Cool-ability of used fuel in storage racks

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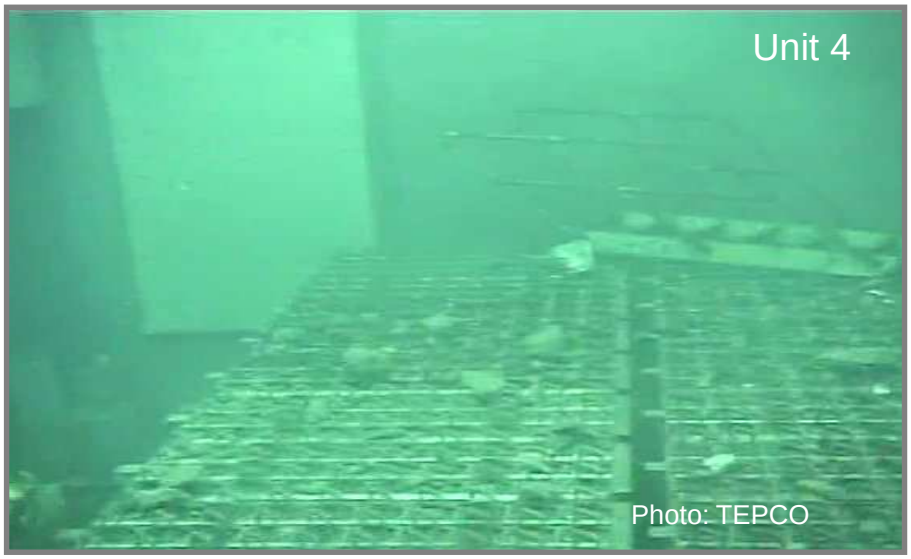
AREVA

Cool-ability of used fuel in storage racks

- **Fukushima**
  - **Contamination of Pool Water with Cs137**
    - Unit 1 (June): 14 GBq/m^3
    - Unit 2 (April): 150 GBq/m^3
    - Unit 3 (May): 150 GBq/m^3
    - Unit 4 (April) 0.055 GBq/m^3
  - **Oder-of Magnitude estimation**
    - Core Inventory ~1.E17 Bq Cs137
    - Spent fuel pool ~1000 m^3
    - if Cs from used fuel, then damage fraction is
      Unit 1: ~1.E-4; Unit 2/3 ~1.E-3; Unit 4 ~1.E-7

- ►Fuel elements in Pools are mainly intact



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►**Even so there is no major damage in the used fuel pools observed, the event triggered a discussion about the safety of used fuel pools in general.**

First Question: Under which circumstances does a used fuel pool burn, and under which not?

