Short overview on the PARAMETER program at LUCH

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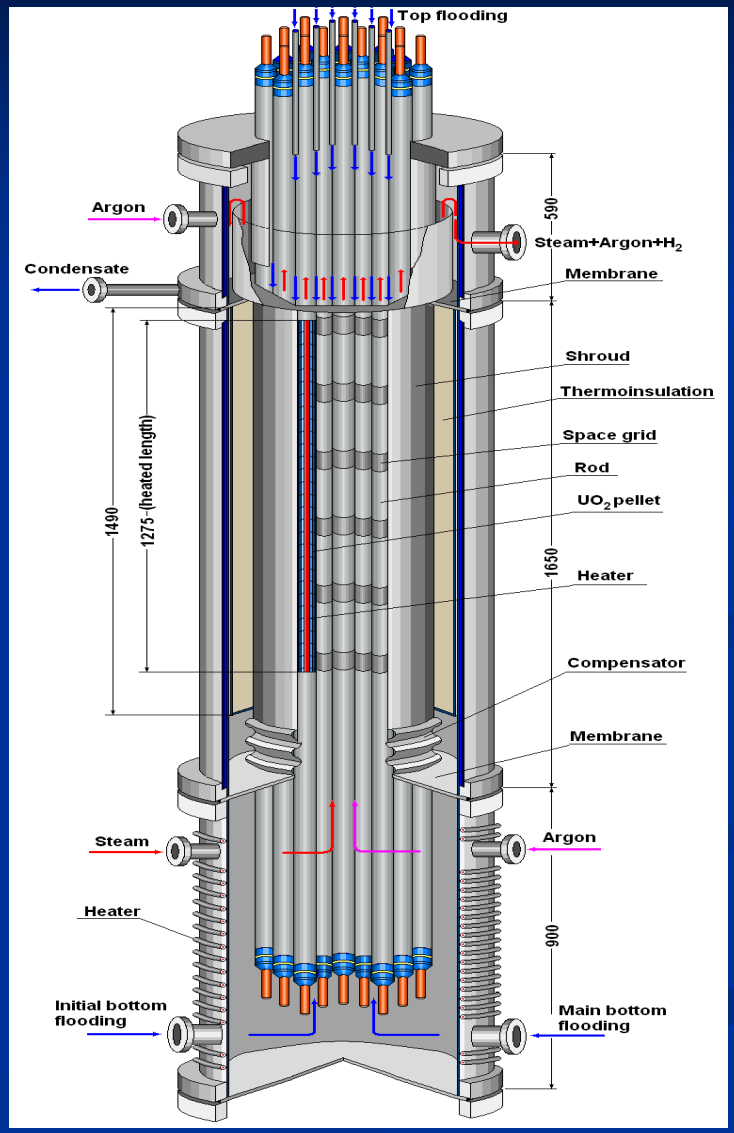
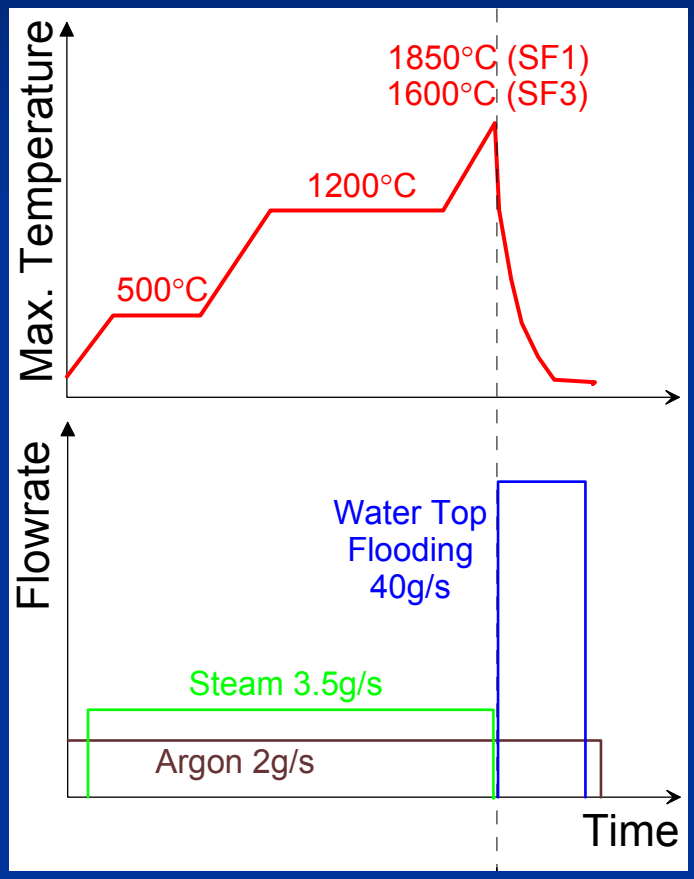
PARAMETER-SF tested bundle

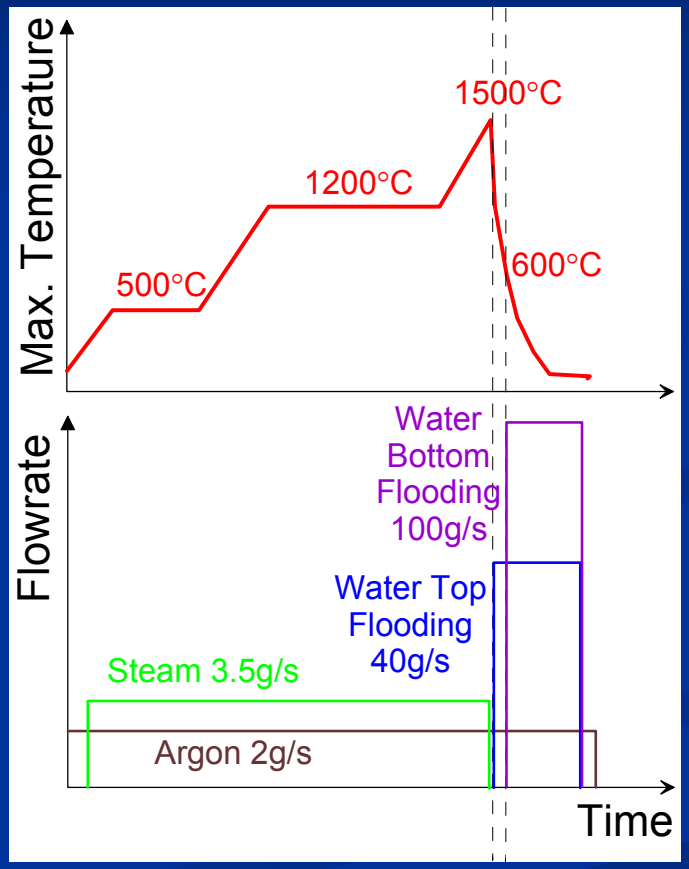
Bundle type	VVER-1000
- number of fuel rods	19
- heated	18
- unheated	1
Fuel rod	
- cladding, mm	∅ 9,13/7,73 (Zr1%Nb)
-pellets	UO_2
- heater length , mm	1275
Spacer grid	Zr1%Nb
Shroud	Zr1%Nb
-SF1	hexahedral
-SF2, -SF3, -SF4	cylindrical
Peripheral rods	
-SF3/-SF4	12/12
Heater	Ta
Thermal insulation	ZrO_2 ZYFB-3



