FSUE SRI SIA “LUCH”
IBRAE RAS
FSUE EDO “GIDROPRESS”

Computational assessment (pre- and post-test) of fuel assembly tests in frame of the Project 3194

(ISTC Project # 3194)

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Dresden, 6-9 March 2007

Background of the PARAMETER-SF1 test

- The main goal of flooding experiments is to investigate bundle behaviour and the hydrogen source turn resulting from water injection into an uncovered LWR core
- Main feature of VVER is water injection into core from bottom and top simultaneously
- PARAMETER SF-1 is the first experiment modeling behaviour of overheated VVER bundle in uncovered core under conditions of top water injection
- General answer from planned set of PARAMETER tests is experimental data for severe accident management instruction development
- These data include:
  - bundle cooling possibility
  - structural elements status
  - Hydrogen release

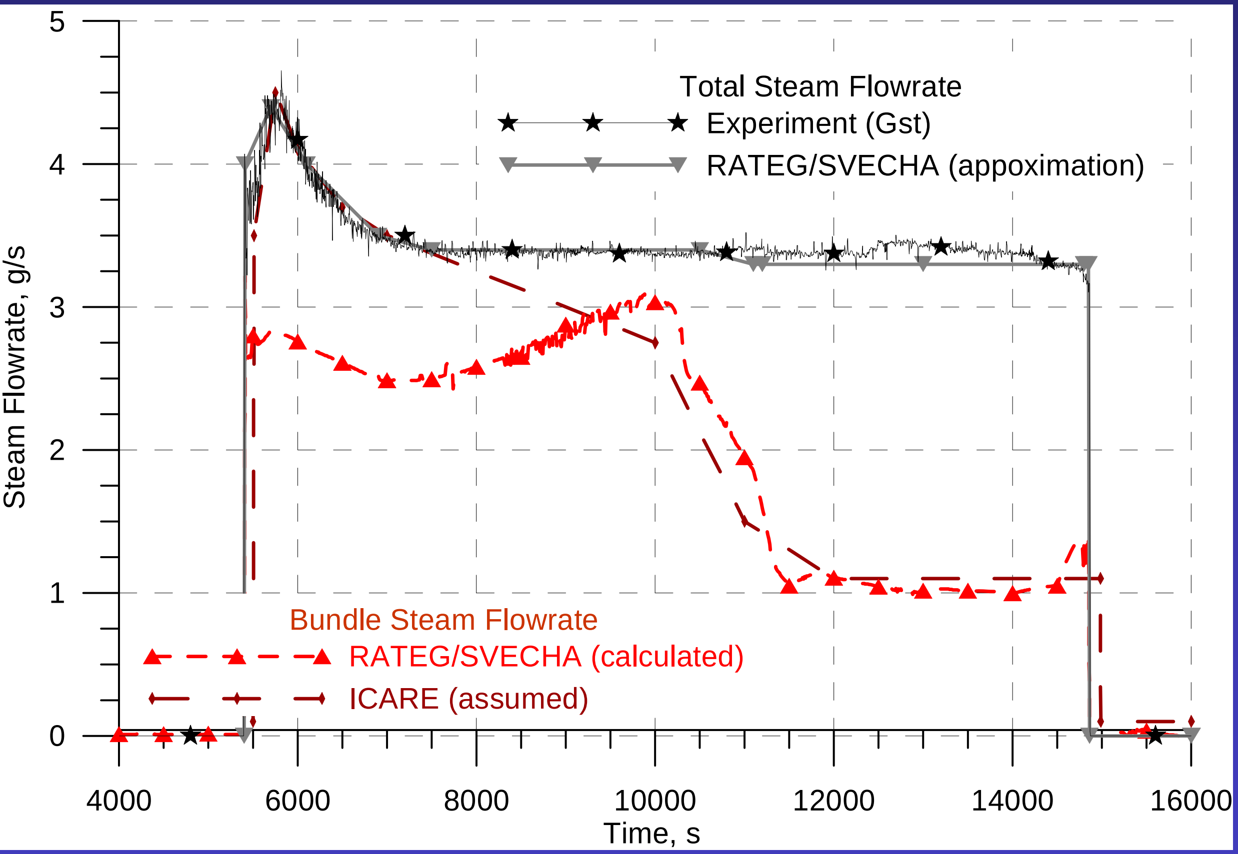
Analytical assessment of measured data

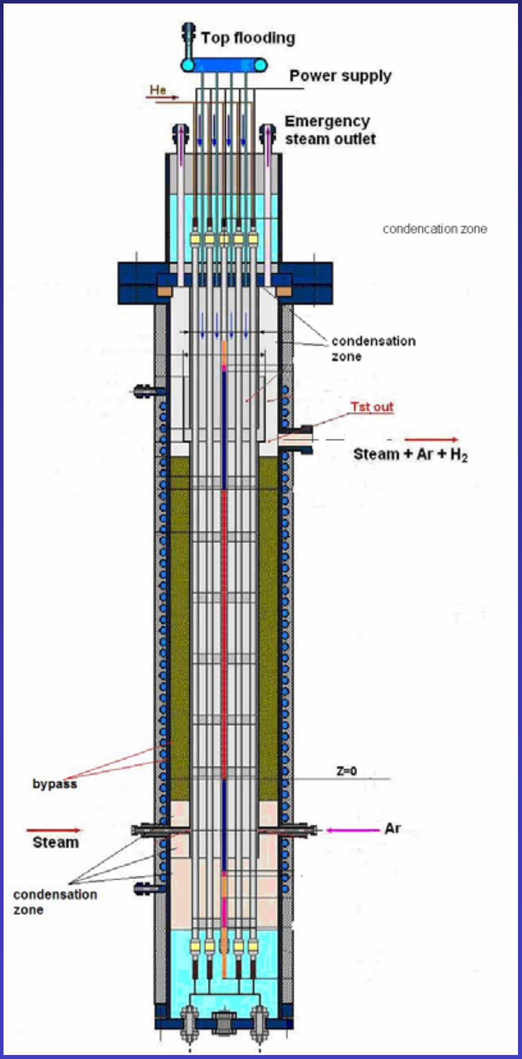
- Goal – to verify codes models against obtained experimental data
- Used codes (pre- and post-test calculations) - RATEG/SVECHA, RELAP , MELCOR 1.8.5, PARAM TG, ICARE/CATHARE, ATHLET, MAAP4.
- Participants IBRAE, KKC KI, GIDROPRESS, NPO LUCH, GRS, EdF.