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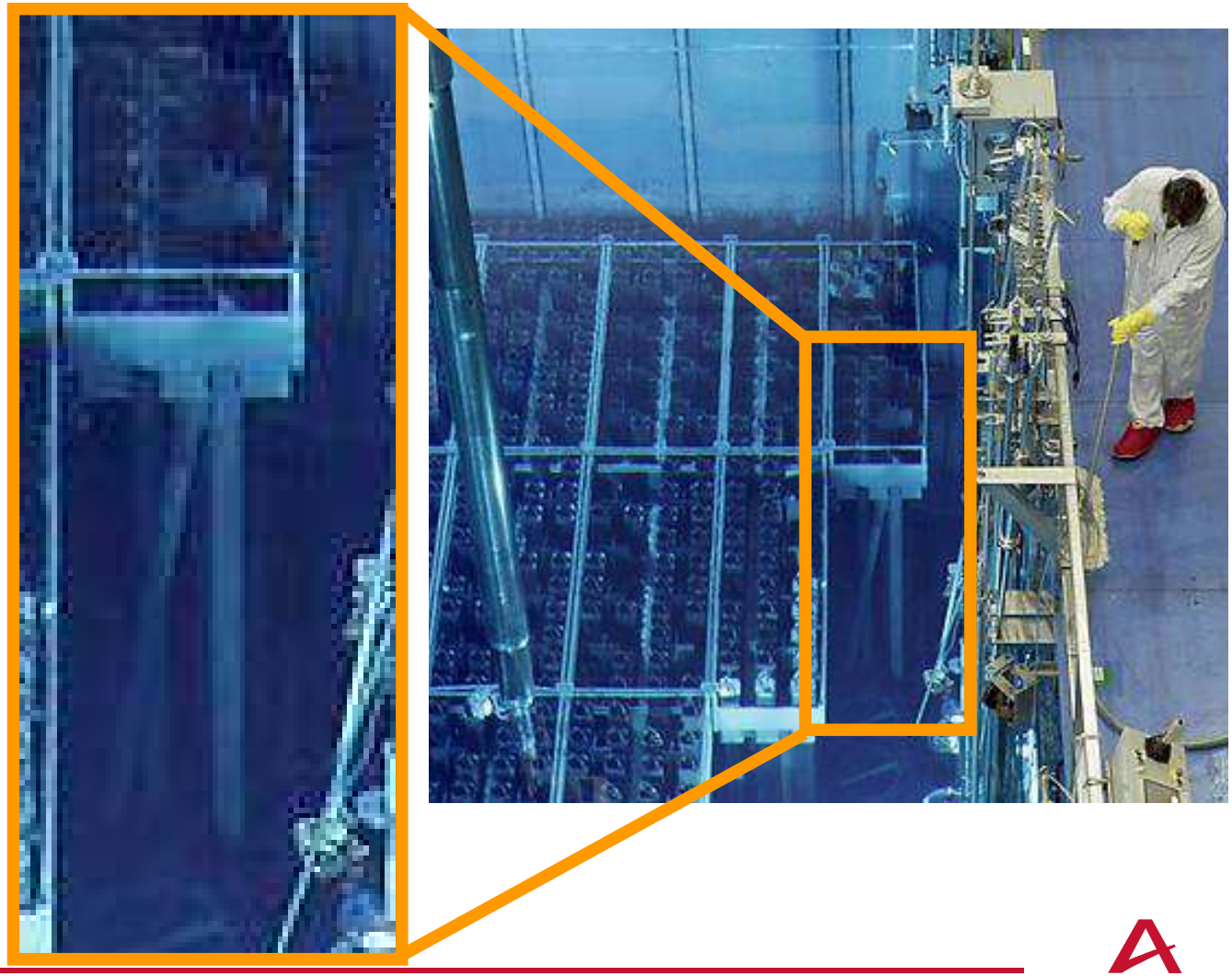
- **Examination of fuel pools in German boiling water reactor Series 69**
  - **Shutdown, in part for several years**
  - **Fuel Pool inventory < 0.5 MW**
  - **Non-compact storage racks**
  - **Open at side**
  - **Fuel assemblies stored with canisters on**



