

Cool-ability of used fuel in storage racks

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Cool-ability of used fuel in storage racks

► Fukushima

◆ Contamination of Pool Water with Cs137

- Unit 1 (June): 14 GBq/m³
- Unit 2 (April): 150 GBq/m³
- Unit 3 (May): 150 GBq/m³
- Unit 4 (April) 0.055 GBq/m³

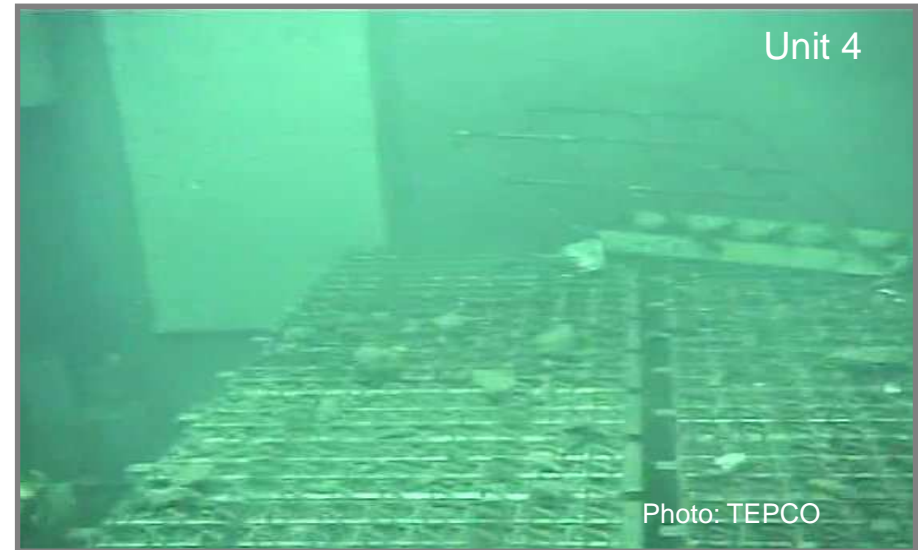
◆ Oder-of Magnitude estimation

- Core Inventory ~1.E17 Bq Cs137
- Spent fuel pool ~1000 m³
- 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

- 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?