Main phenomena

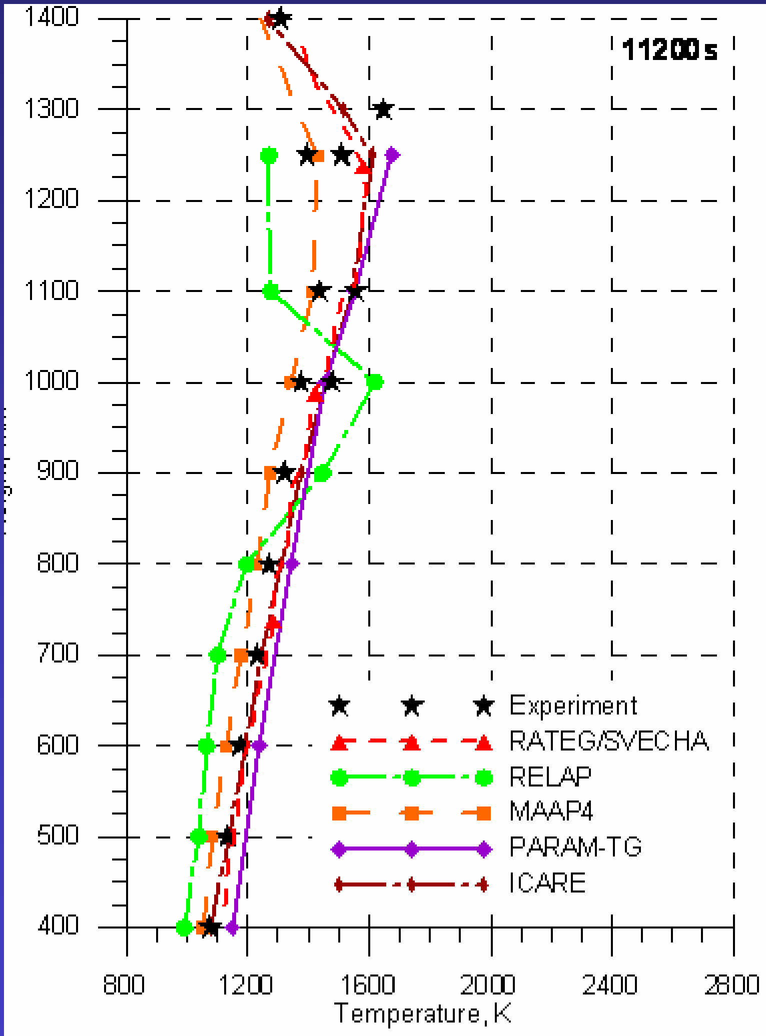
- Steam condensation
- Oxidation of claddings, shroud, spacer grids
- Zr melting
- UO_2, ZrO_2 dissolution with melt
- Water ejection due to CCFL
- Metallic and oxide melt relocation
- Oxidation of melt
- Melt solidification