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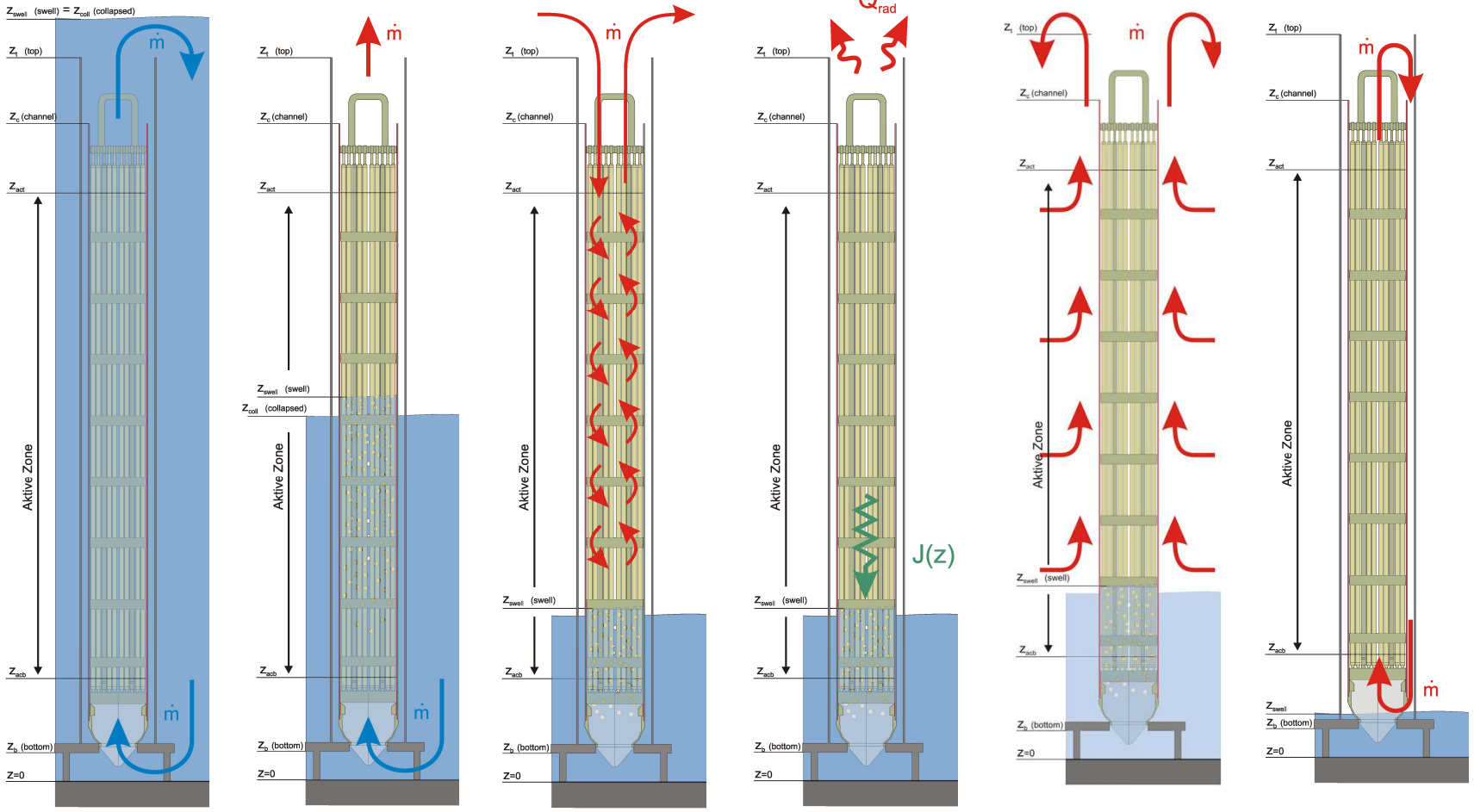
Cooling Mechanisms



Water natural convection | **Evaporation** | **Internal gas convection** | **Radiation & Conduction** | **External convection** | **Gas natural convection**

