Recent experience with MELCOR 2.2

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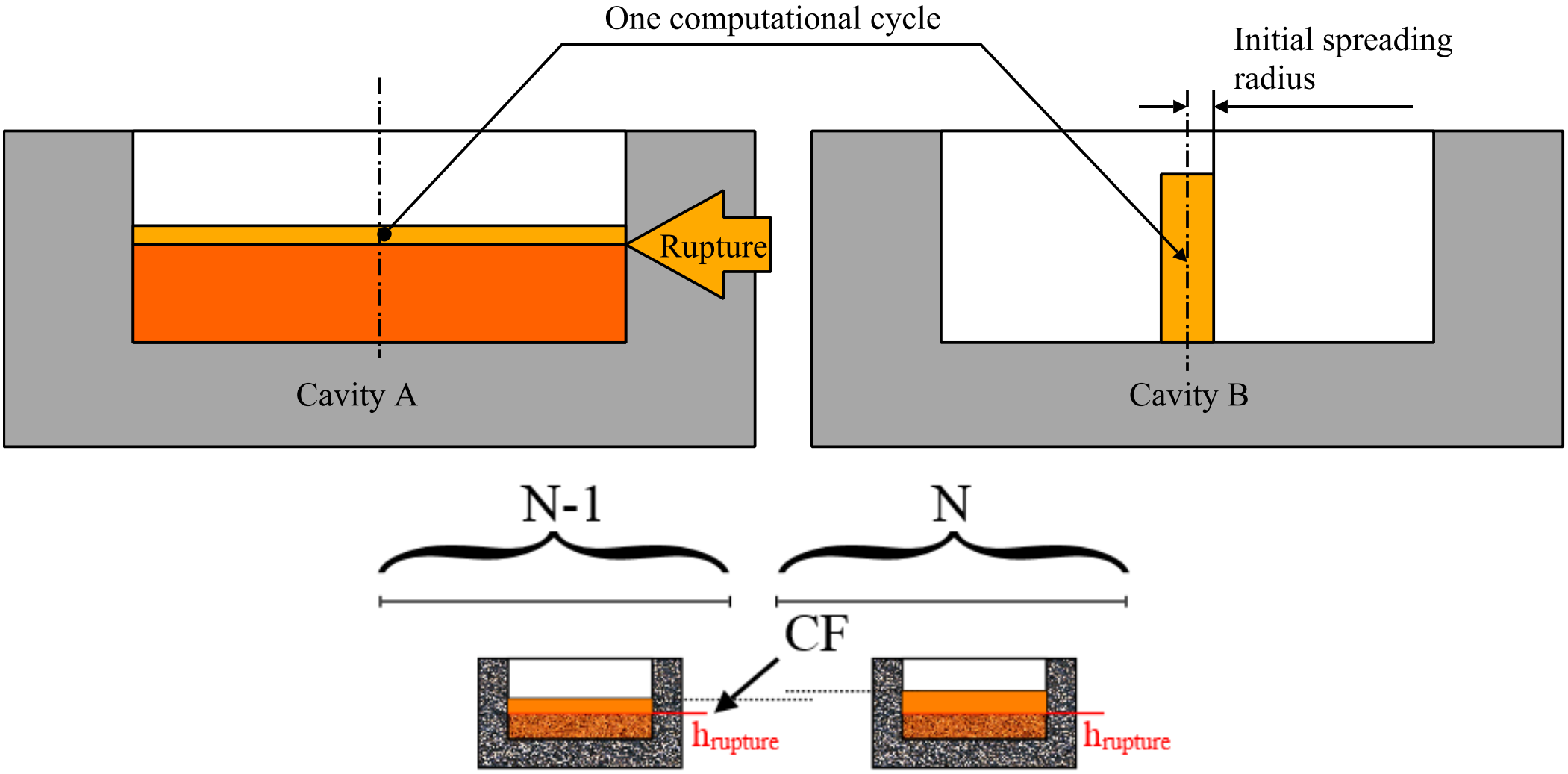
Outline

