

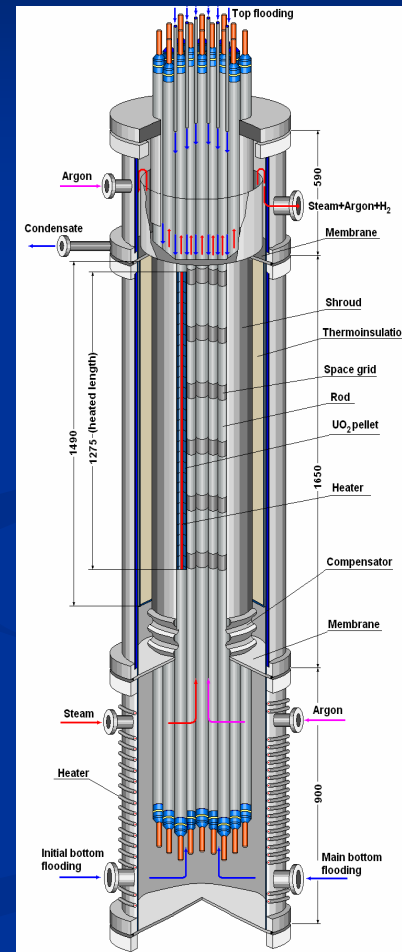
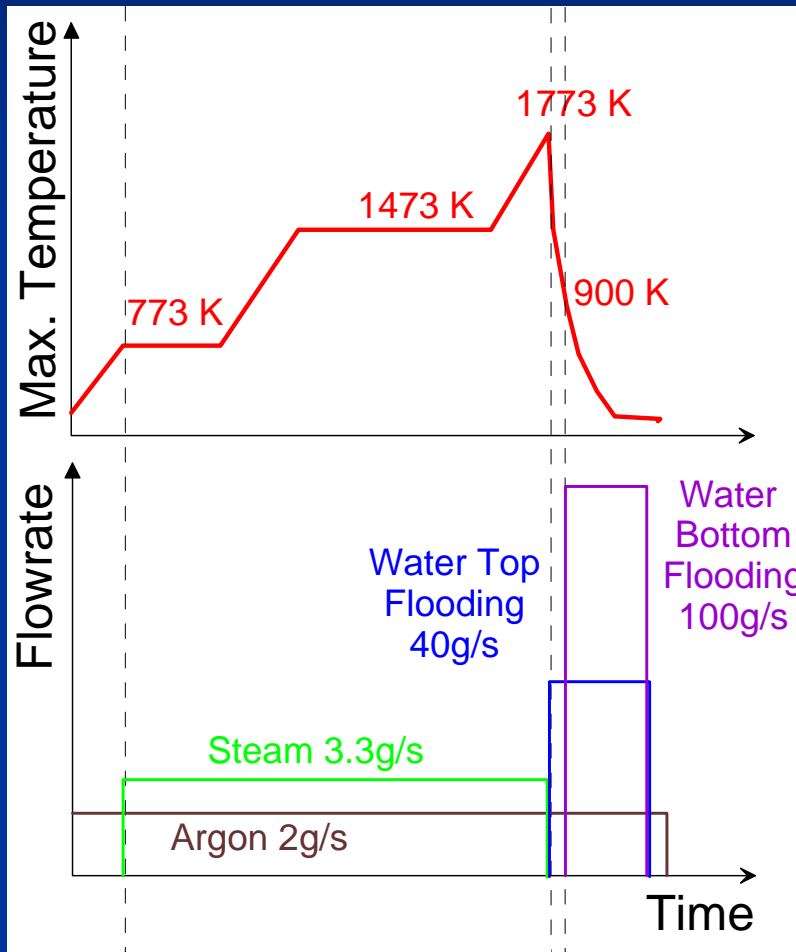
**FSUE SRI SIA “LUCH”
IBRAE RAS
FSUE EDO “GIDROPRESS”**