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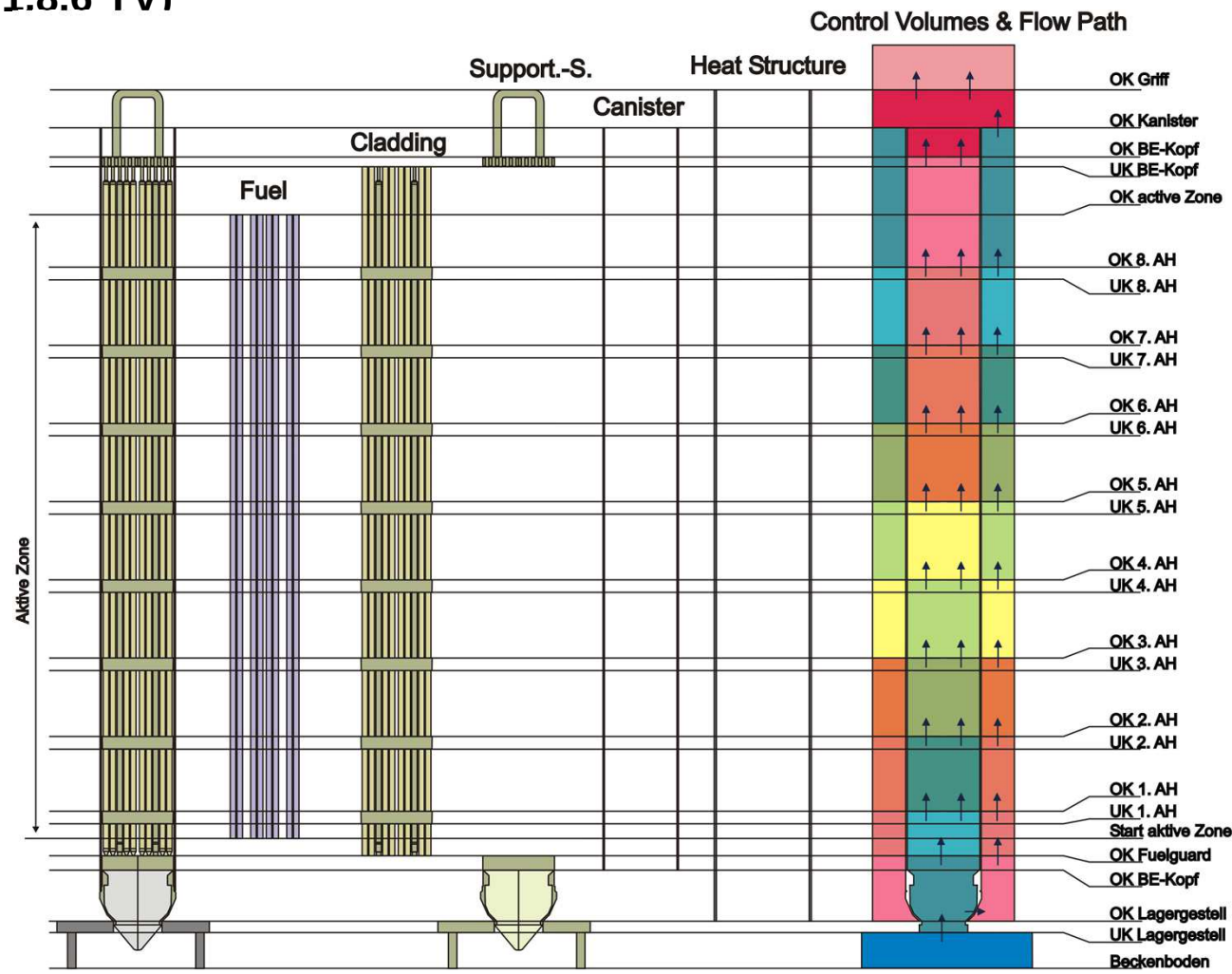
- **Fuel element modeling (MELCOR 1.8.6 YV)**
  - Each grid spacer in separate core level (account surface for Zr-oxidation)
  - Cladding includes skeleton and grid spacer (Zr-SS doesn't work)
  - Each segment between grid spacers own CVH
  - Axial CVH connected with 2 Flow Paths to allow gas-gas countercurrent flow
  - COR-boundary heat structure outside adiabatic -> mimicry periodic boundary conditions inside rack
  - Cross section as check value