1. CAV-related issues
2. Windows vs. Linux results
3. Forrtl errors
4. Variable field names
5. Lipinski DHF model

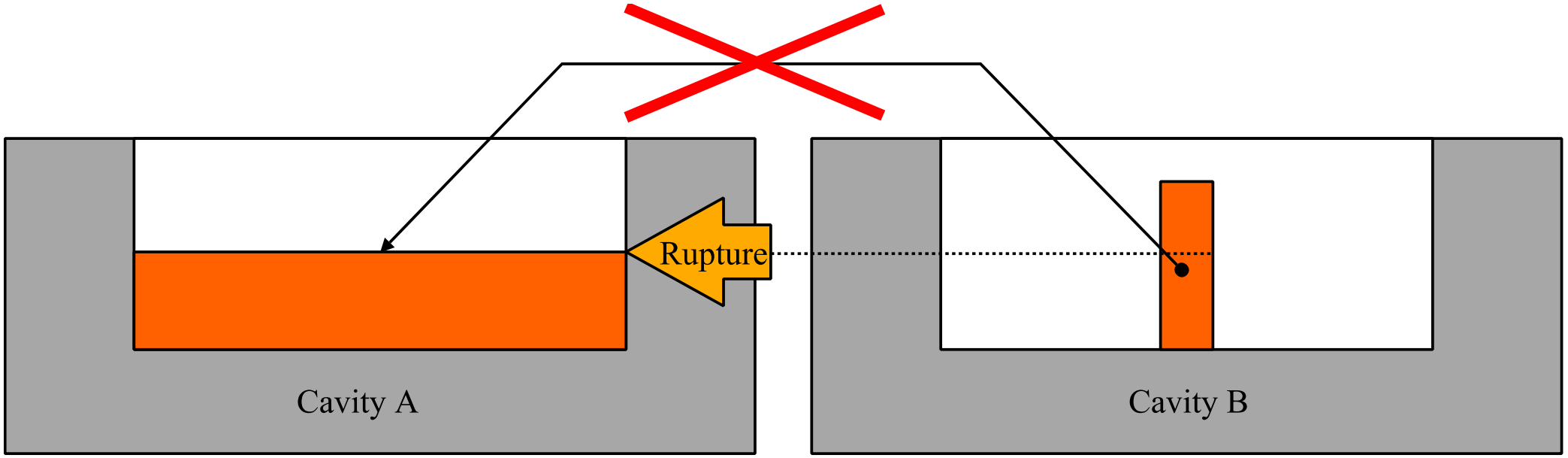
CAV-related issues

Uncertain corium transfer between cavities



- **Proposal: user definition of e.g. maximum mass flow rate [kg/s]**

Impossible backflow

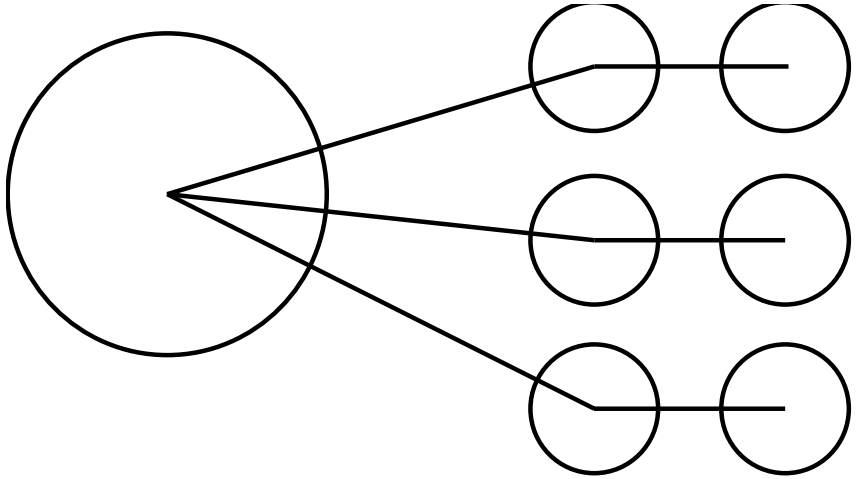


- Impossible corium levels equalizing
- Unrealistically tall cylinder of spreading corium => unrealistic axial ablation rate

Impossible backflow - video

Corium distribution among cavities

- **To properly represent a 2D geometry:**
  - parallel flow to multiple cavities simultaneously



Sleeping cavity cannot be changed from restart

- Initial spreading radius RADTINI – *ignored*
- CV associated to cavity – *ignored*
- NRAYS – causes *forrtl*: severe (172): Program Exception
- CAV_U: ibubx, cond.crust, watingr, erupt => MELCOR *error*

=> Filed as BUG no. 2107 @ MELZILLA

Common CAV-related error

```
forrtl: error (65): floating invalid
           _CAV_CAVSUR@12              128  cavsur_NSI.f90
```

- Occurs when aerosol opacity calculation is triggered in a cavity flooded by water
- Problem solved by Rodney Schmidt and Brad Beeny from SNL in March 2019
- Bug will be repaired in the next official release
- Error in MELCOR 2.2.11932 can be by-passed by omitting the RADLEN parameter for the CAV input