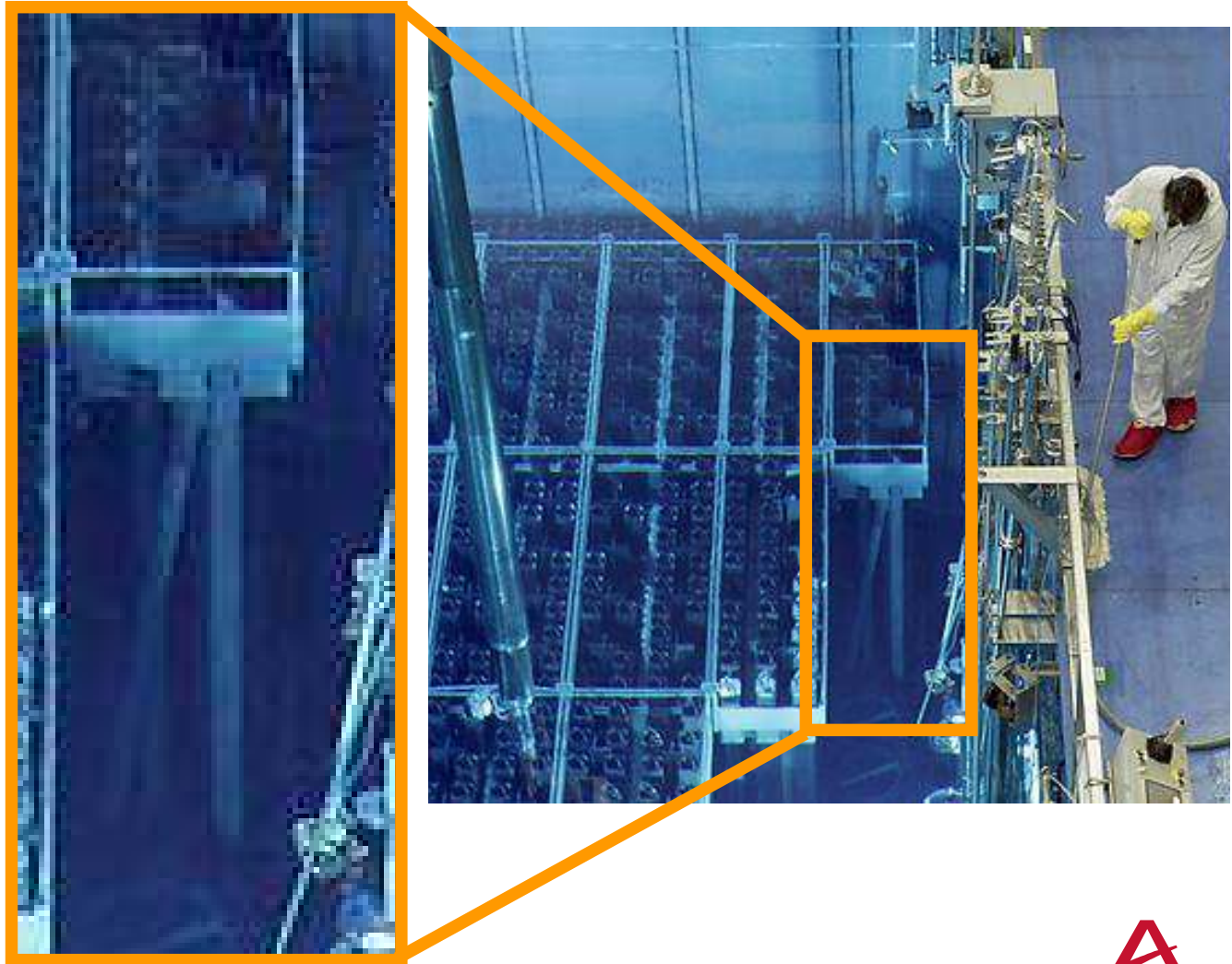


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