PARAMETER-SF tests scenario

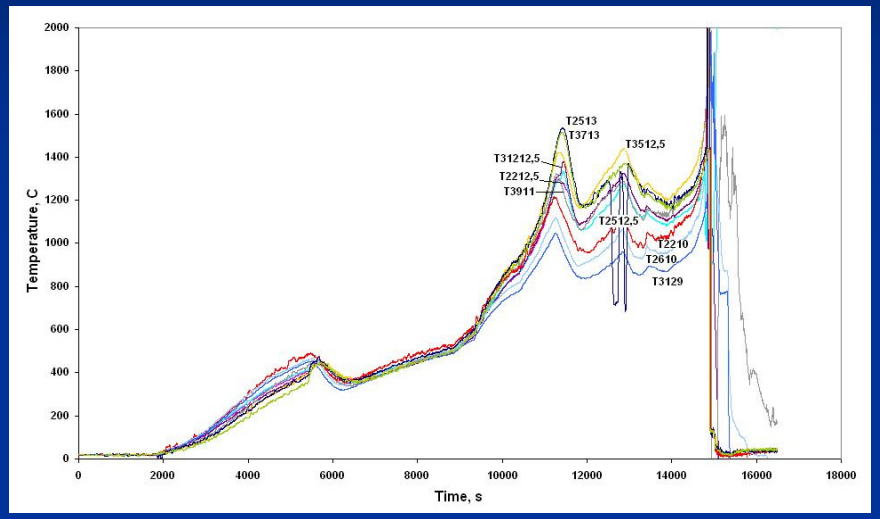


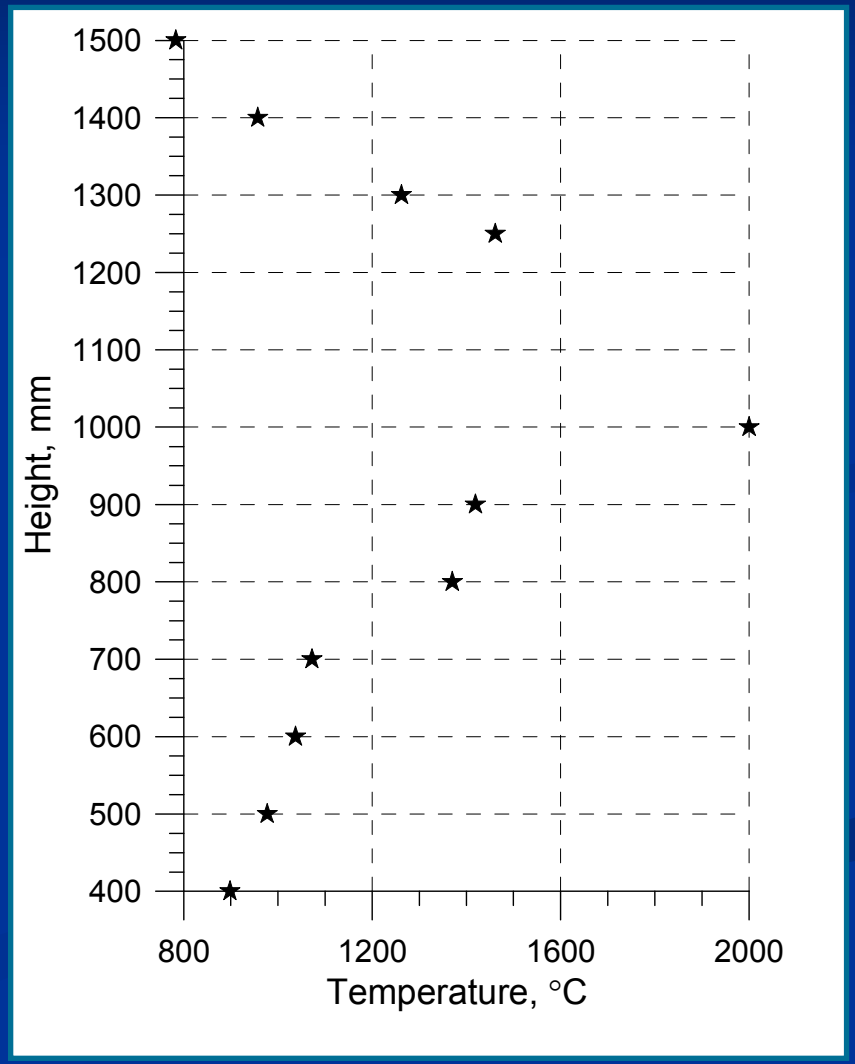
PARAMETER-SF1, -SF3 tests



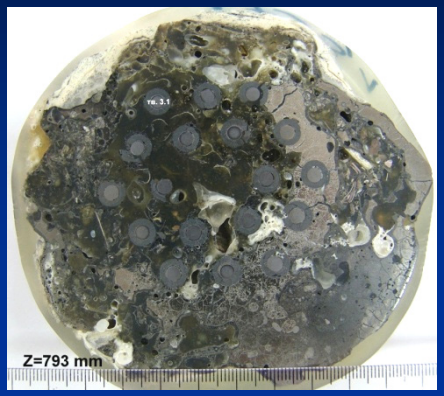
PARAMETER-SF2 test

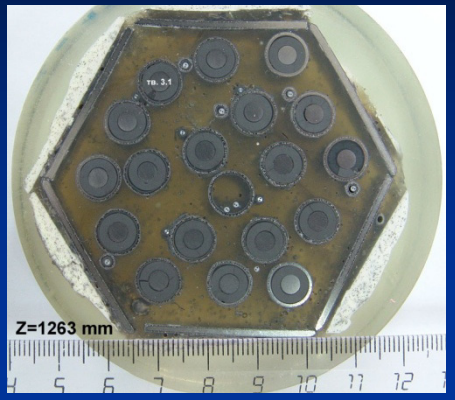
PARAMETER-SF1. Temperature evolution



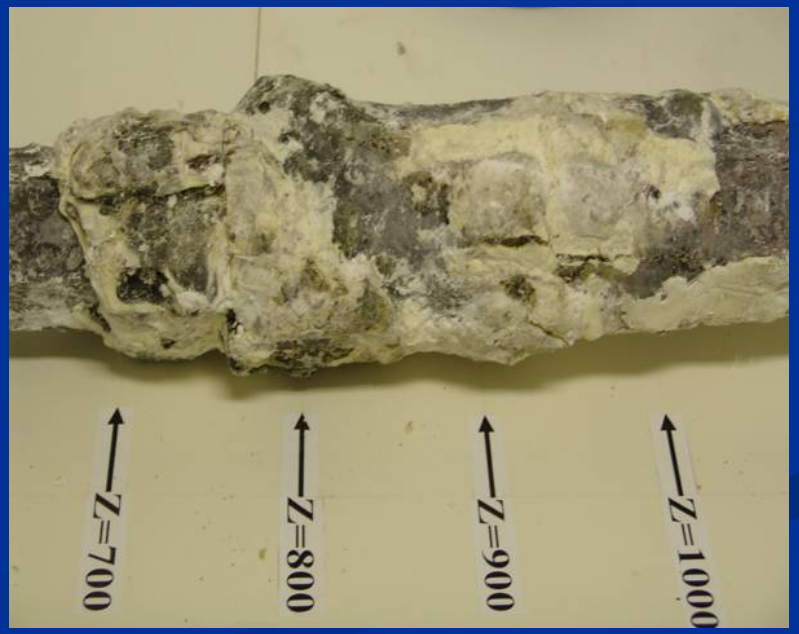


PARAMETER-SF1 test – main results



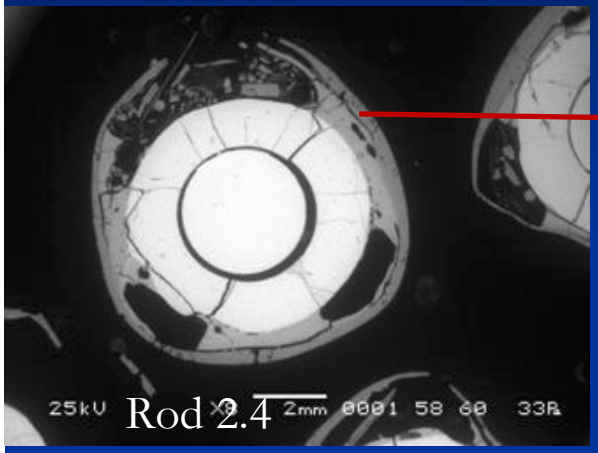


Thermoinsulation shroud appearance