CAV SCs ignored

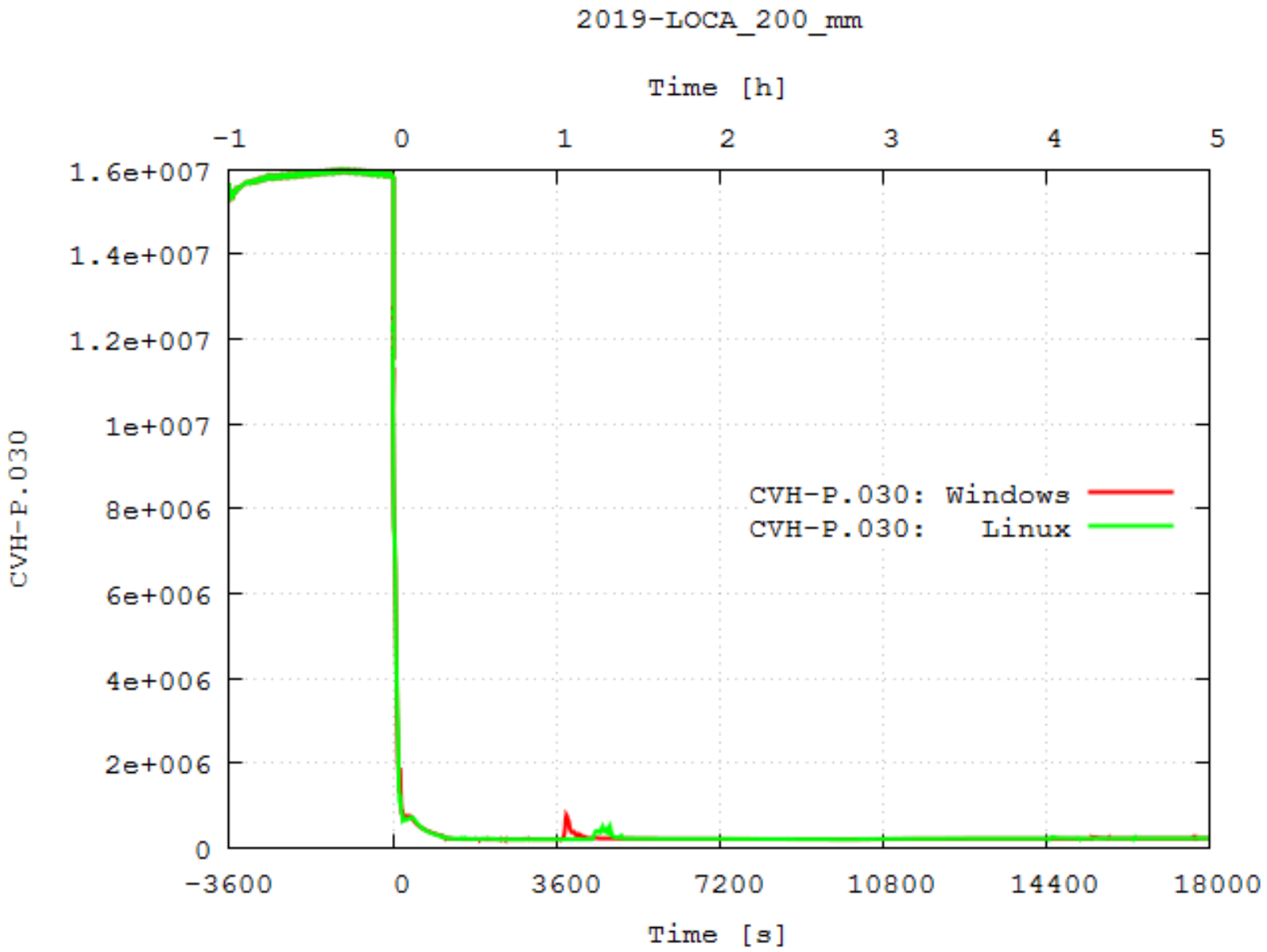
- **Melt viscosity enhancement (SC2302) is not listed ('PrintCurrentSC') and is probably ignored**
  - Same corium spreading behavior observed for
    - Kunitz multiplier
    - Ramacciotti correlation
- **Debris spreading model (SC2303) is not listed ('PrintCurrentSC') and some of it's coefficients seem to be ignored**
  - However, changes in the SCs have some noticeable effect