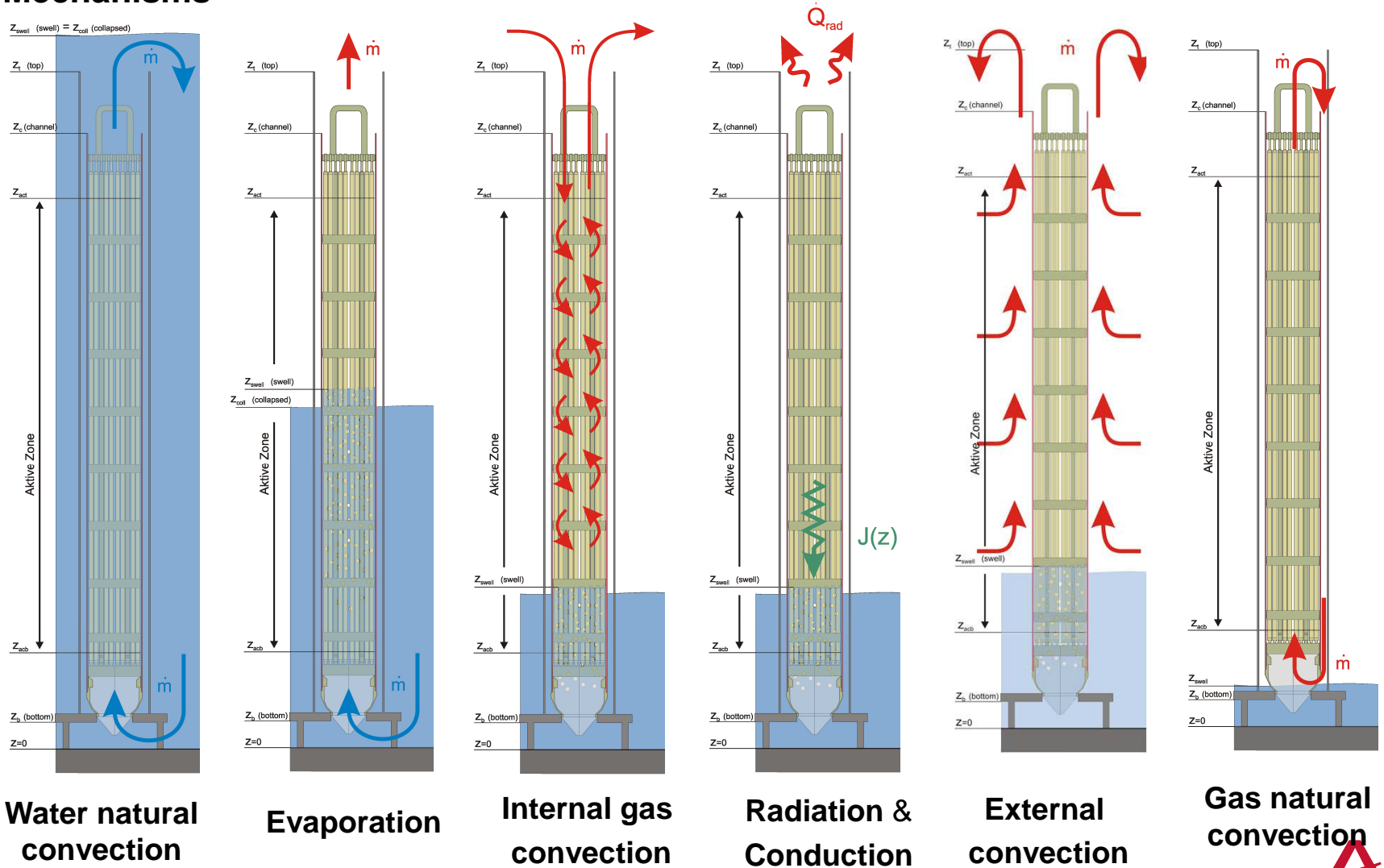
► Examination of fuel pools in German boiling water reactor Series 69

