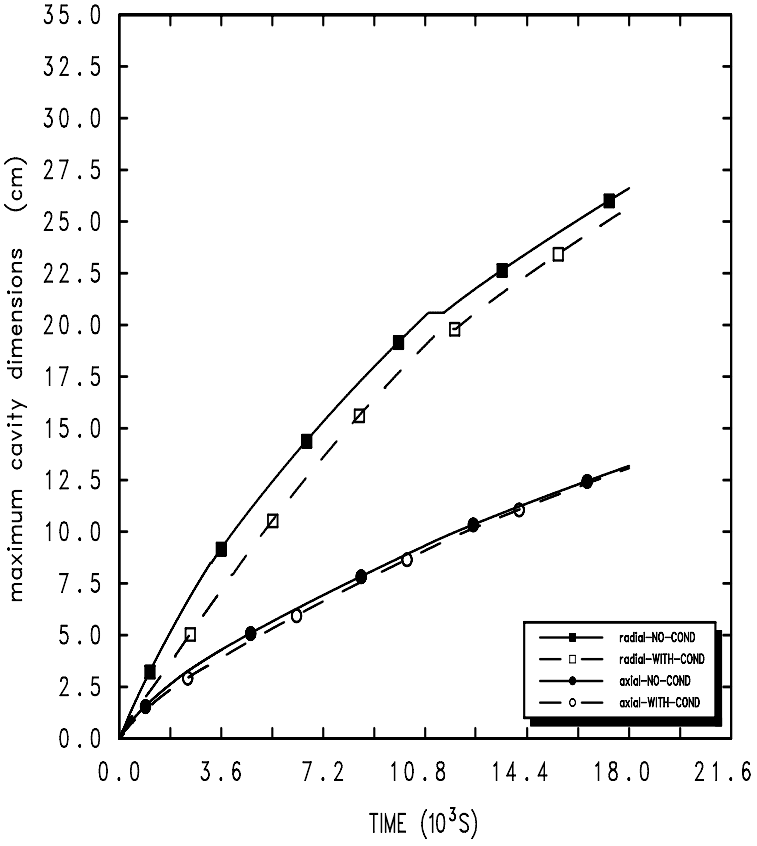
original calculation beginning at 1hour and the new calculation with the heat conduction