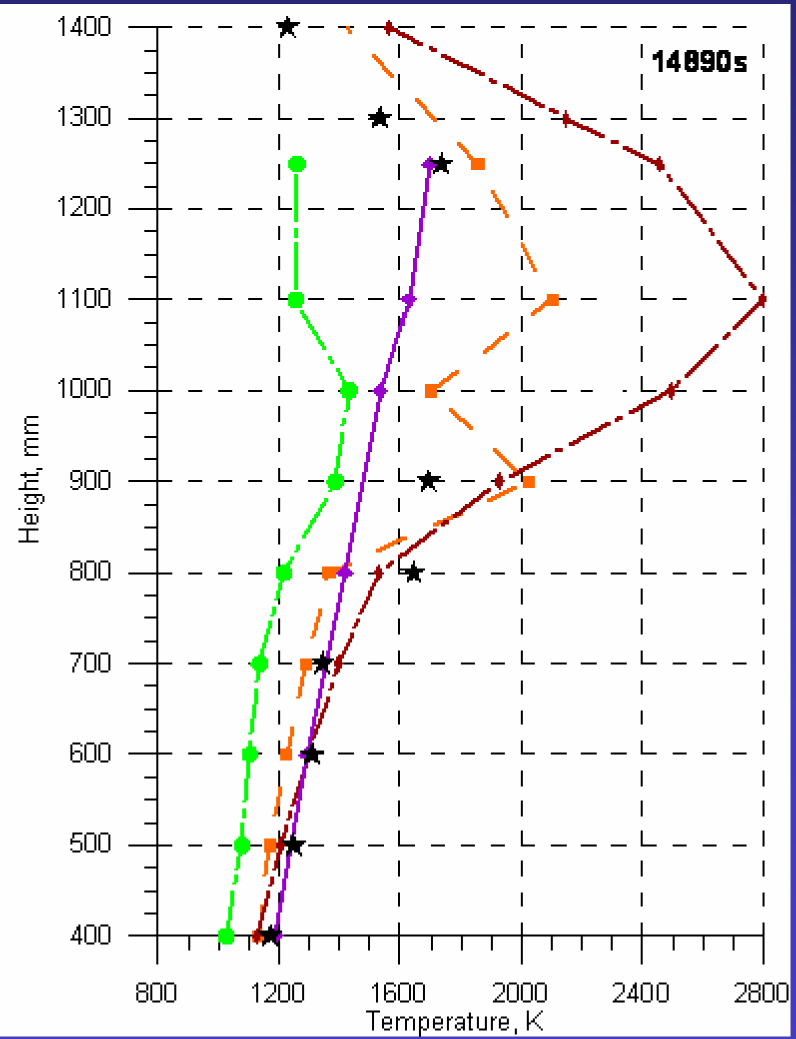
Steam condensation



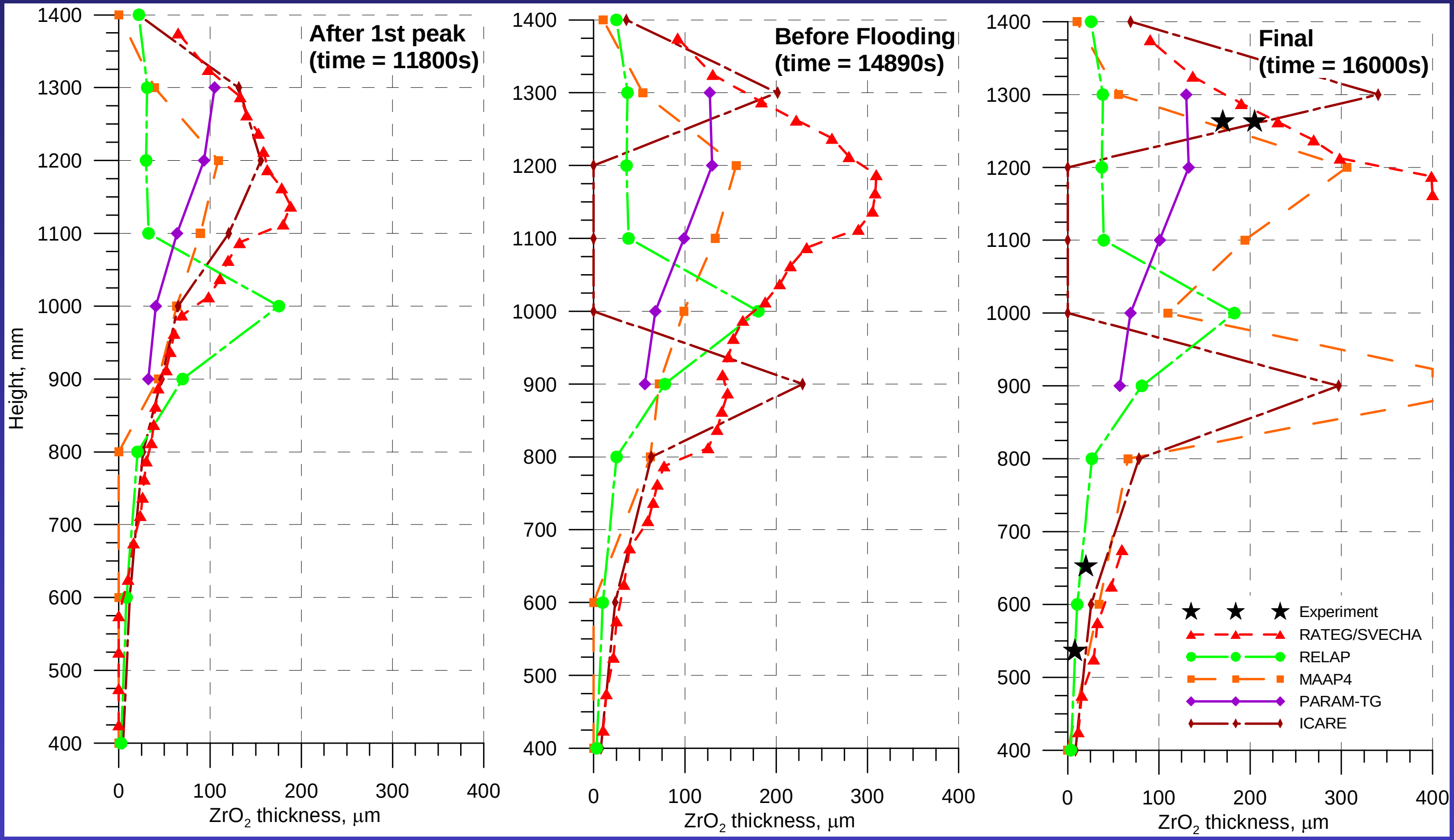


Temperature front propagation



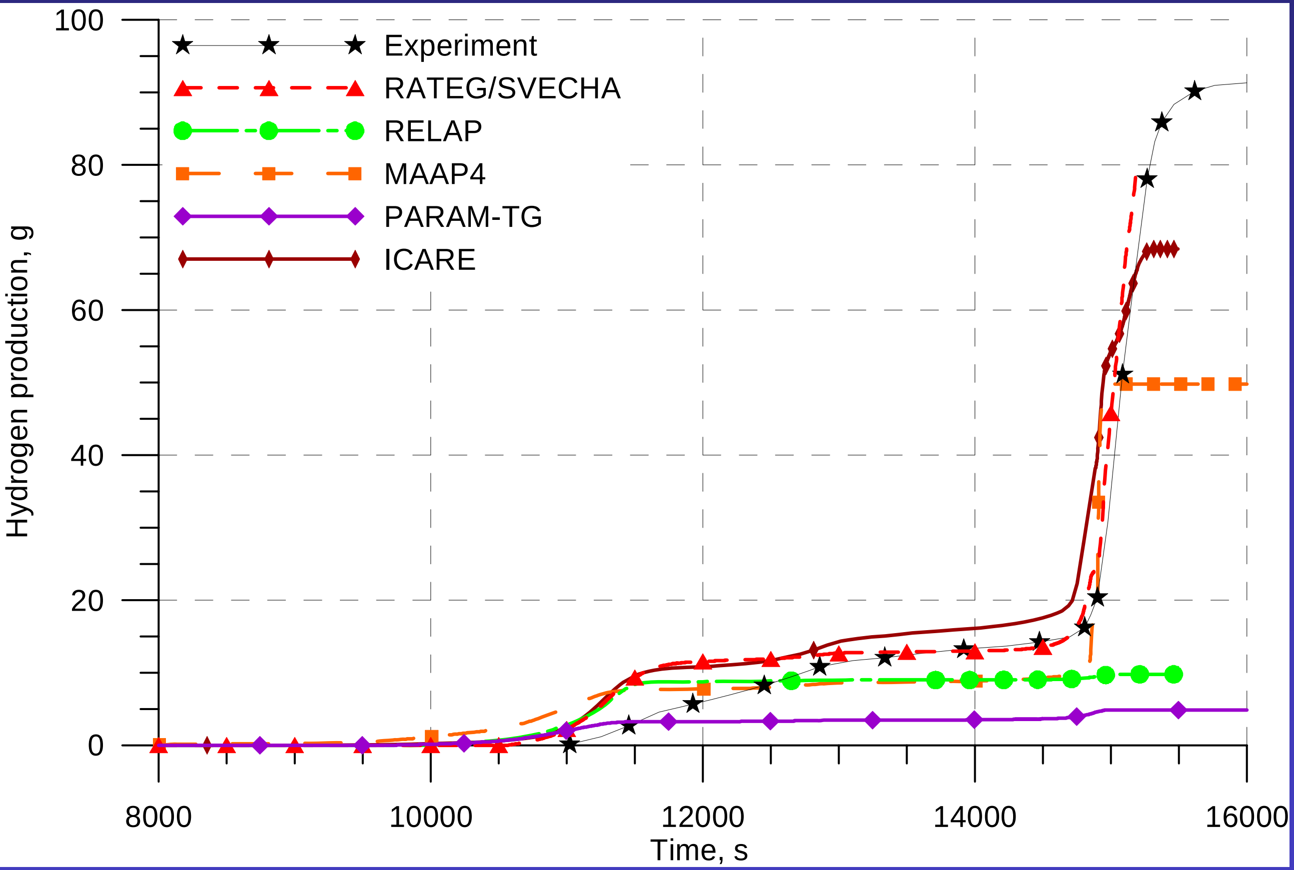


Cladding oxide scale distribution



Хочу больше звездочек

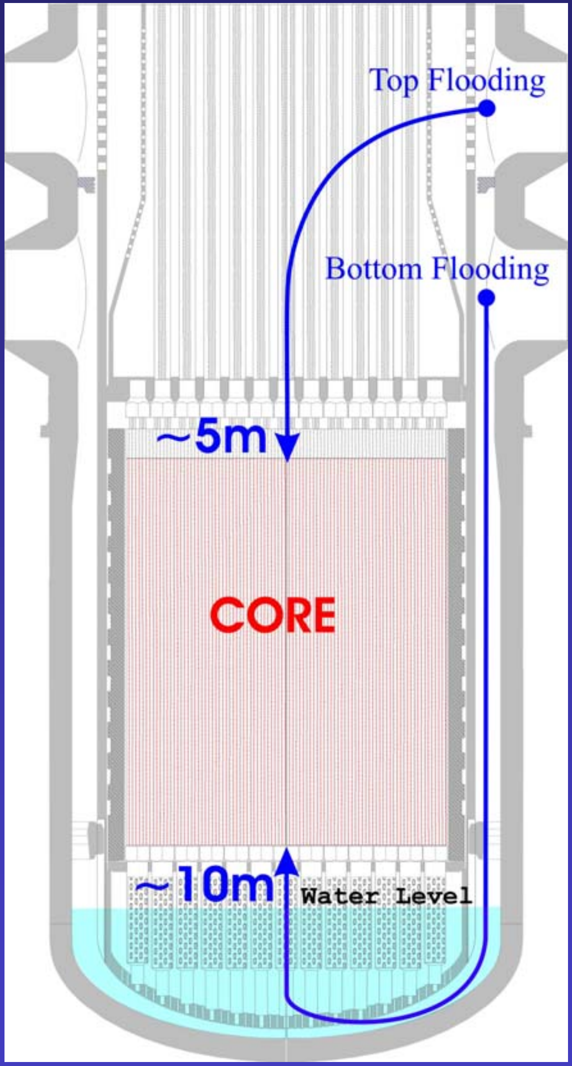
Hydrogen Production



General SF1 outcomes

- SF1 Experimental data are well consisted (temperature, oxide scale thickness, UO2 dissolution, hydrogen release) and is generally well predicted by codes.
- SF1 test justified that the top flooding of overheated >2000C lead to:
  - Significant rod cladding degradation (to 40%)
  - Increase of produced hydrogen total mass by factor of 3 (30 g before quenching staring and 91 g is total mass)
- SF1 test provided valuable outcomes to be used for in VVERS SAM procedures development and verification
- Additional test are expected to extend data about VVER bundle behavior under top/bottom flooding conditions

SF2 test justification



- VVER-1000 Large Break LOCA with Blackout simulation
- Top & Bottom flooding by (with) ECCS (pumps) in case of power restore
- Flooding rate depends on (the) type and (the) number of (the) pumps in (under) operation
- Minimal flooding rate ~4 g/s per rod
- Pressure ~3÷4 ata (atm)
- Boiling or saturated water in vessel

Objectives and Tasks (1)