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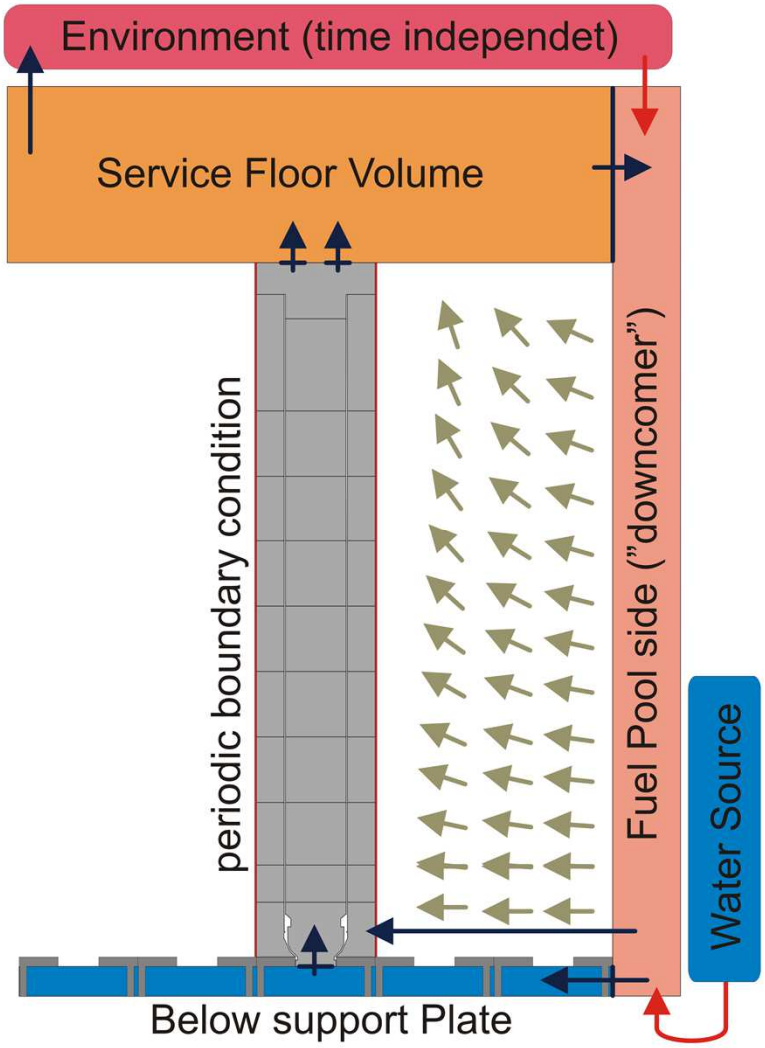
- **Environment modeling**
  - **Natural Circulation**
    Fuel -► Service Floor - ► Downcomer -► Below Plate -► Fuel assembly
  - **Ventilation**
    - Time-independent atmosphere
    - Controlled (m^3/s) fresh air inflow
    - Free outflow
  - **Fix water level based on CF**
    - Save time
    - Scanning through parameter sets
  - **Gas / Water flow in bypass**
    - Strongly dependent on rack design
    - Complex convection
    - Largest flow directly above plate (water) or water surface (gas/air)
    - Largest uncertainty, covered by parameter study