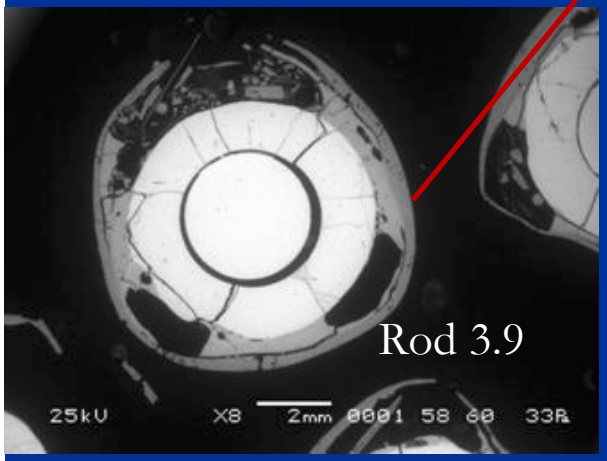


Shroud appearance

Schematic view of the bundle after PARAMETER-SF1 test

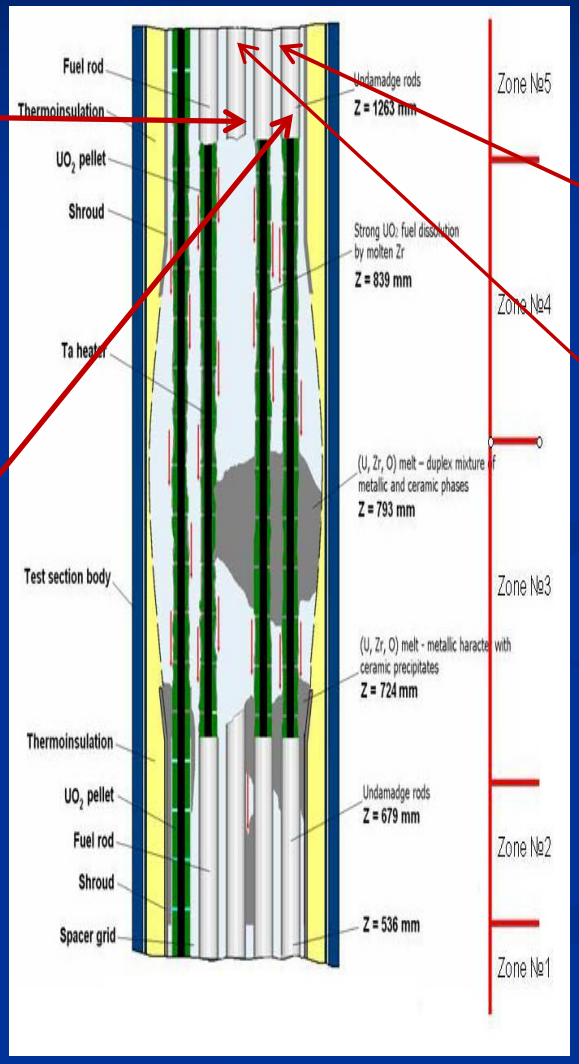


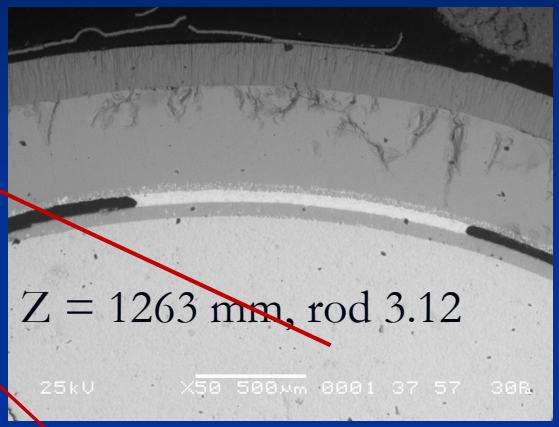
Rod 2.4



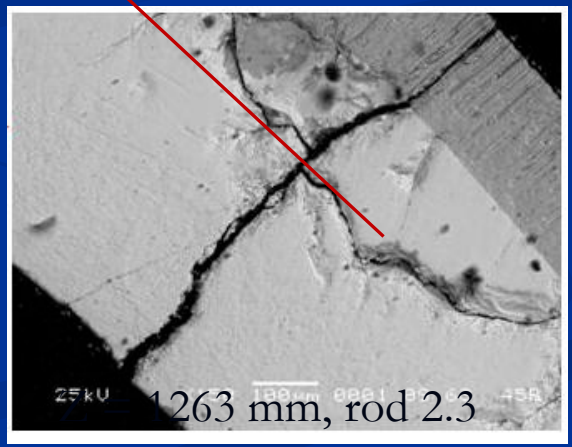
Rod 3.9

Z=1066 mm



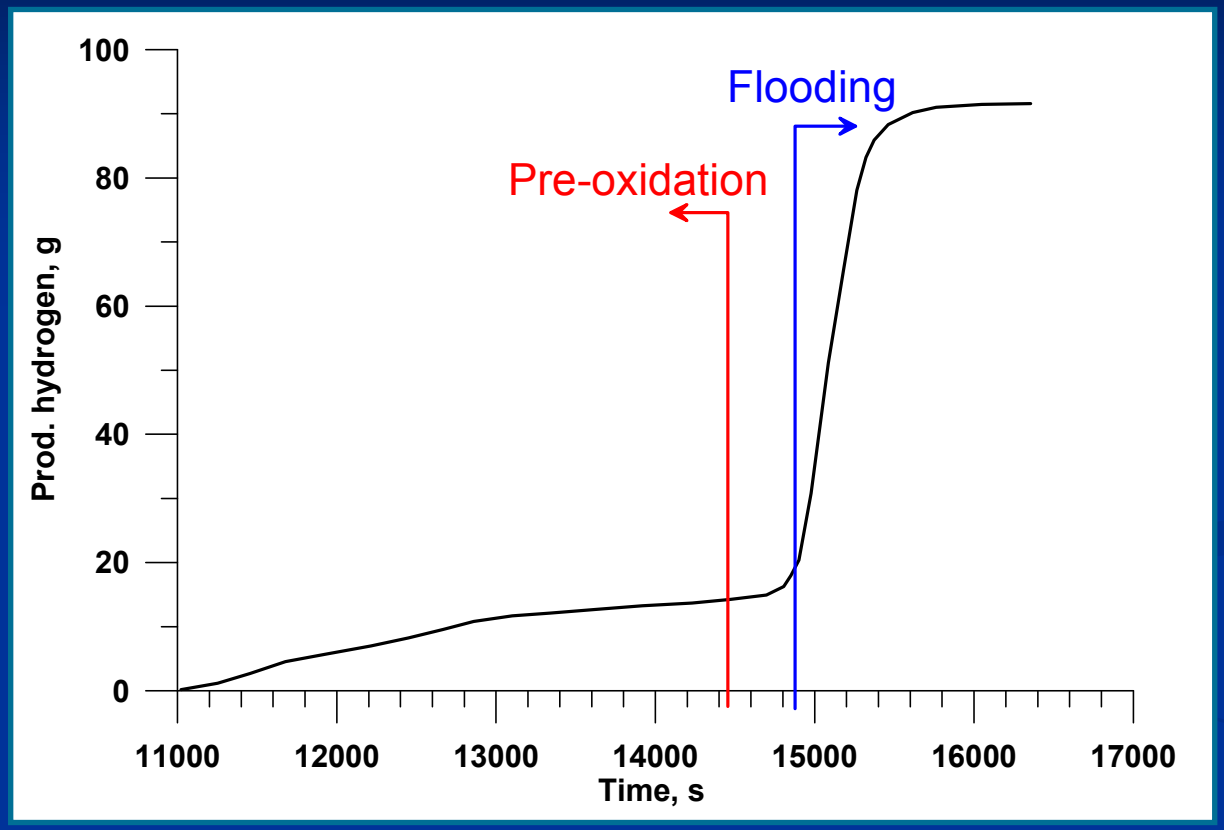


Z = 1263 mm, rod 3.12



1263 mm, rod 2.3

PARAMETER-SF1 – hydrogen release

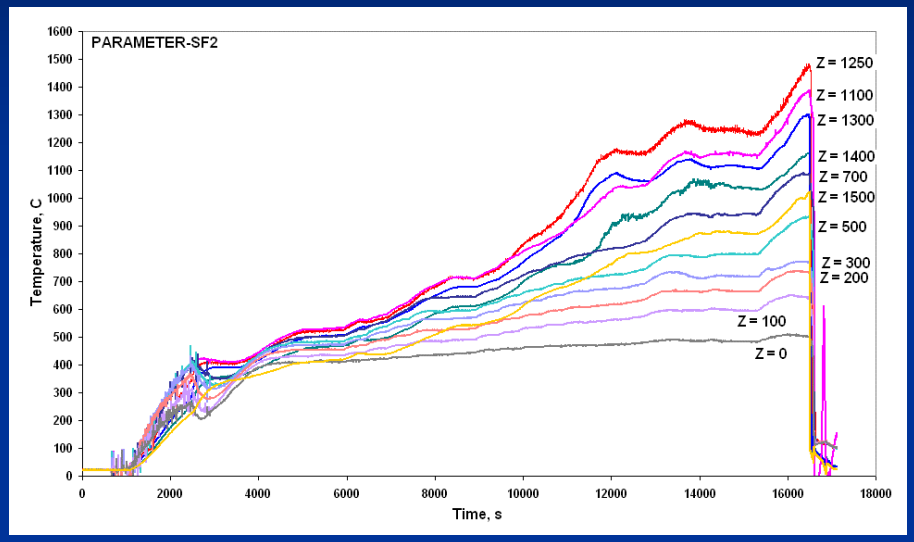