Windows vs. Linux results

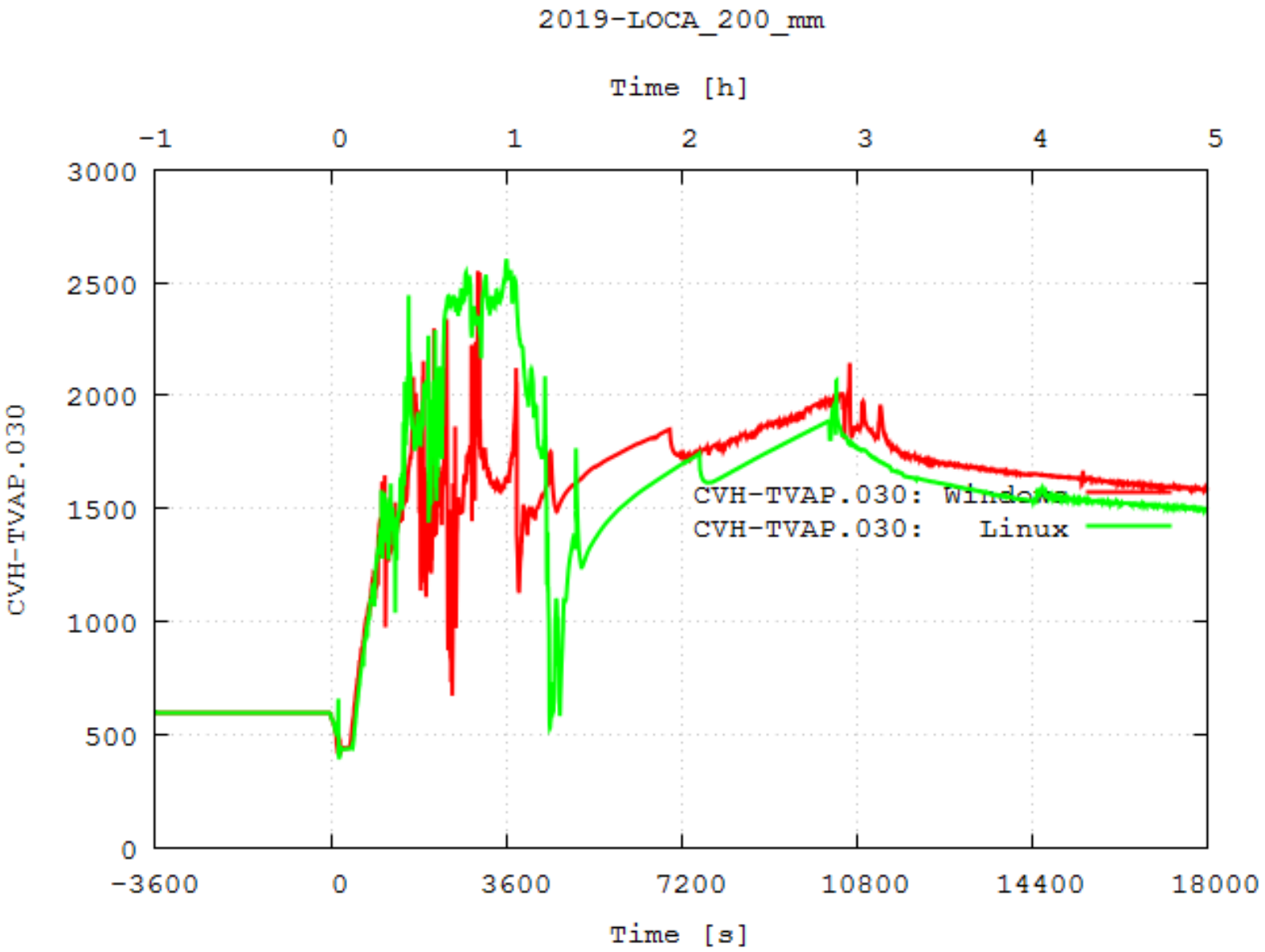
Windows vs. Linux

- 200 mm LOCA + SBO
- VVER-1000/320 reactor
- MELCOR 2.2.11932

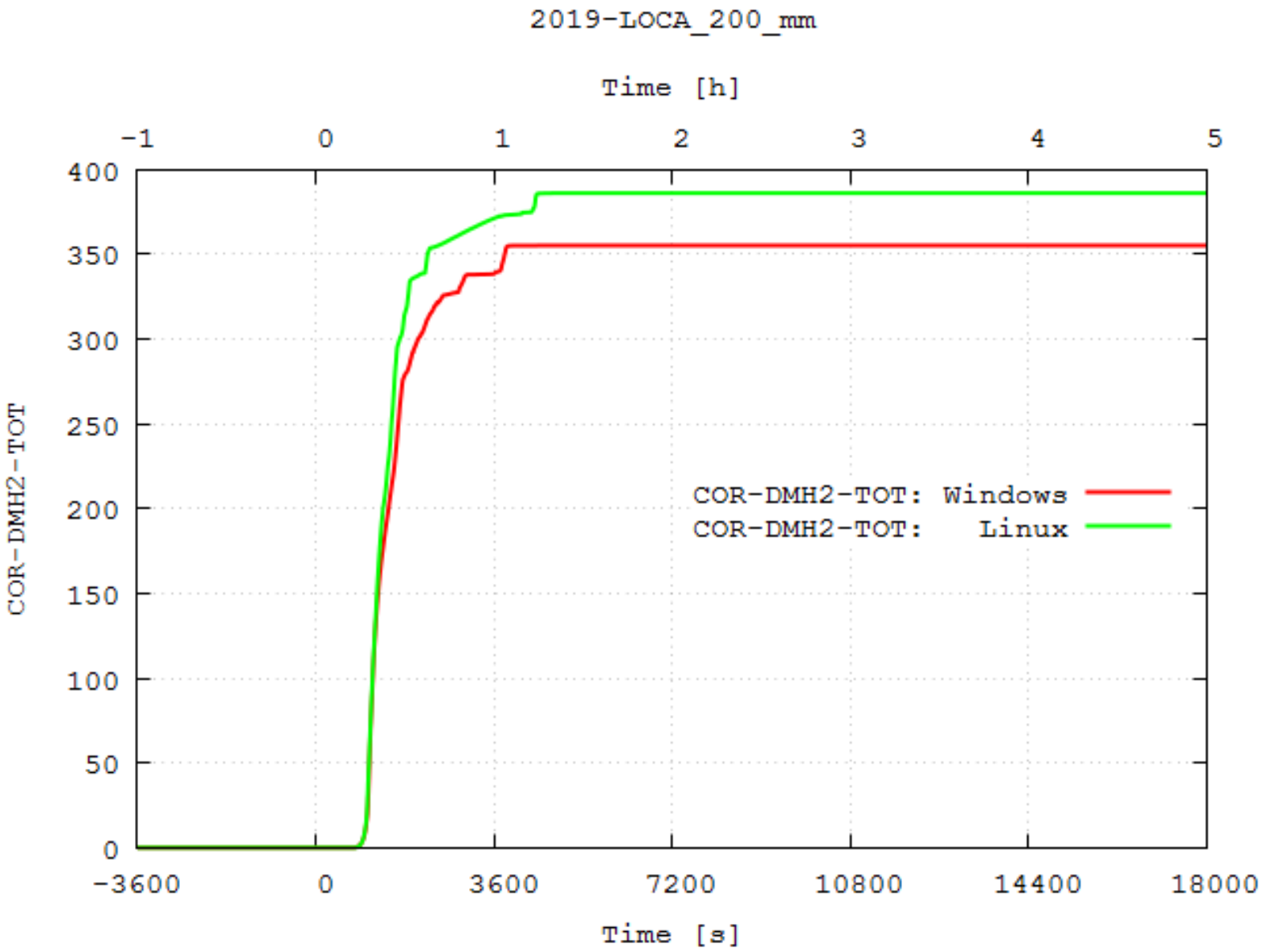
Windows vs. Linux: core pressure



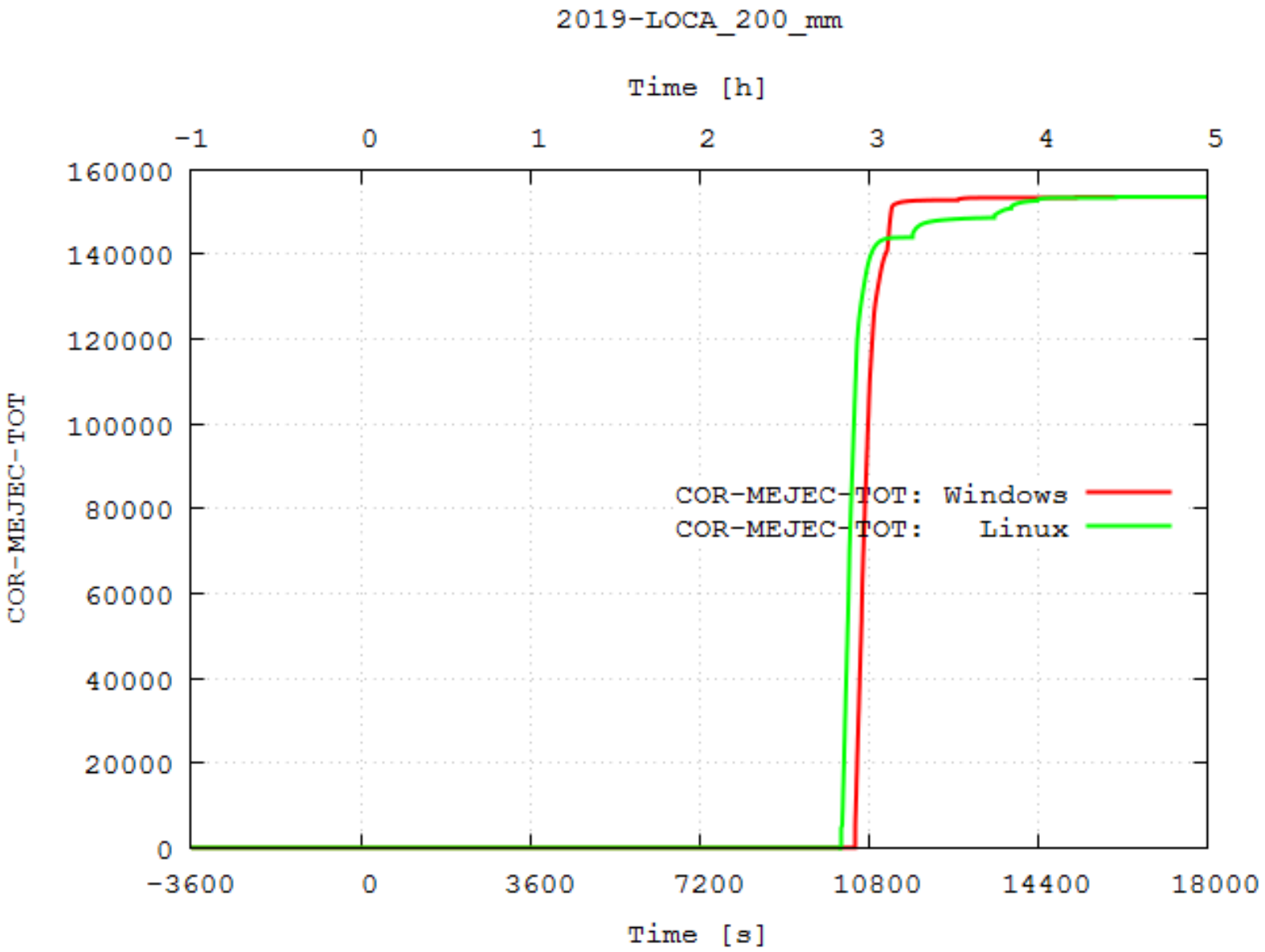
Windows vs. Linux: core temperature



Windows vs. Linux: H_2 production