- ◆ 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



Cool-ability of used fuel in storage racks

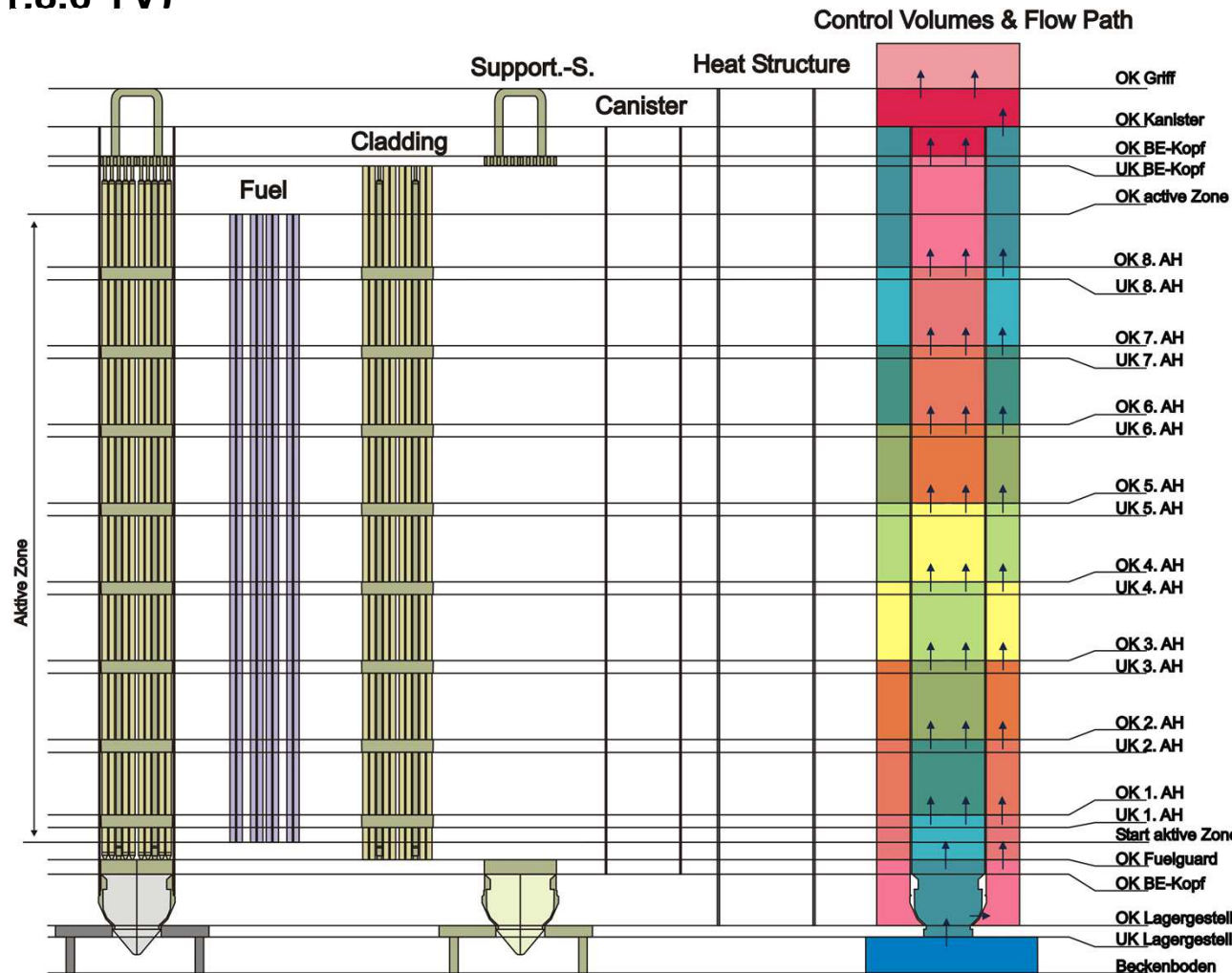
► Cooling Mechanisms



Cool-ability of used fuel in storage racks

► 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

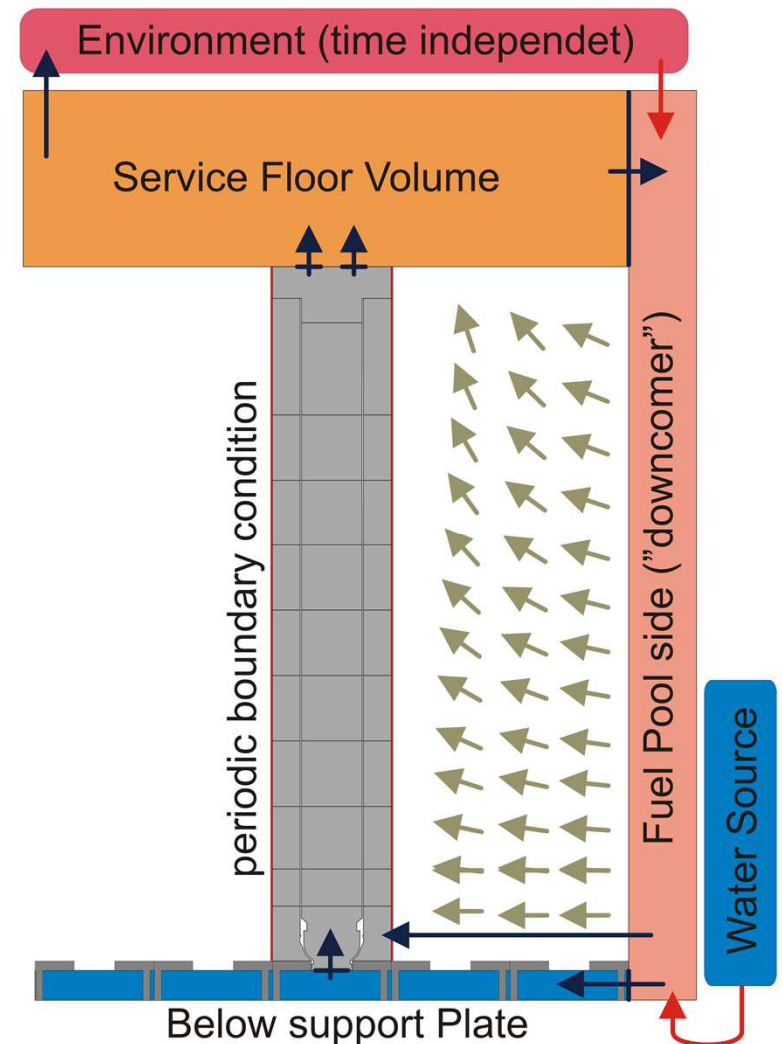
- Time-independent atmosphere
- Controlled (m^3/s) fresh air inflow
- Free outflow