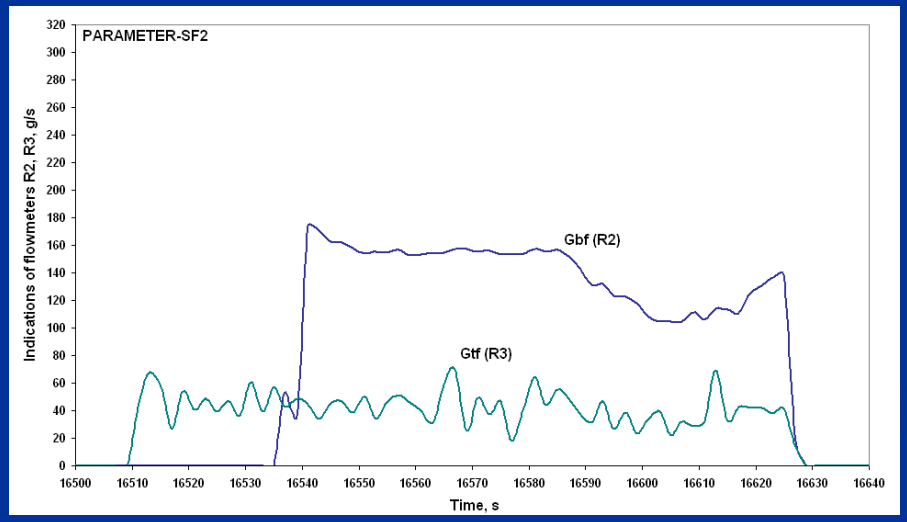
Before flooding start – 20 g
Total mass – 91 g

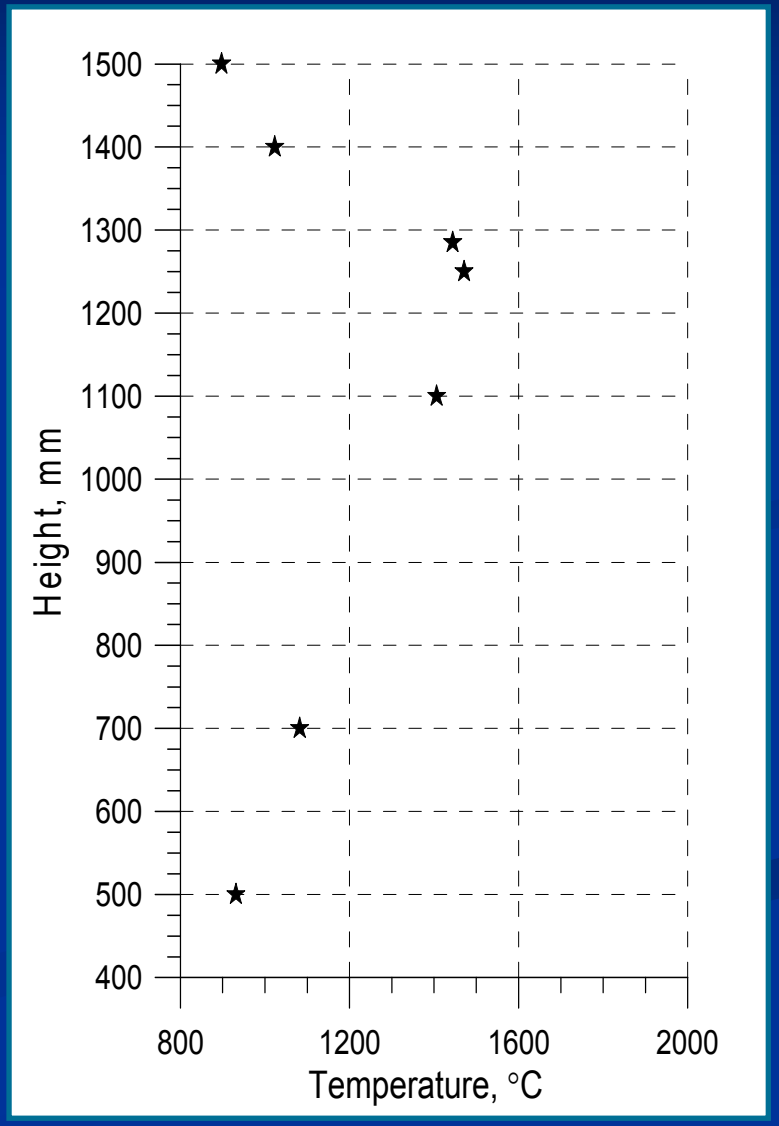
Peculiarities of SF1 test

- Pre-oxidation phase under non-isothermal conditions
- No pronounced cladding spallation
- Quenching from top at cladding temperature ≥ zirconium melting point
- Extensive melt formation and its oxidation
- Intensive hydrogen generation during quenching