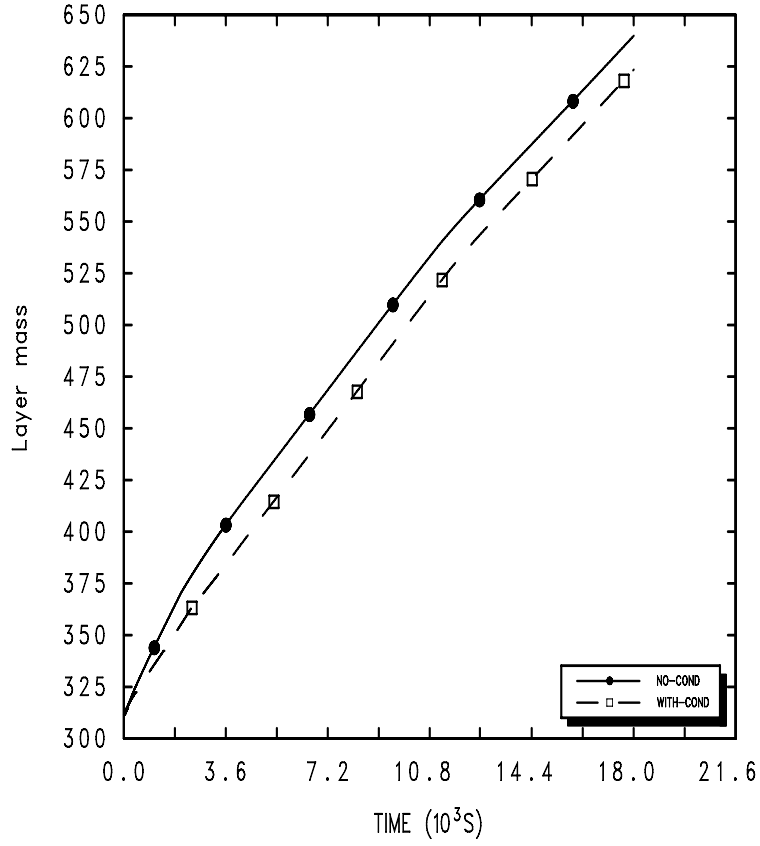


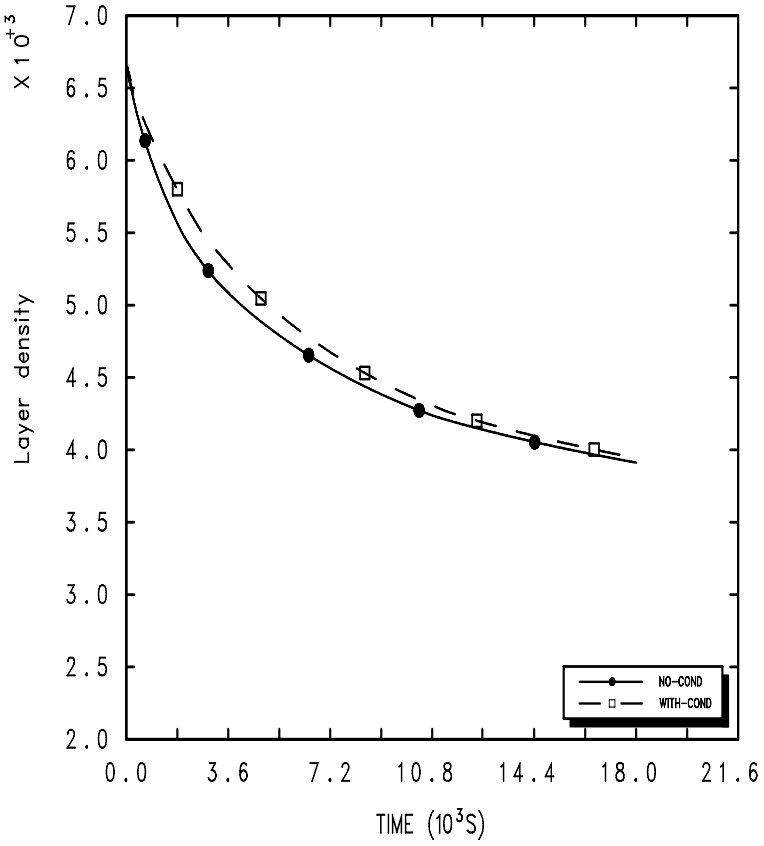
# CCI–2 by CORCON: max cavity dimensions and layer mass

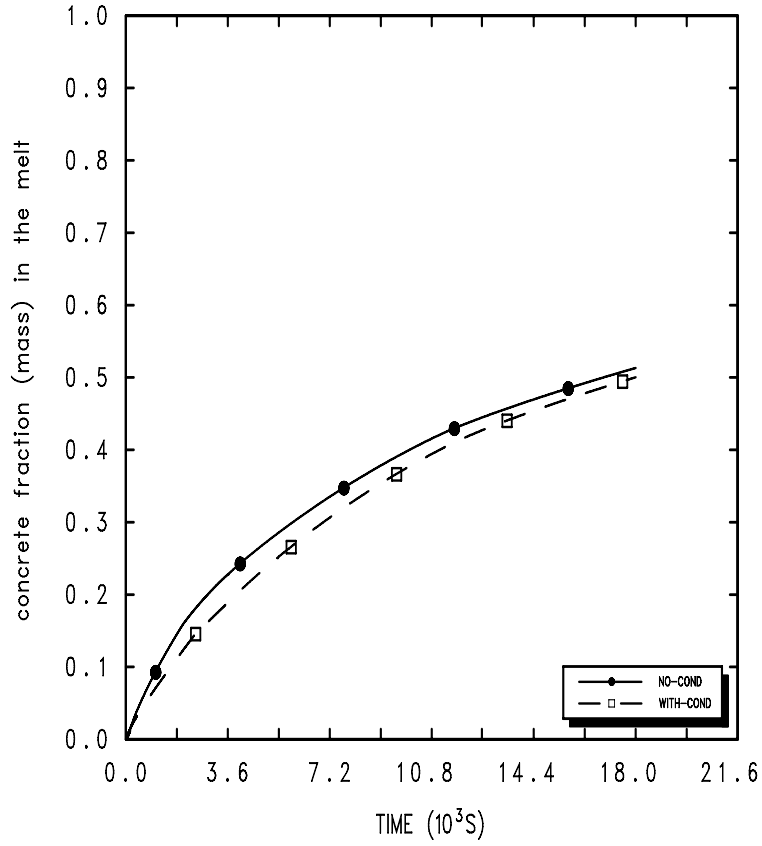
( init mass 311.5kg: 88.5kg lost at the beginning of the test )