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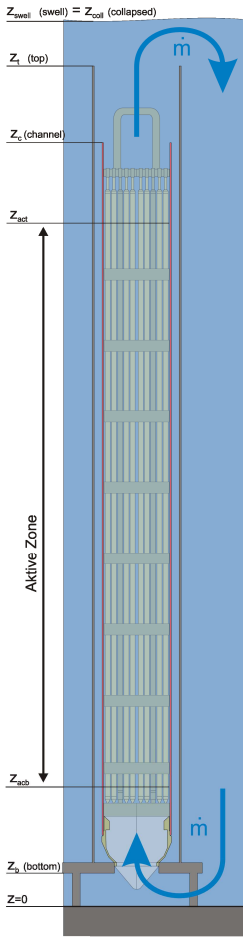
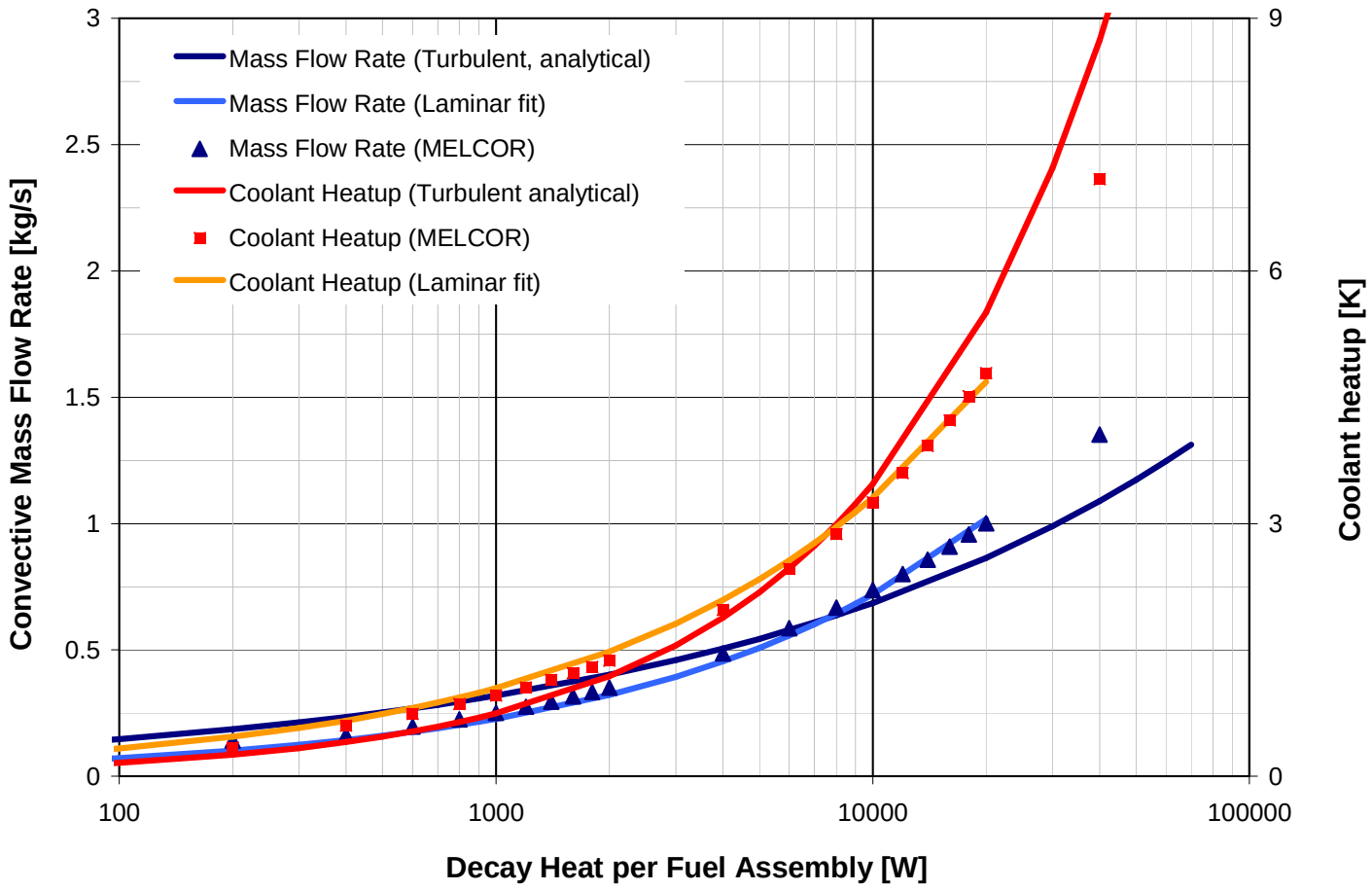
- **Water natural convection**