PARAMETER-SF2. Temperature evolution

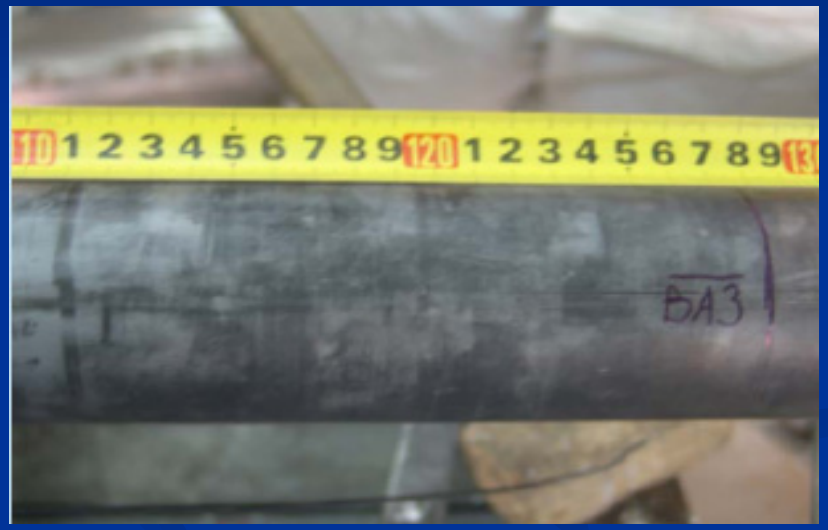






PARAMETER-SF2. Post-test shroud appearance

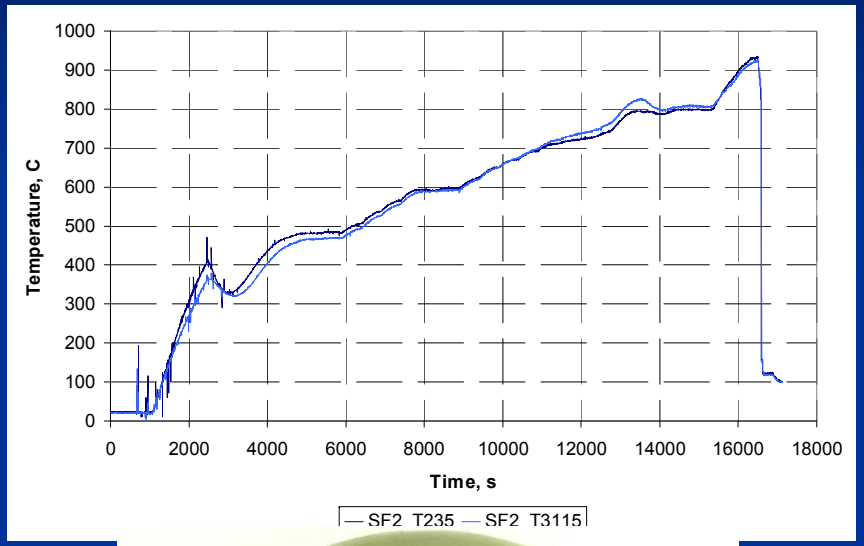
Z = 850-1050 mm



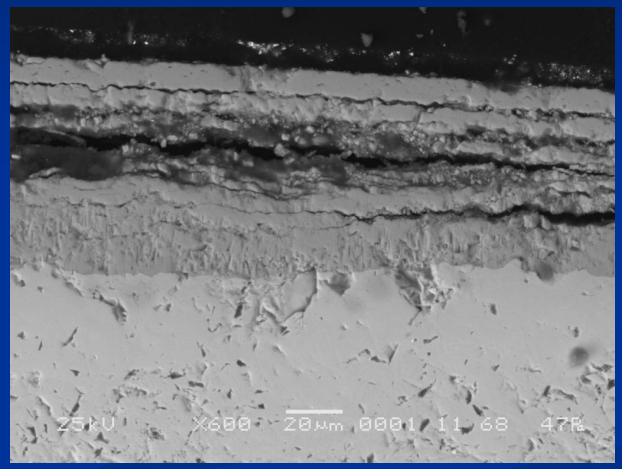
Z=1100-1300 mm

- Shroud kept its integrity
- Thin oxide scale on the outer surface

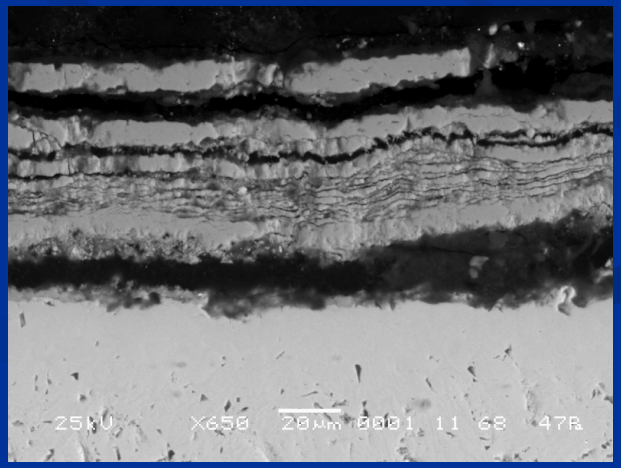
PARAMETER-SF2. Metallographic examination of the cross - section at Z=513 mm