- To obtain data on FA & grids deformation which may affect on rods cooling
- To define FA temperature field and flow area non-uniformity (angle and radial) influence on cooling front propagation
- To summarize results on adequacy of 3D effects modeling by 1D codes
- To assess oxidation models

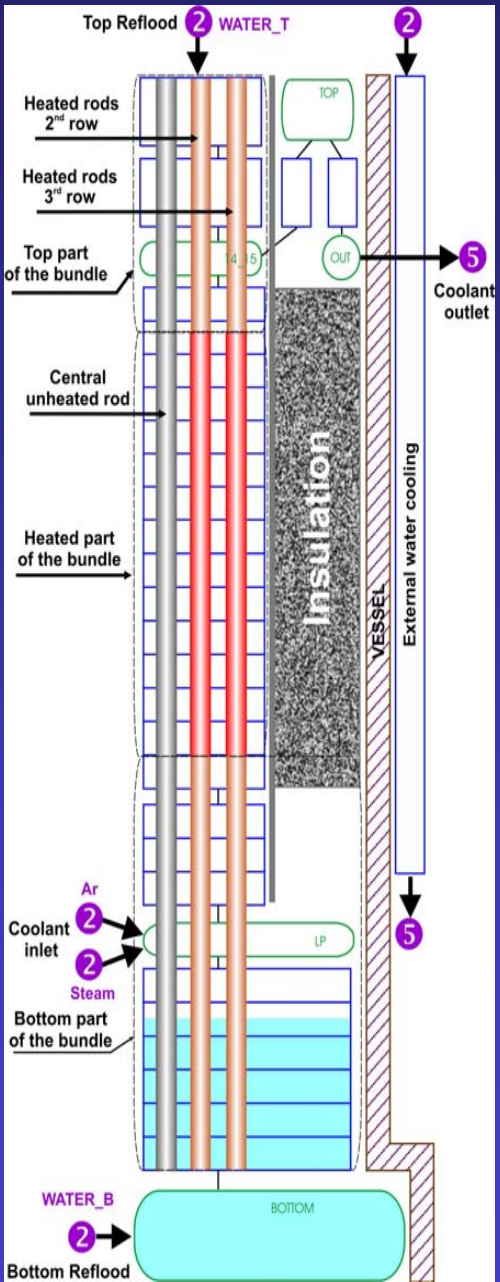
Objectives and Tasks (2)

- Collect data for heat exchange models assessment during flooding phase
  - Using measured TC data together with calculated phases velocities and volume fraction assess heat transfer coefficients, estimate model parameters and limitations in experiment conditions
  - Find out the evaporation rate for CCFL models enhancement

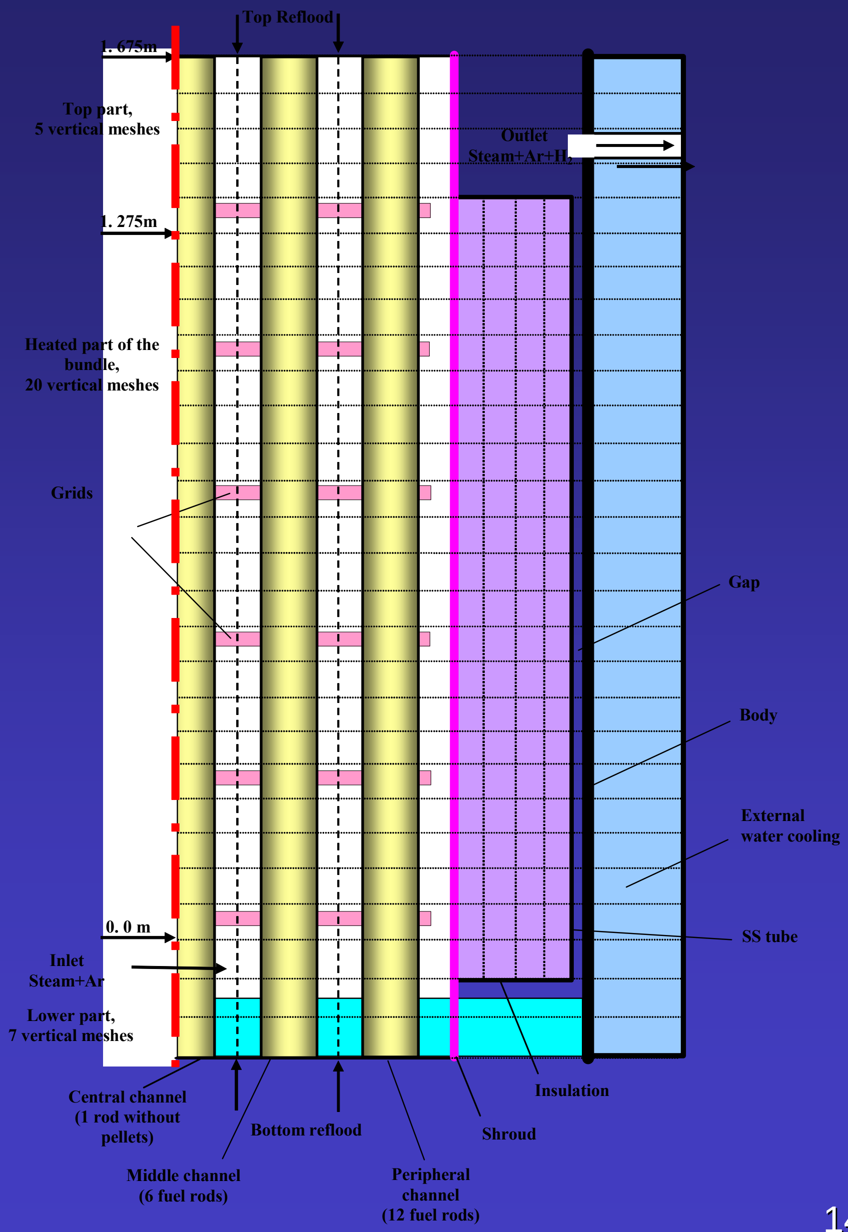
Objectives and Tasks (3)

- Collect data for CCFL model improvement during flooding phase
  - Measure integral water partition: ejection, evaporation, bundle filling
  - Based on these data and test section stored energy verify and improve heat transfer and Counter Current Flow Limitation models