Windows vs. Linux: melt ejected from a breached RPV



Forrtl errors

Forrtl error during intensive core degradation

- **200 mm LOCA for the VVER-1000 reactor**

- **forrtl: error (65): floating invalid** `coreu3_NSI.f90`
  - Δt_{max} = 1.0E-04 s => crash (CORDBD)
  - Δt_{max} = 1.0 s => OK ✓

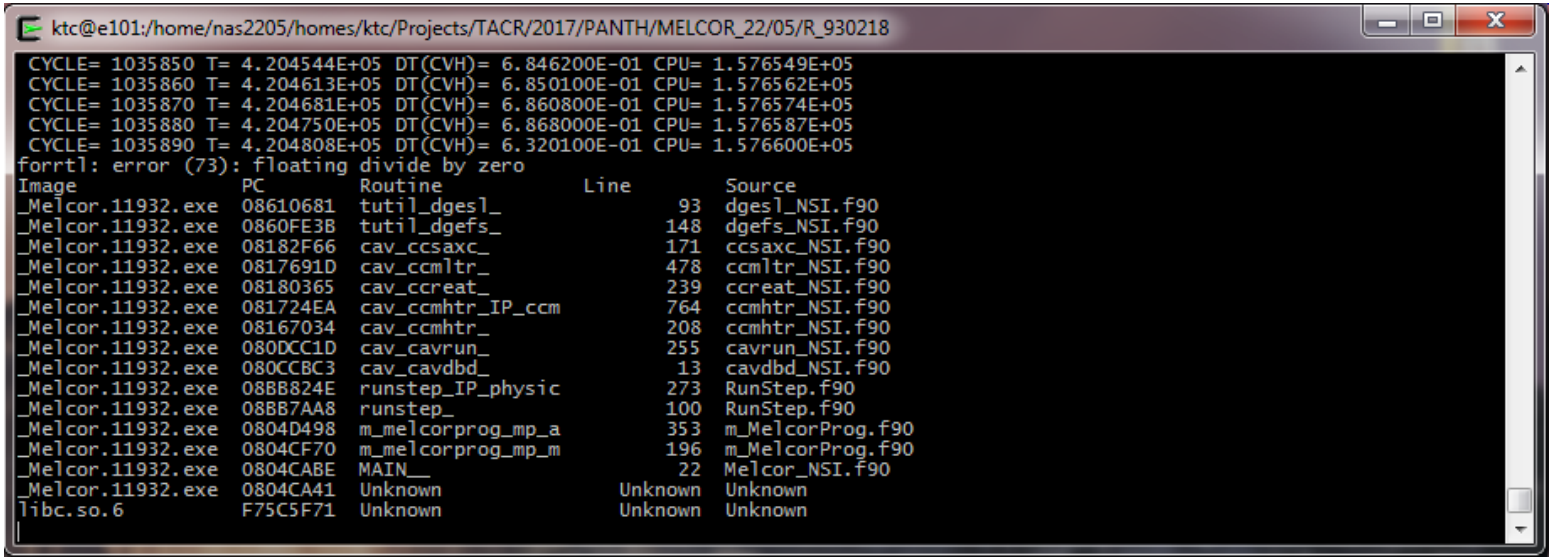
- **forrtl: error (73): floating divide by zero** `coreu3_NSI.f90`
  - Δt_{max} = 1.0E-04 s => crash
  - Δt_{max} = 1.0 s => OK ✓

- **Bug #2164 reported**

Forrtl error during MCCI

- **200 mm LOCA for the VVER-1000 reactor**

- **forrtl: error (73): floating divide by zero** `dgesl_NSI.f90`
  - Δt_{max} = 1.0E-04 s => crash
  - Δt_{max} = 1.0 s => OK ✓