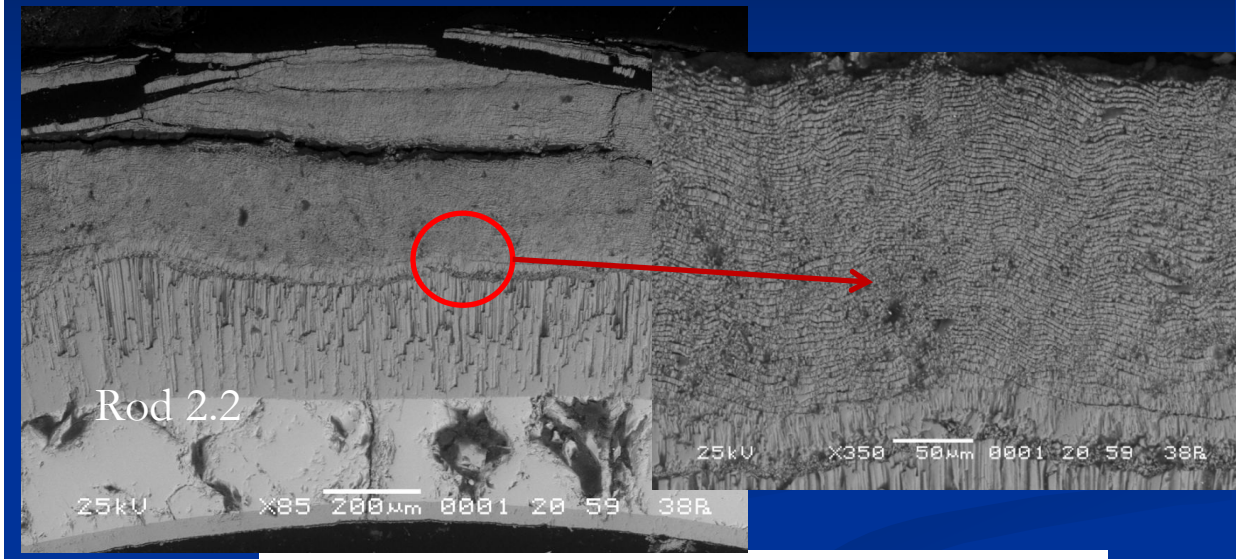
Rod 2.4

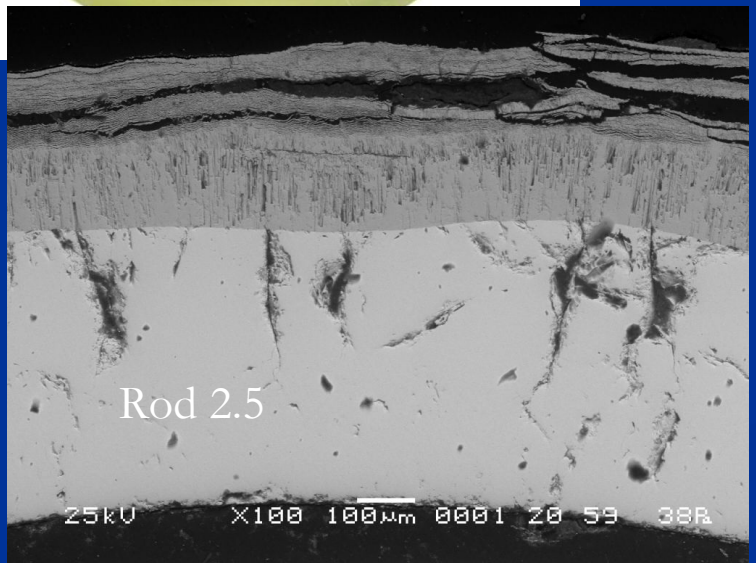


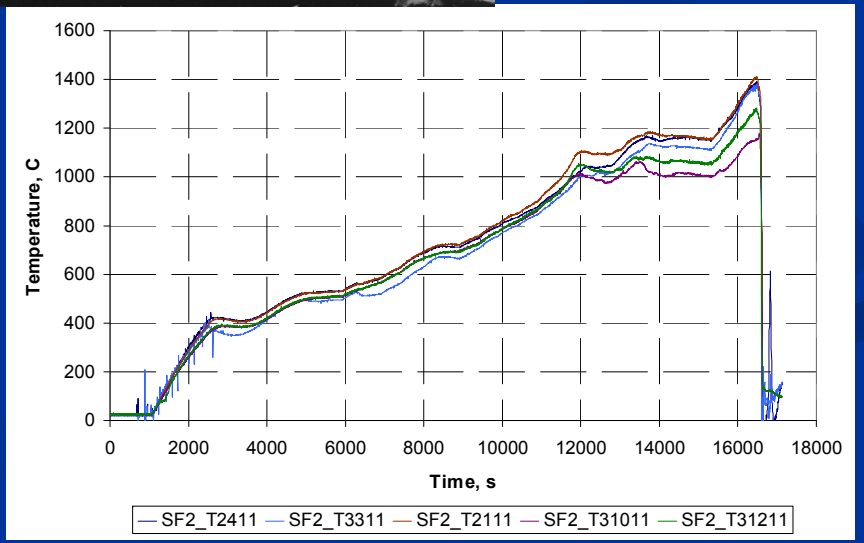
Rod 2.6



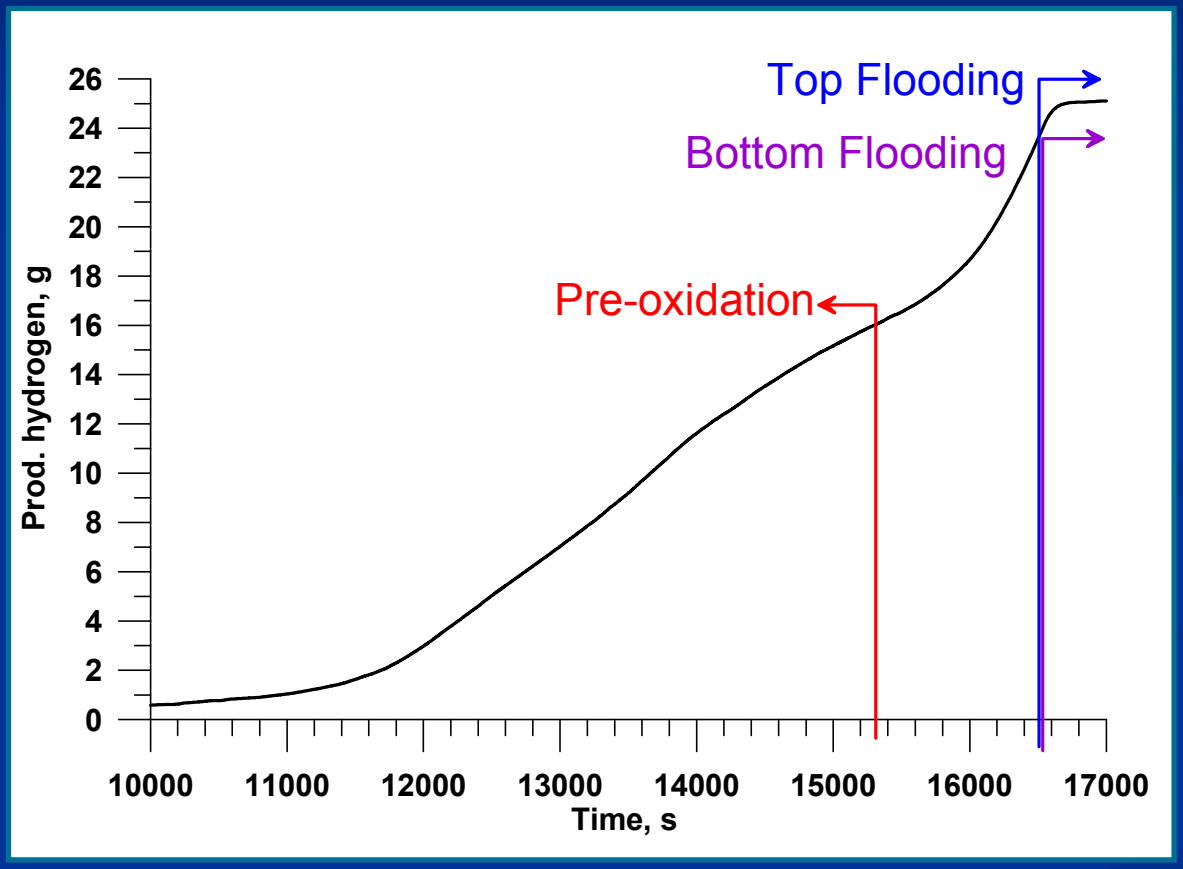
PARAMETER-SF2. Metallographic examination of the cross- section at Z=1103 mm