SOCRAT



ICARE



Modeling Problems

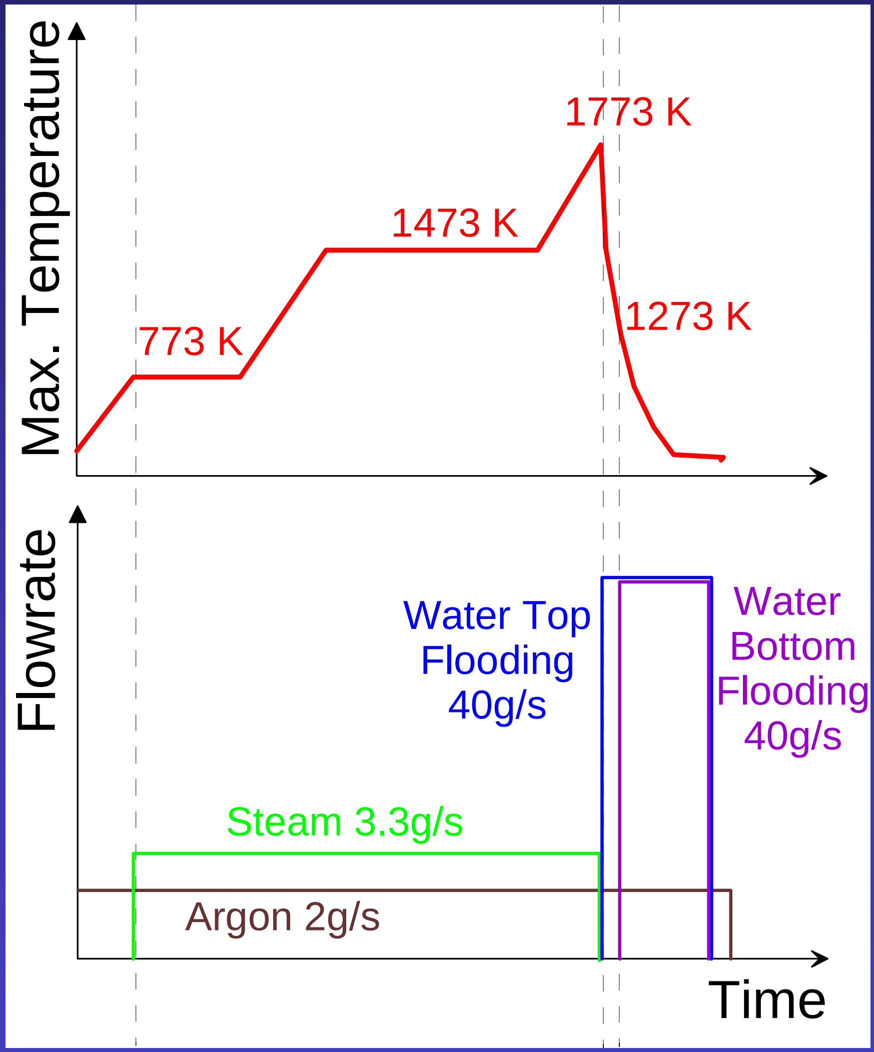
SOCRAT/B1

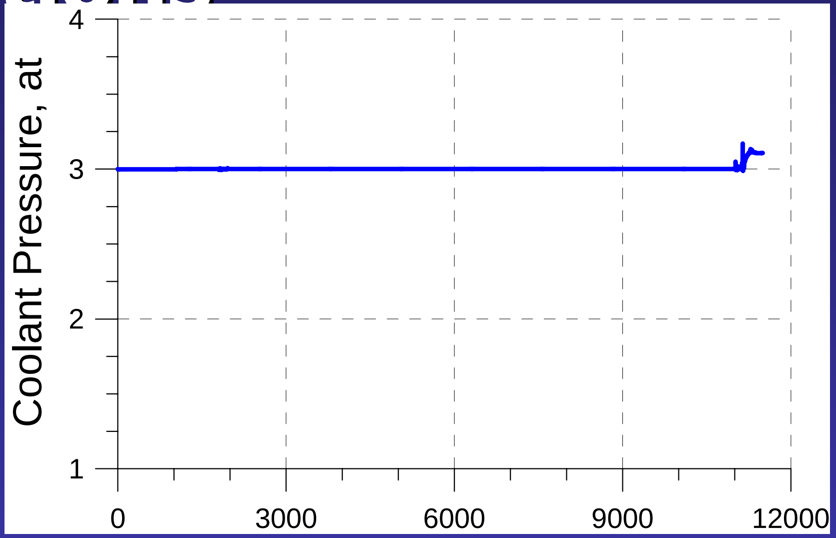
- Absence of special top reflooding model, base wall heat transfer and interface friction models were used
- Absence of grid model, grids not modeled

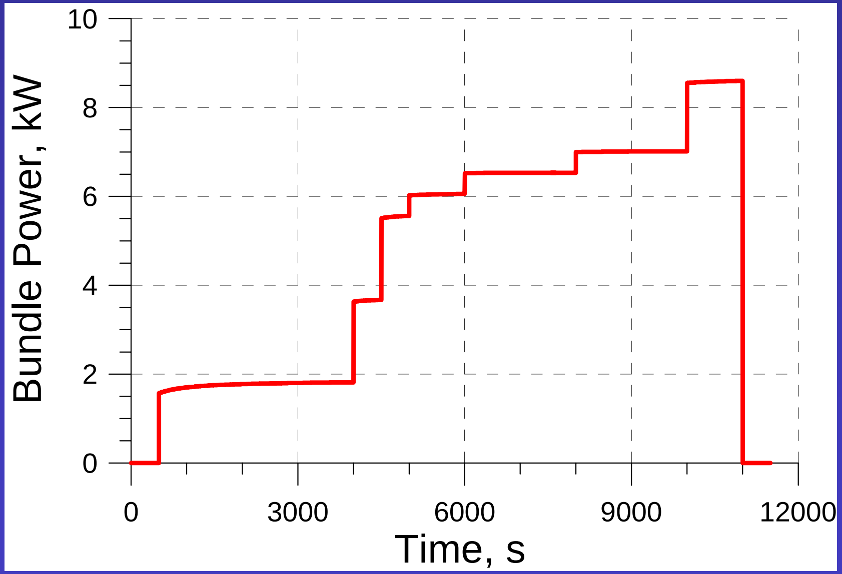
ICARE/CATHARE V1

- Absence of special top reflooding mode.
- Current modeling of top reflood involves only equilibrium water+steam downward movement.

Proposed PARAMETER-SF2 test conditions



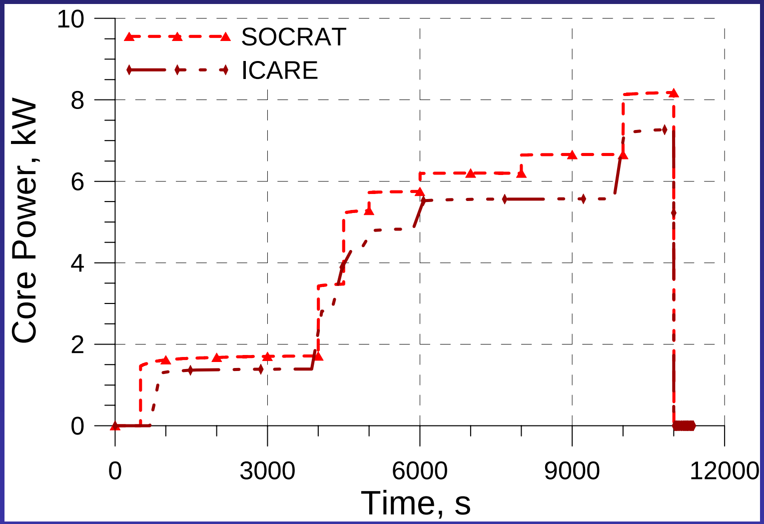


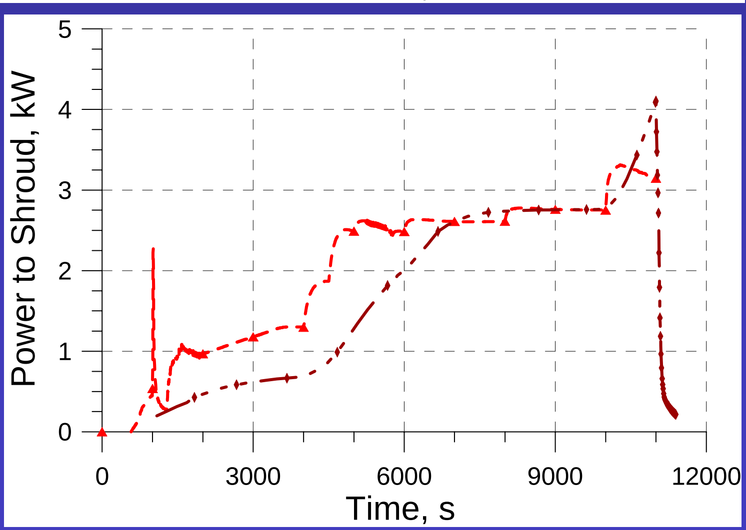


Sensitivities

- Assessment of required power level for pre-oxidation phase (~1470K)
- Assessment of acceptable temperatures deviation and delay of beginning of water injection
- Pre flooding water level assessment – to avoid unpredictable early flooding from bottom by steam or flashing