- **Bug #2164 reported**

CCMLTR error during MCCI

- **200 mm LOCA for the VVER-1000 reactor**

- **CCMLTR**
  - Δt_{max} = 1.0E-04 s => crash (CCMLTR)
  - Δt_{max} = 1.0 s => OK

```
<Diagnostic Message> Time= 3.7303E+05 Dt= 1.7890E-01 Cycle= 1399223 (CAV) L,C= 3,2180800
 Warning message for cavity CAV_2
 * * * CCMLTR * * *, APPARENT CONVERGENCE FAILURE
 METAL/GAS/OXIDE Reaction in Bulk, for LMX
  RELATIVE ERROR IN TOTAL MASS =  4.0907E-16
<Diagnostic Message> Time= 3.7303E+05 Dt= 1.7890E-01 Cycle= 1399223 (MEX) L,C= 3,2180801
 REQUEST FOR FORCED PLOT DUMP SEQUENCE IGNORED. TOO MANY FALLBACKS.
 ALL FUTURE REQUEST DURING THIS EXECUTION IGNORED.
<Diagnostic Message> Time= 3.7303E+05 Dt= 2.8353E-01 Cycle= 1399224 (CAV) L,C= 3,2180802
 Warning message for cavity CAV_1
 * * * CCMLTR * * *, REDOING SOLUTION FROM NEW STARTING GUESS
<Diagnostic Message> Time= 3.7303E+05 Dt= 2.8353E-01 Cycle= 1399224 (CAV) L,C= 0,2180803
 Error message for cavity
 * * * CCMLTR * * *, MATRIX AK IS SINGULAR IN FIRST CALL TO CCSAXB
 ********** FATAL ERROR, EXECUTION TERMINATED
```

- **Bug #2164 reported**

Variable field names

Variable field names

- **MELCOR manual:**
  - The tagged placeholder on an input record includes the variable name and the default value enclosed in a set of triple curly parenthesis, {{{}}}, i.e., {{{SAREA=1.0}}}
- **Reality:**
  - Using the data

```
FL_ID       'PV_Inj'                          1101
...
FL_SEG      1
            1    {{{SAREA=2.00000E-01}}}      1.00000E-01      2.50000E-01
```

  - MELGEN response:
    - Diagnostics during input processing FL package:
      ERROR: Error in table: FL_SEG Row: 1 FLOW PATH: PV_Inj
      THE DATA IN FIELD 2 IS OF THE INCORRECT TYPE
- **What is wrong?**

Lipinski DHF model

Lipinski DHF model: definition

The COR package uses the Lipinski zero-dimensional correlation [21] to calculate the dryout heat flux, q_d, which is then applied as a limiting maximum heat transfer rate from a particulate debris bed (using the cell cross-sectional area rather than the total particulate surface area), which may occupy one or more axial levels:

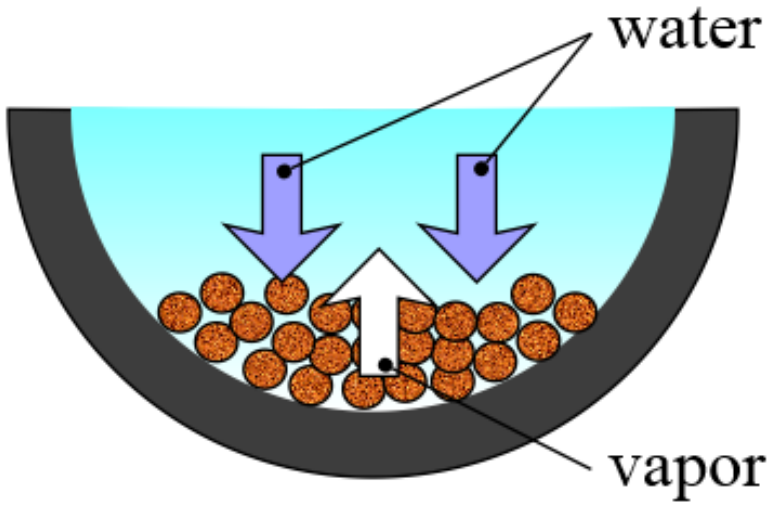
$$q_d = 0.756\ h_{lv} \left[\frac{\rho_v\ (\rho_l - \rho_v)\ g\ d\ \varepsilon^3\ (1 + \lambda_c / L)}{(1-\varepsilon)\left[1 + (\rho_v / \rho_l)^{1/4}\right]^4} \right]^{1/2} \qquad (2\text{-}114)$$

In this equation, h_{lv}, ρ_l, and ρ_v are the latent heat ,liquid, and vapor densities of water, respectively; g is the gravitational acceleration; d is the debris particle diameter; ε is the bed porosity; L is the total bed depth; and λ_c is the liquid capillary head in the debris bed,