PARAMETER-SF2 – hydrogen release

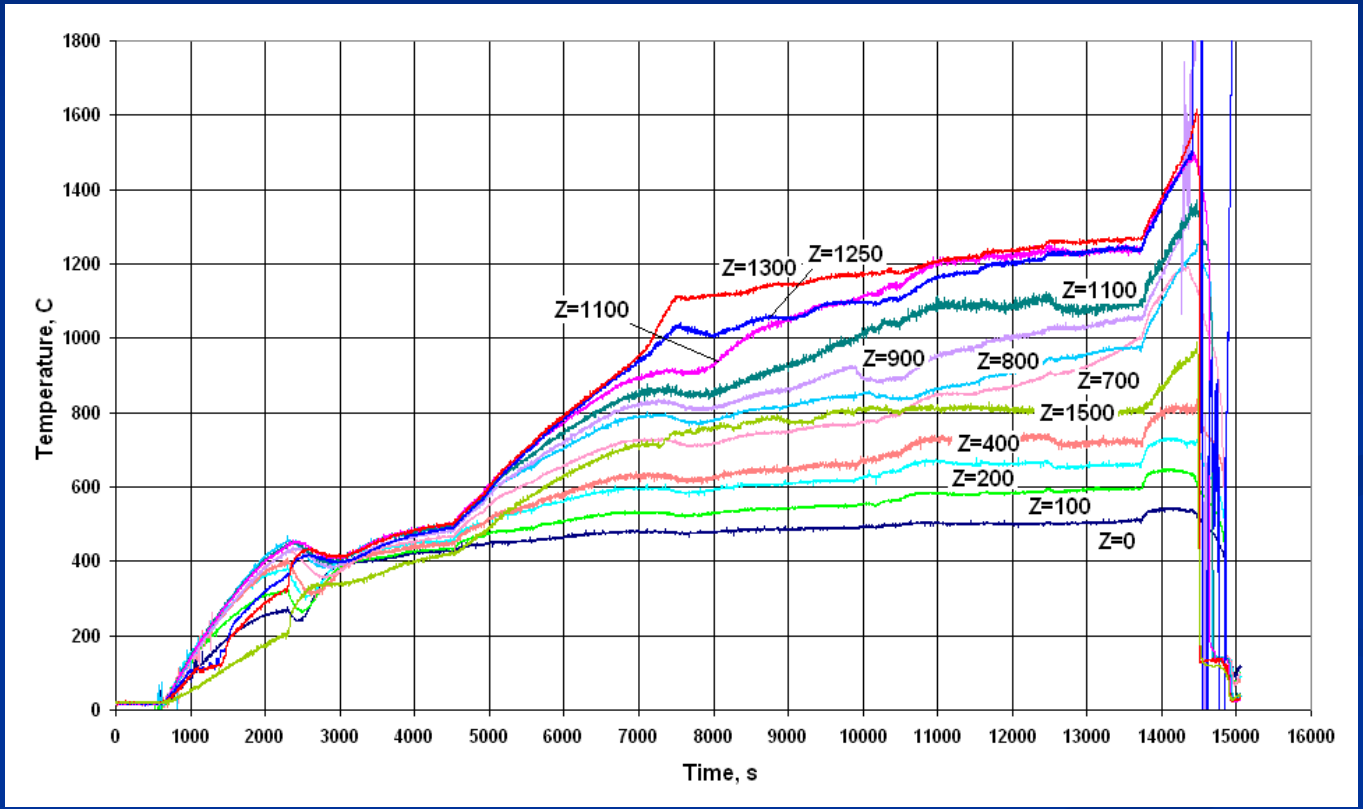


Before flooding onset – 23,5 g
Total mass – 25 g

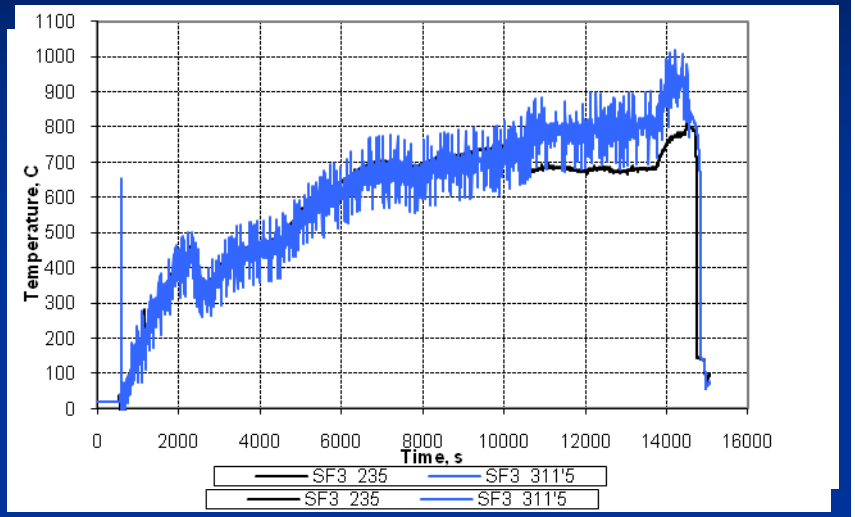
Peculiarities of SF2 test

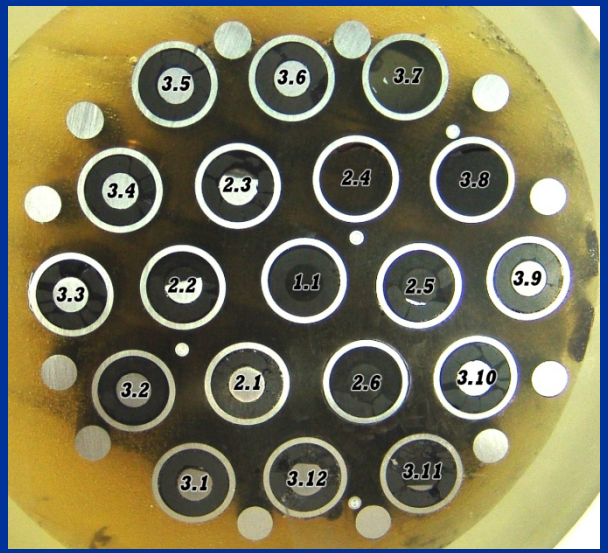
- Preoxidation at 1200C for 3500 s
- Quenching from top and bottom at 1500C
- Pronounced cladding spallation
- No intensive hydrogen generation during quenching

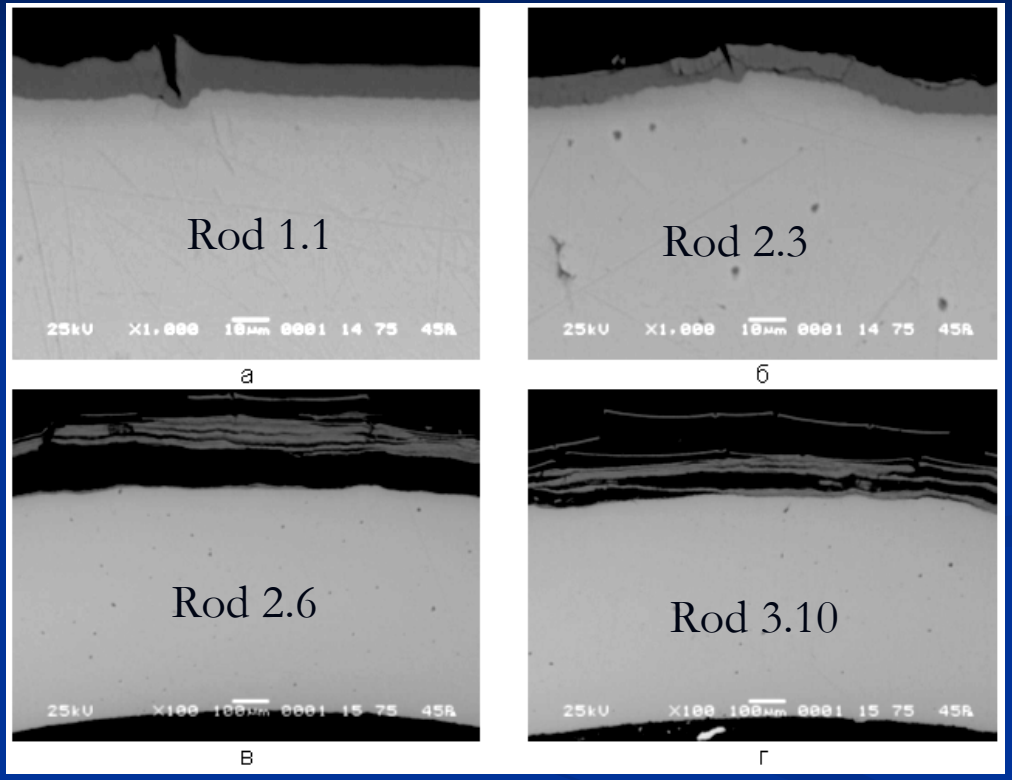
PARAMETER-SF3. Temperature evolution



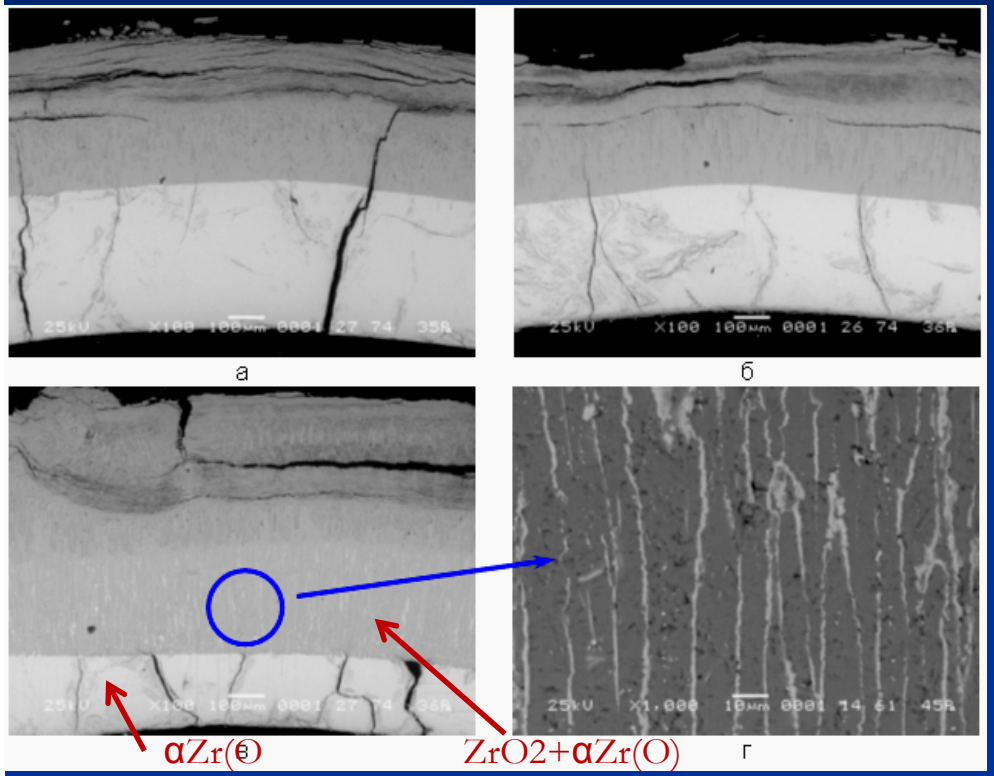
PARAMETER-SF3 test. Metallographic examination of the cross -section at Z=500 mm