Power balance





Pre-oxidation stage

- Total power ~6÷7 kW
- Core power ~5.5÷6.5 kW
- Response ~100 K/kW

Transient phase II

- Total power ~9 kW

Heat loss to shroud

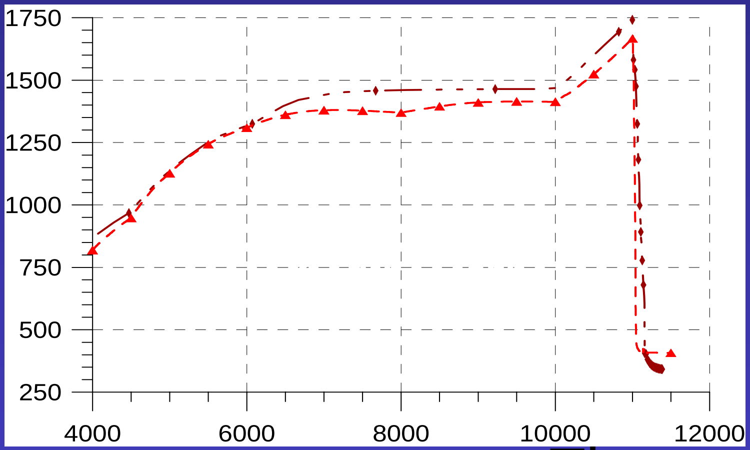
- ~50% of total power
- No significant temperature dependence on steam flow rate

Bundle hottest zone

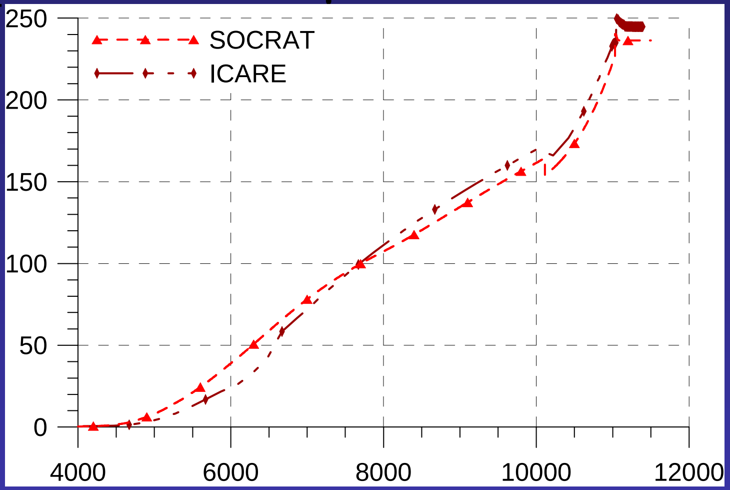
Maximum cladding temperature at 1250 mm (6 thermocouples)