◆ Fix water level based on CF

- Save time
- Scanning through parameter sets

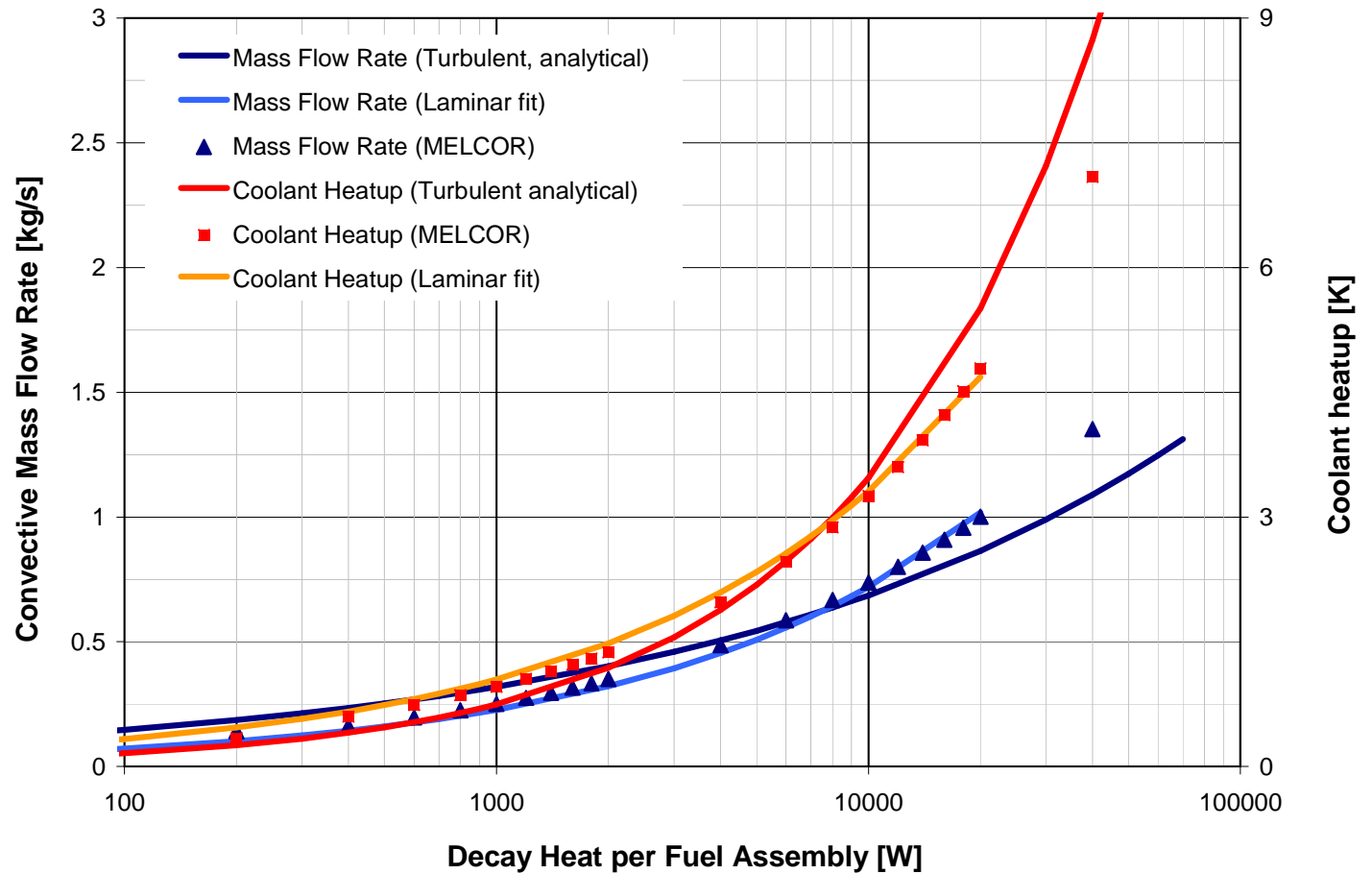
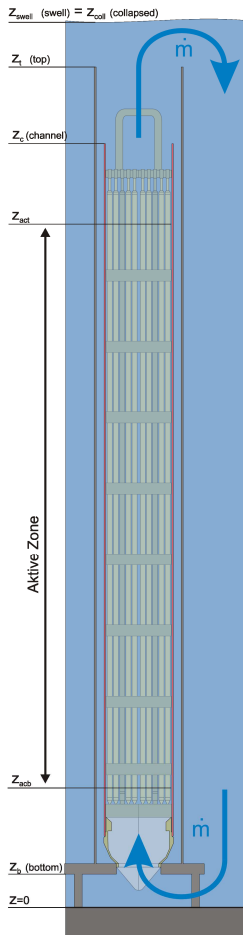
◆ Gas / Water flow in bypass

- Strongly dependent on rack design
- Complex convection
- Largest flow directly above plate (water)
or water surface (gas/air)
- Largest uncertainty, covered by parameter study