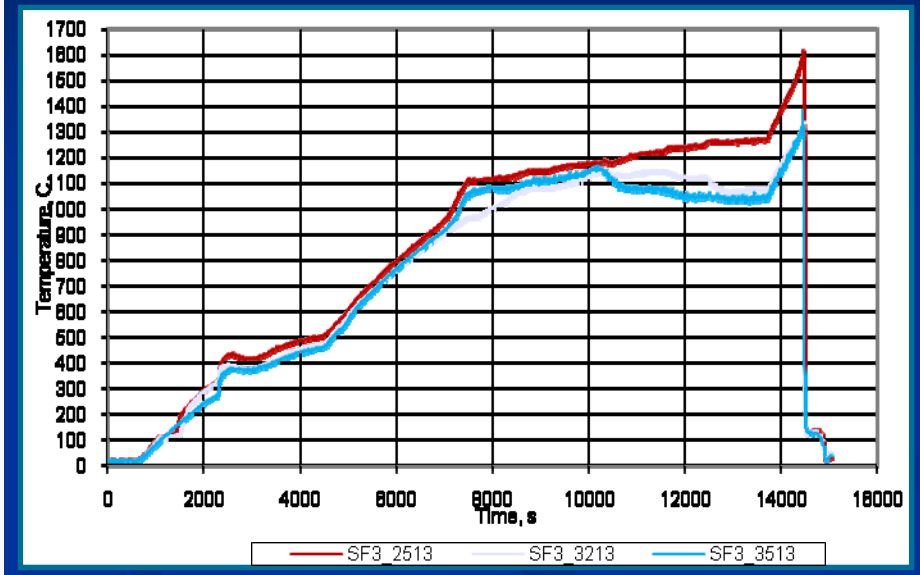






PARAMETER-SF3. Metallographic examination of the cross section at Z=1300 mm

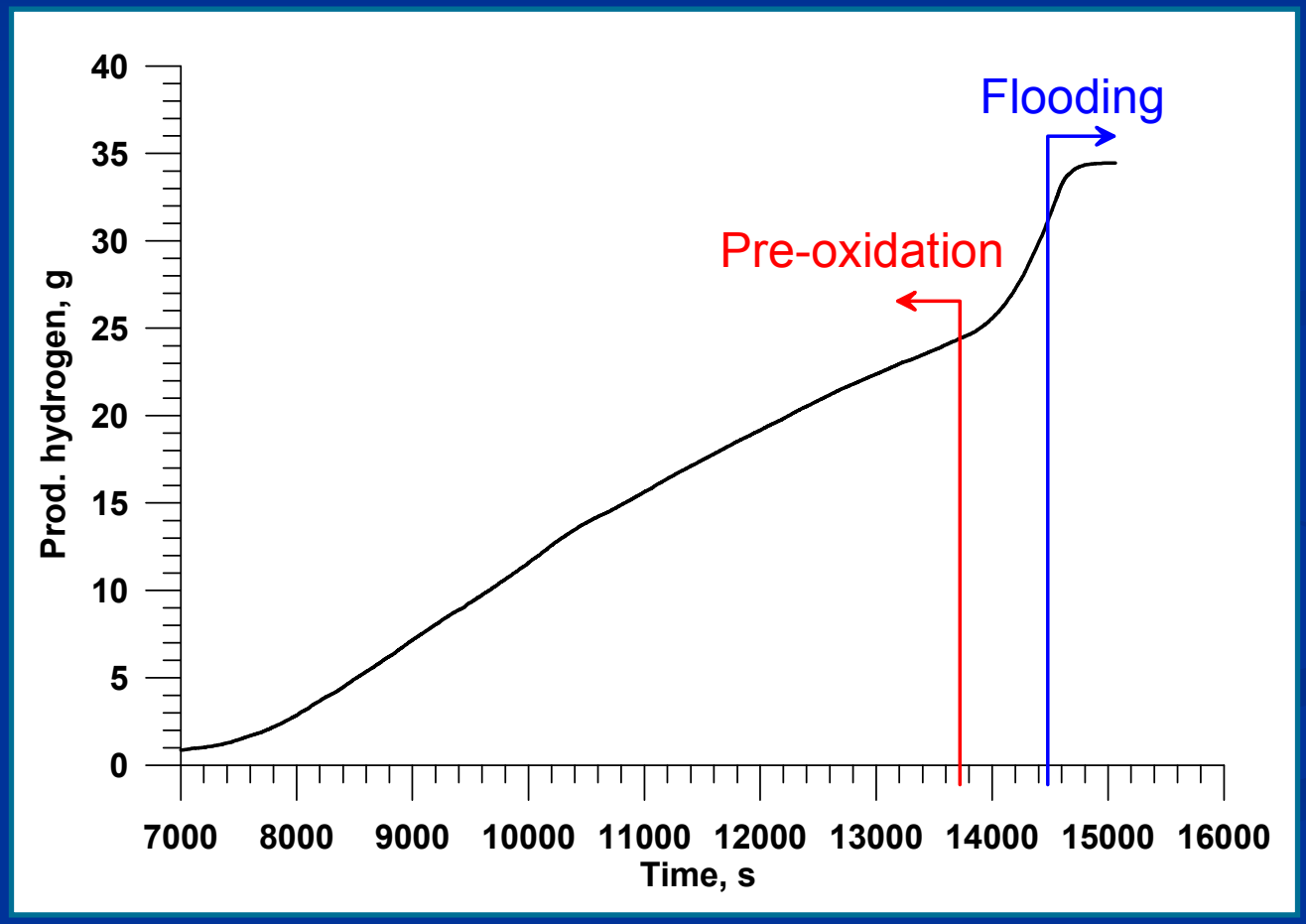




- 5 claddings are available for measurement after handling
- ZrO2+αZr(O) layer on metallic layers could be interpreted to be cubic oxide

PARAMETER-SF3 – hydrogen release

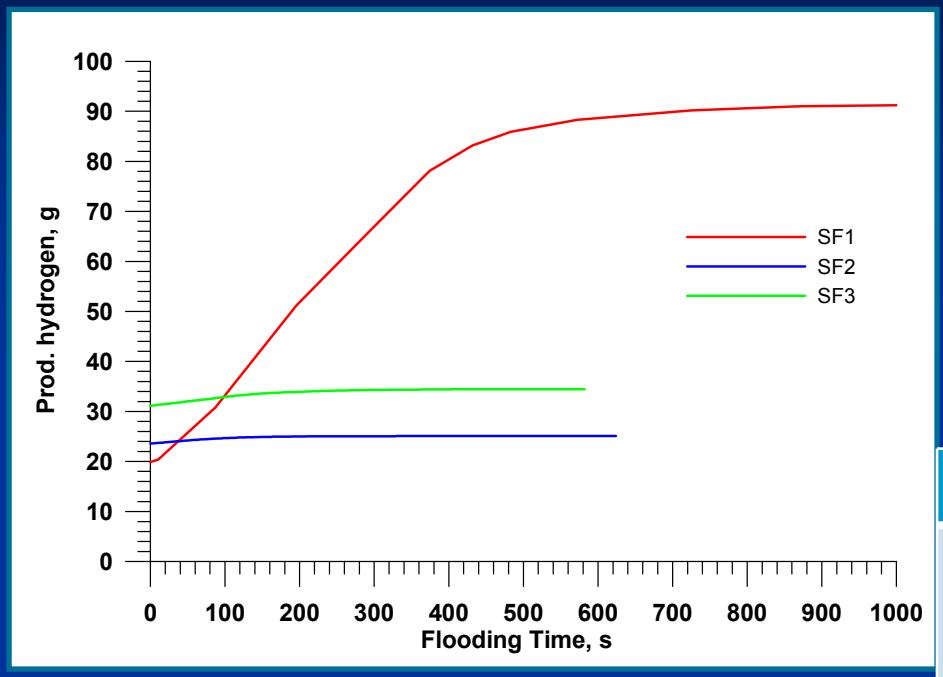
Before flooding onset 31 g
Total mass 35,5 g



Peculiarities of SF3 test

- preoxidation at 1200C for about 5000 s
- quenching from top at 1600C
- pronounced claddings spallation
- no intensive hydrogen generation during quenching

PARAMETER-SF. Hydrogen release



Hydrogen release

	SF1	SF2	SF3
Before flooding onset (g)	20	23.5	31
At flooding phase	71	less than 1.5	less than 3.5
Melt formation	yes	no	no
Total mass	91	25	34,5

Conclusion

- Four tests were done with Zr1%Nb claddings
- In SF1 test, significant hydrogen release was observed during quenching of partially molten bundle
- In SF2 and SF3 test, pronounced cladding spallation was observed, but no hydrogen release during quenching
- Performed tests demonstrated strong effect of melt formation on hydrogen release. It may be considered as a main factor of effectiveness of core quenching under BDBA conditions