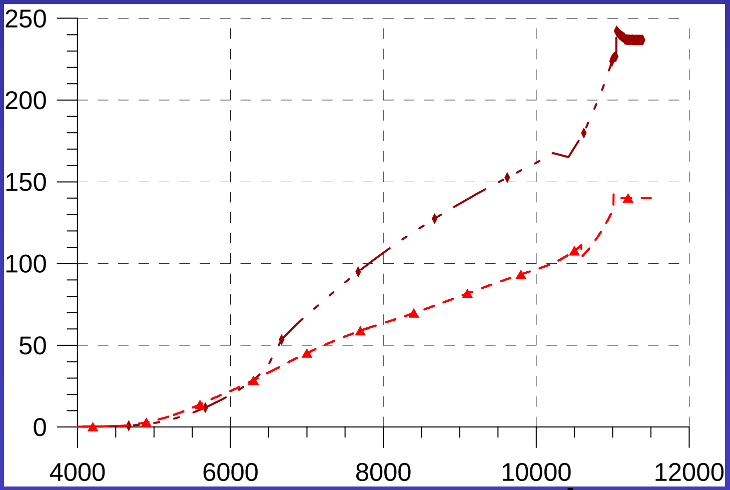
ZrO_2 thickness, μm

Temperature, K



Time, s





Time, s

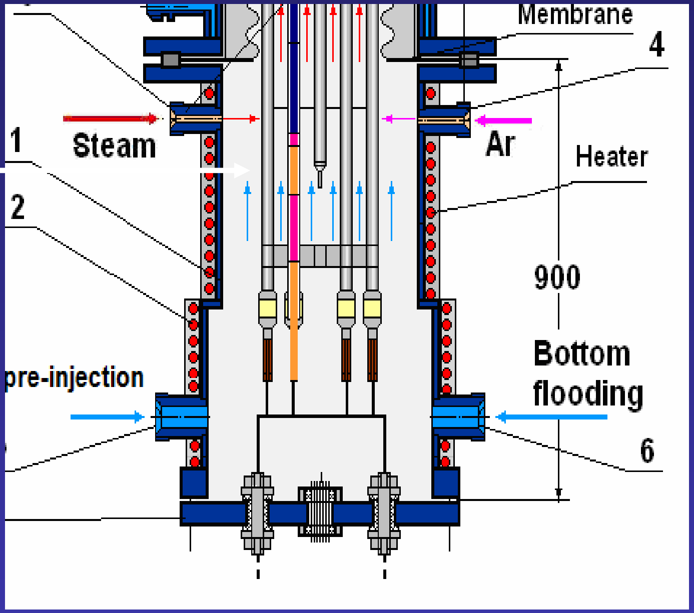
Calculated Max Temperatures

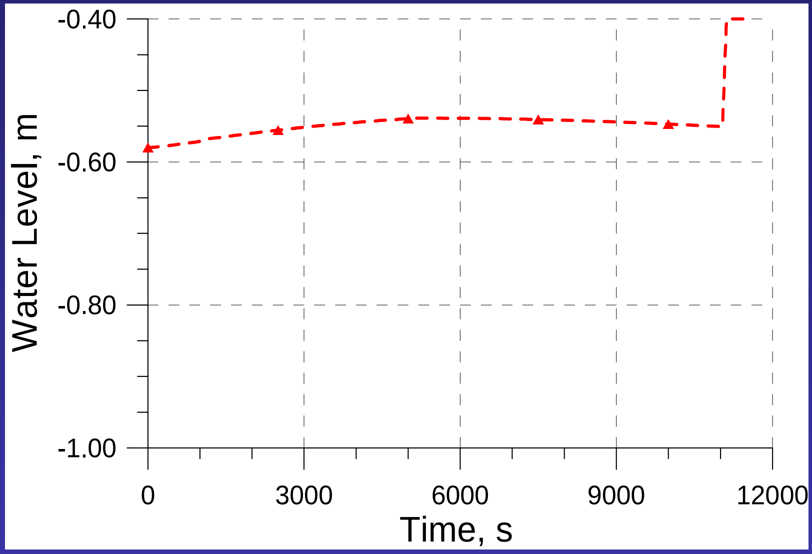
SOCRAT 1200 ÷1250mm

ICARE 1250 ÷1300mm

Test section water level

proposed



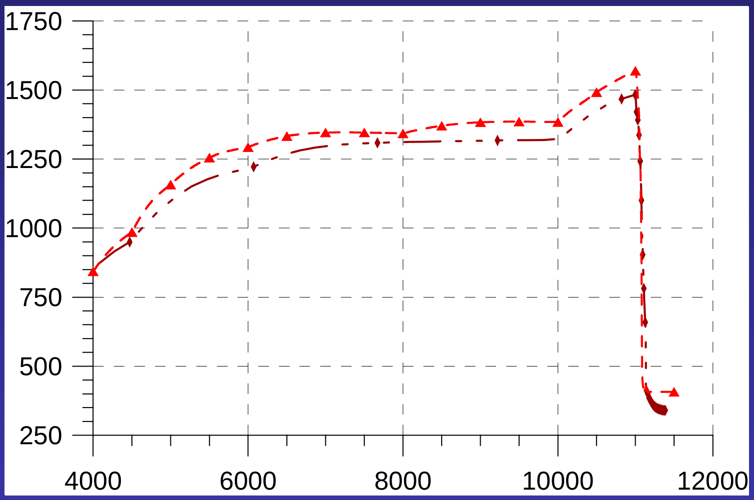


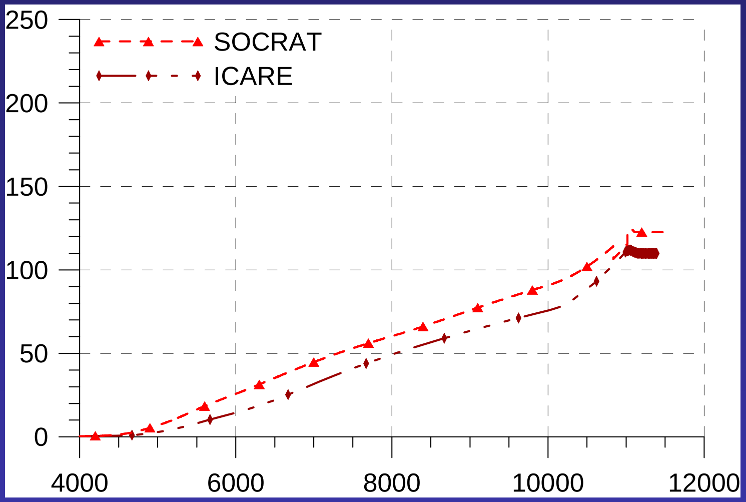
- Water level relevant to VVER-1000 SFD simulation
- Reduction of quench water impact on bottom chamber structures (electrodes degradation, FA cooling by steam)
- Assessment of body temperature and heater power calculated by SOCRAT