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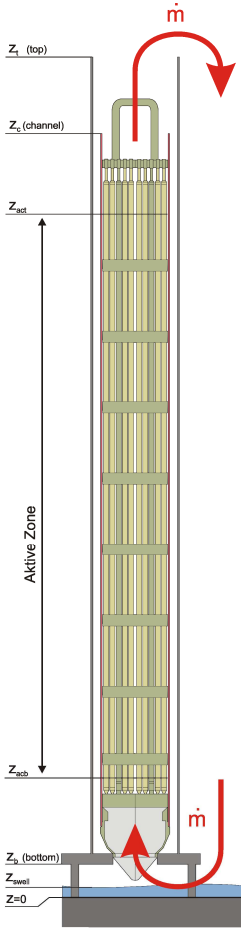
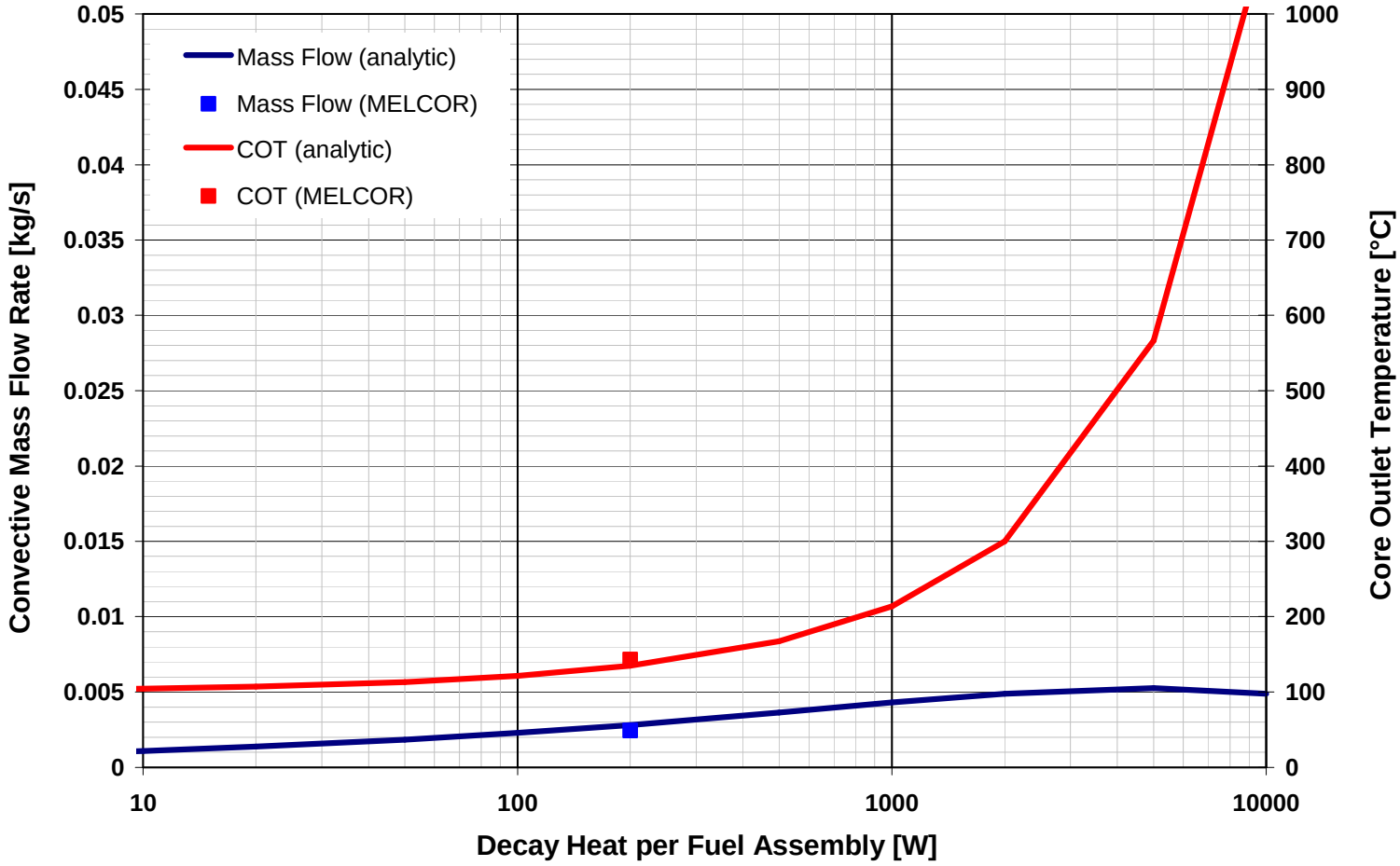
- **Gas natural convection (ongoing work)**





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Physical Conclusions

- **A fuel pool dry out does not necessarily lead to a major fission product release**
- **Accident strongly depends on the design of the fuel racks**

Technical Conclusions

- **Implementation of grid spacers and skeleton**
  - as Cladding Component is unsatisfactory (wrong Heat transfer during power operation)
  - as SS not possible, as Zr-SS don't work / collapse at simulation start
  - as NS is possible as long as no simulation of control rods
- **Vertically stacked CVH must be connected by two flow path, otherwise…**
  - ….a temperature inversion situations can not be relaxed
  - …. the time step drops to unsatisfactory values

Questions to the audience

- **What happens after melt down of the CORE boundary structures?**
- **Transfer- Package Full error - Unknown origin, unknown fix**