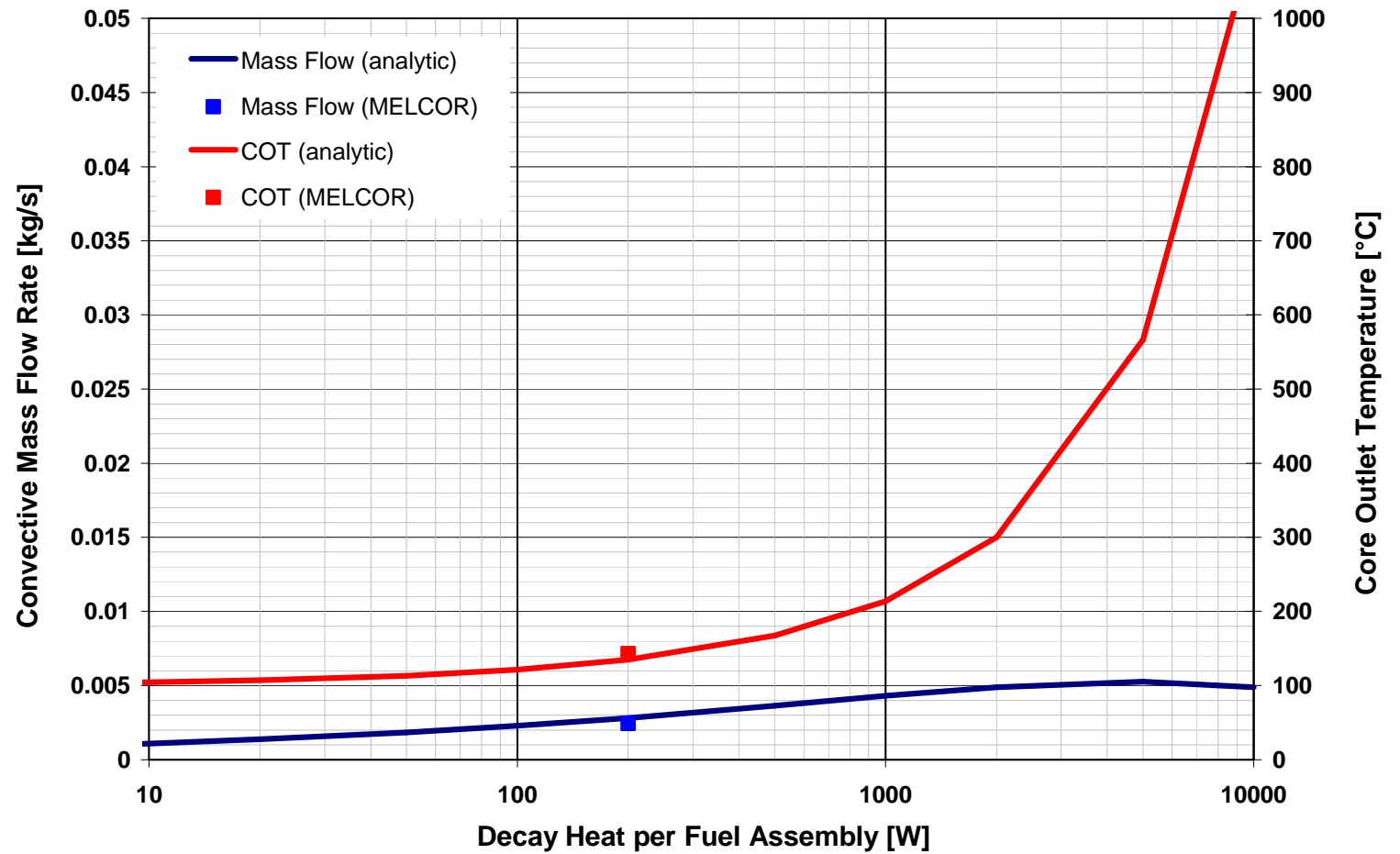
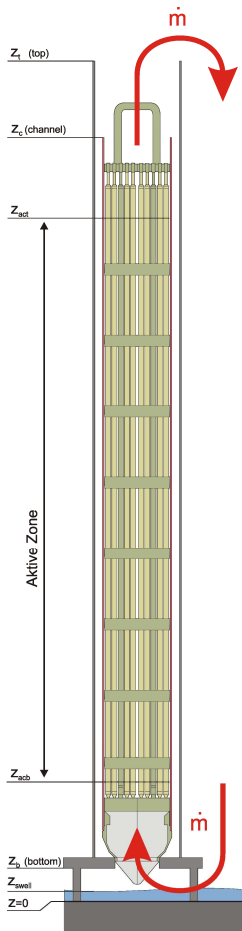
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► Water natural convection



Cool-ability of used fuel in storage racks

► Gas natural convection (ongoing work)



Cool-ability of used fuel in storage racks

▶ 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



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