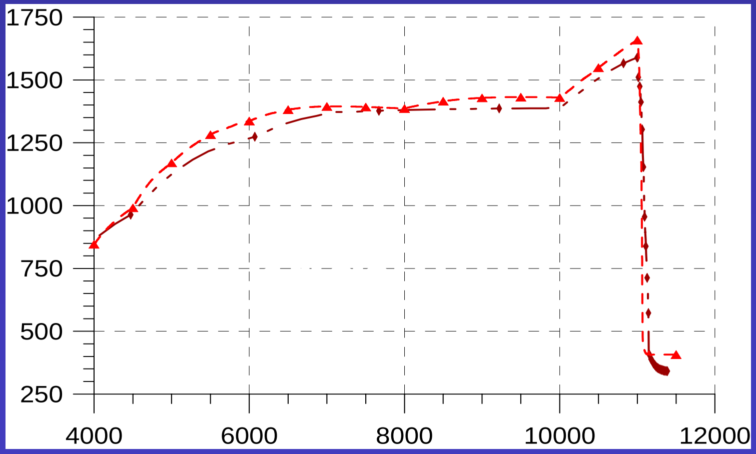
Oxidation at 1000÷1100 mm

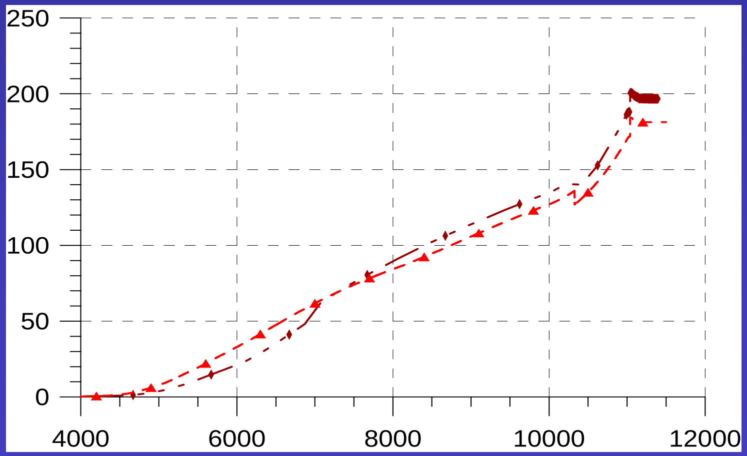
Temperature, K

ZrO_2 thickness, μm





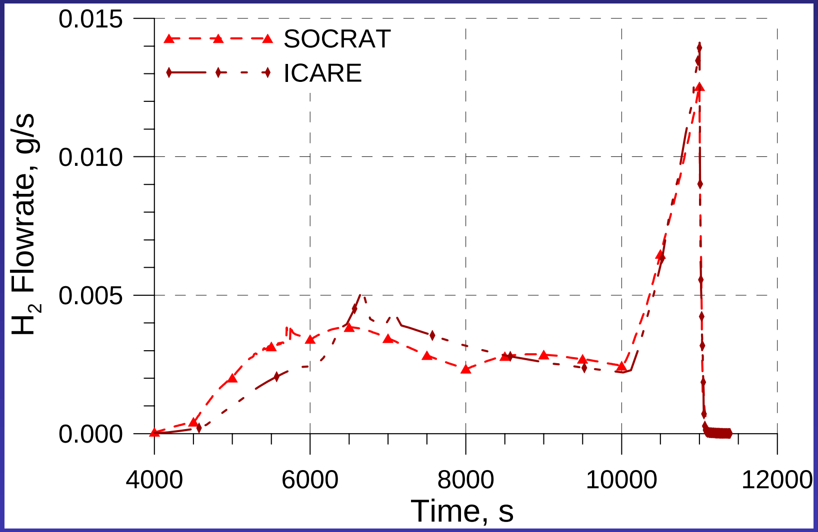


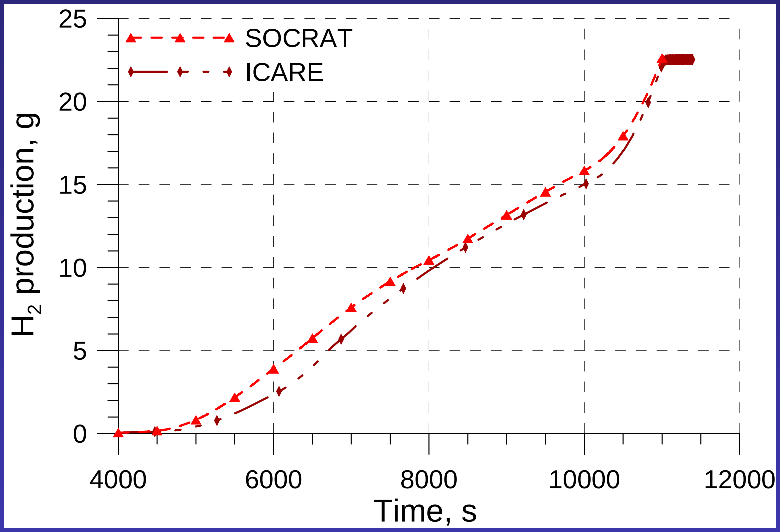


Time, s

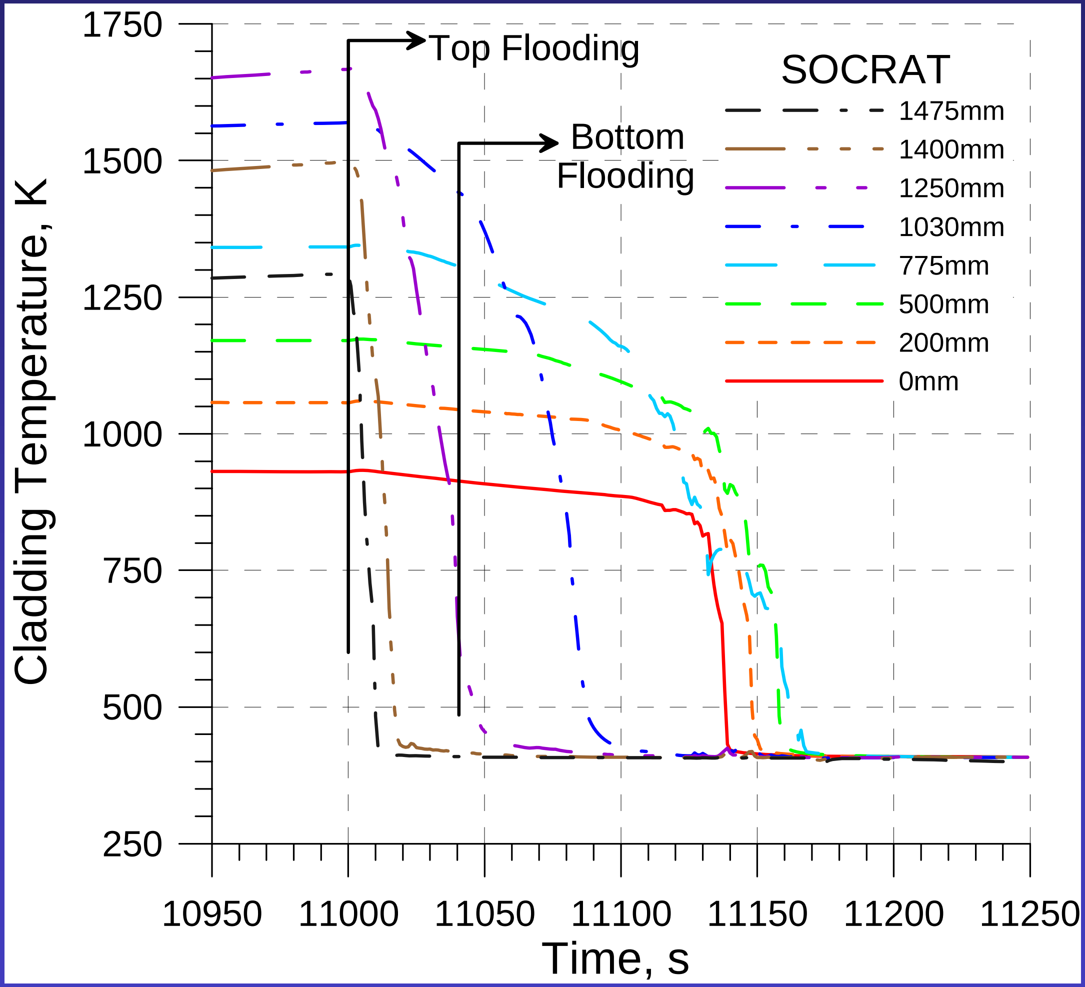
Time, s

Hydrogen generation



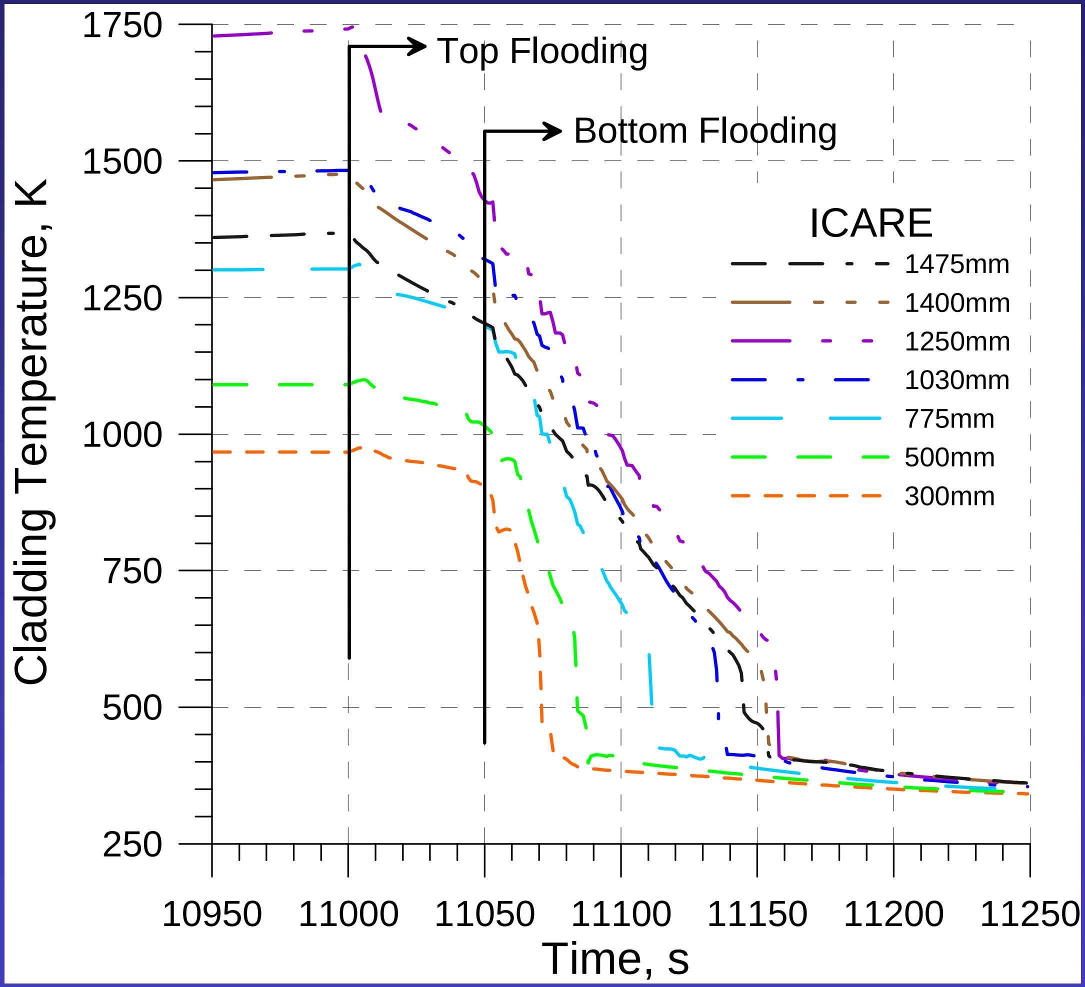


Flooding Phase (SOCRAT calculations)



- Well predicted cooling front propagation up to 1000 mm from top flooding
- Simultaneous cooling by steam/water mixture below 1000 mm from bottom flooding

Flooding Phase (ICARE calculations)



- No cooling from top flooding
- Simultaneous cooling by steam/water mixture from bottom flooding

Conclusions

- Pre-test runs are ongoing
- Set of recommendations for SF2 test performance was provided
- Expecting new data for SFD code improvements
  - Thermal-hydraulical models
  - Fuel rod models (oxidation, degradation, heat exchange models)