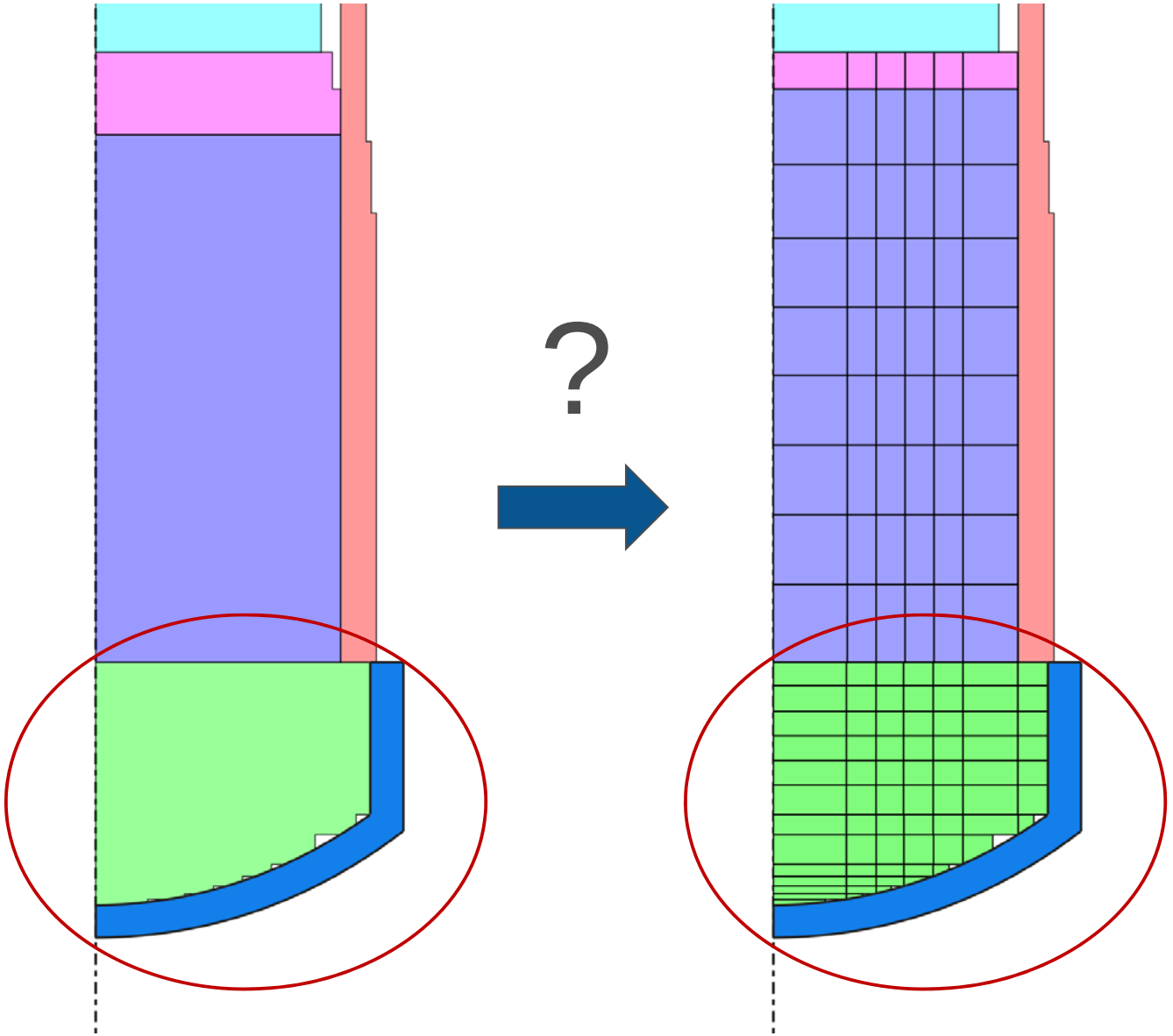
$$\lambda_c = \frac{6\ \sigma\ \cos\theta\ (1-\varepsilon)}{\varepsilon\ d\ (\rho_l - \rho_v)\ g} \qquad (2\text{-}115)$$

where σ is the water surface tension and θ is wetting angle. The leading constant, the nominal capillary head for 0.5 mm particles in approximately 0.089 m of water, and the minimum bed porosity allowed in the correlation are accessible to the user as sensitivity coefficient array C1244. A default minimum porosity of 0.15 was selected to ensure that some heat transfer occurs from molten debris pools. The actual capillary head is adjusted for particle diameter size within the model.

If one or more axial levels give heat transfer rates totaling the dryout maximum, no heat transfer is calculated for particulate debris or other intact structures below this axial level. Furthermore, in cells in which debris is undergoing quenching at the rate given by the dryout heat flux, no convective heat transfer to the pool is calculated for other components in that cell.



Lipinski DHF model: finer LP T-H nodalization



Thank you for your kind attention