# CCI–2 by CORCON: layer density and concrete fraction



# CONCLUSIONS

- CORCON in MELCOR can be used as a tool for estimating the heat conduction losses to concrete during CCI
- our results seem to indicate that conduction of heat in concrete during CCI can play a role at the early stages of the interactions (at least for the experiment)
- our CORCON predictions for the initial phase of the CCI–2 experiment with heat conduction modeling were better than without it (which is not a big surprise); it still does not match fully the experimental results
- calculated temperatures of the melt are always (conduction, no conduction) about a 100C lower than estimated experimental values
- CORCON cannot be used easily for the geometrical setup of the CCI–2 experiment: calculated cavity shapes (radial-to-axial ratios) are rather irrelevant

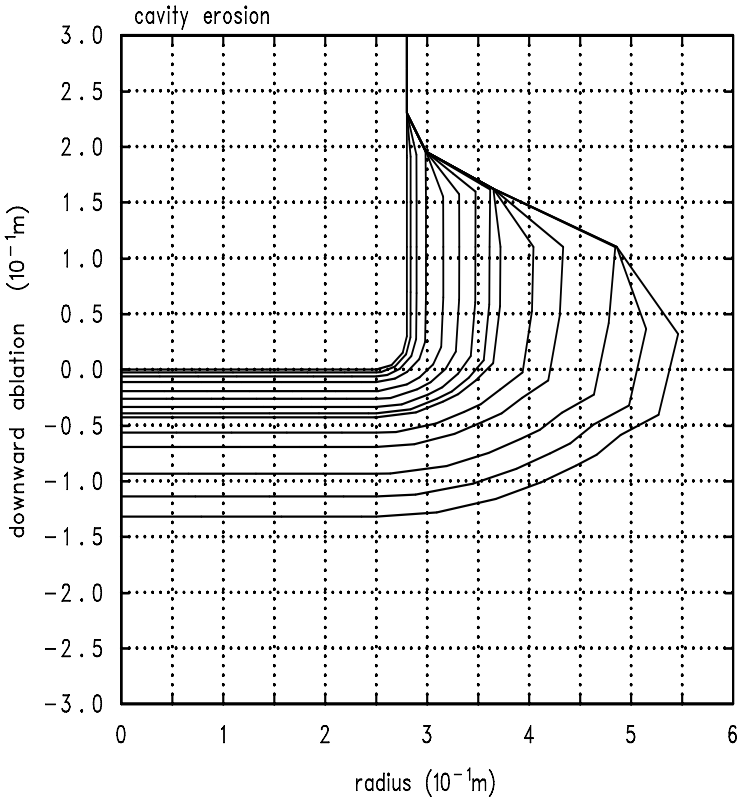
# CONCLUSIONS (contd)

- CORCON in MELCOR gives all the information needed for the heat conduction calculations and also facilitates such modeling as MELCOR is very flexible (CF module of the code, HS module, etc)
- also, different approaches to heat transfer modeling than ours could be used with this tool, e.g. different way of defining the boundary conditions at eroded concrete surface for the conduction calculation
- however, in this demonstration we needed a lot of UNIX scripts, too, because most of the CORCON variables are available only in printed MELCOR ouput files
- just now —with the similar approach— we are looking at the possibility to have an estimate of the heat conduction losses at CCI for the reactor case

# CCI–2 by CORCON: cavity shapes up to 5 hours

ratios of axial to radial erosion depths are not much relevant here

no heat conduction in concrete




with the heat conduction to concrete