Results of PARAMETER-SF2 material investigations

Presented by T.Yudina

*14th International QUENCH Workshop
Karlsruhe, 4-6 November, 2008*

PARAMETER-SF2 - experiment scenario



Post-test appearance of the shroud



Z = 850-1050 mm

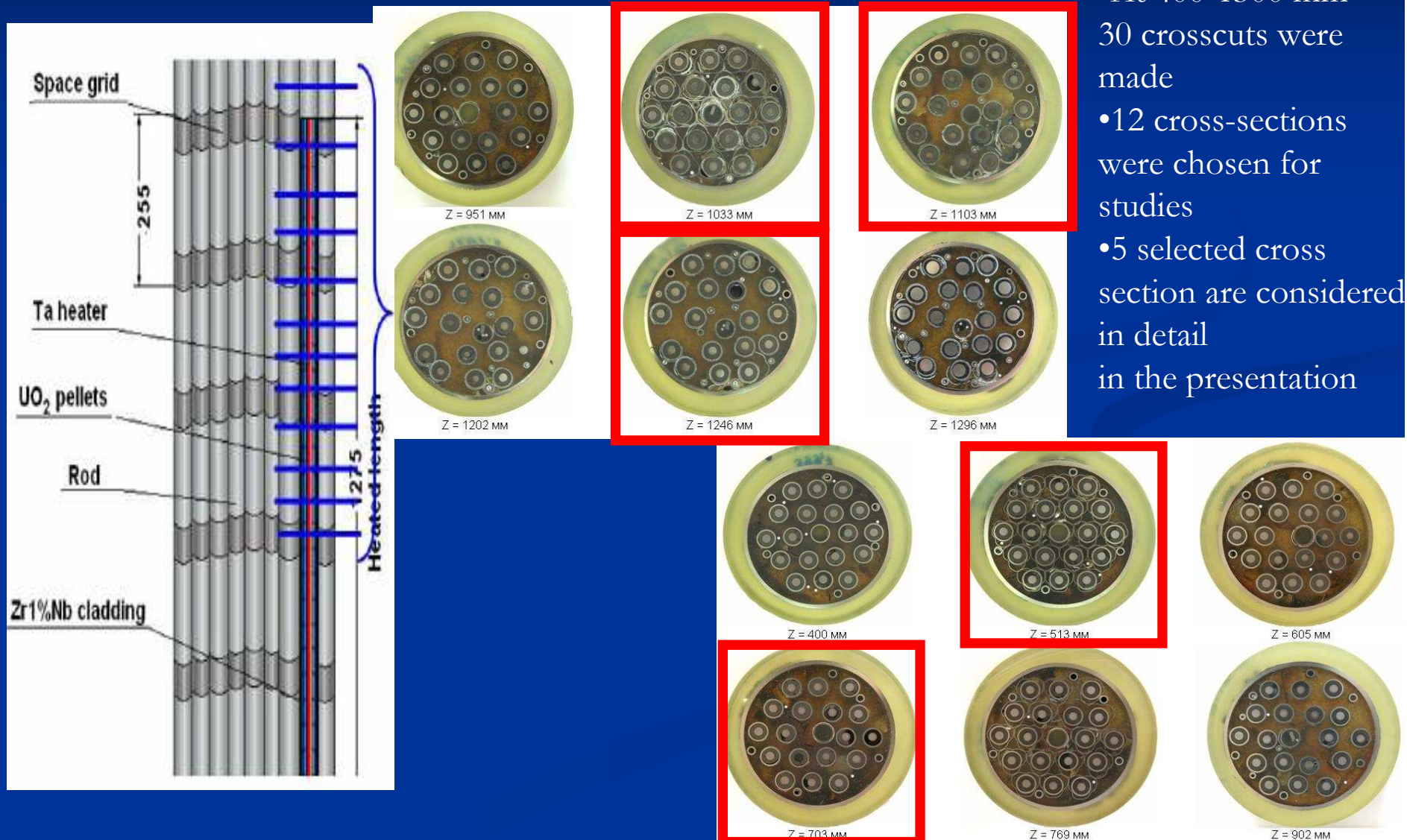


Z=1100-1300 mm

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

Overview of sectioning map for metallographic examination

- At 400-1300 mm 30 crosscuts were made
- 12 cross-sections were chosen for studies
- 5 selected cross section are considered in detail in the presentation

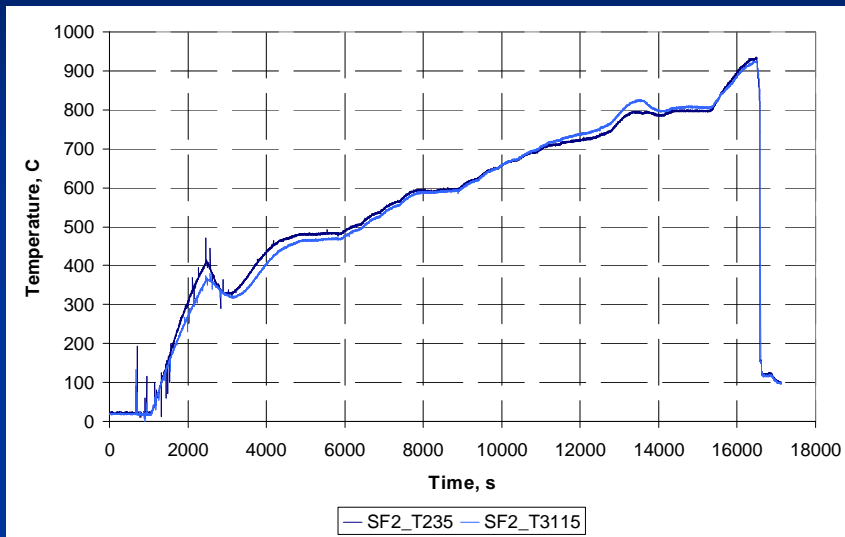


Metallographic examination of the cross - section at Z=513 mm

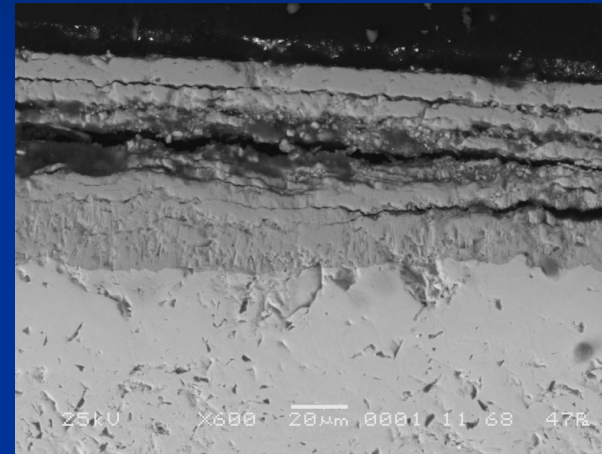


- Rods are in an original arrangement and undamaged
- Intact spacer grid and shroud
- Some pellets have cracks

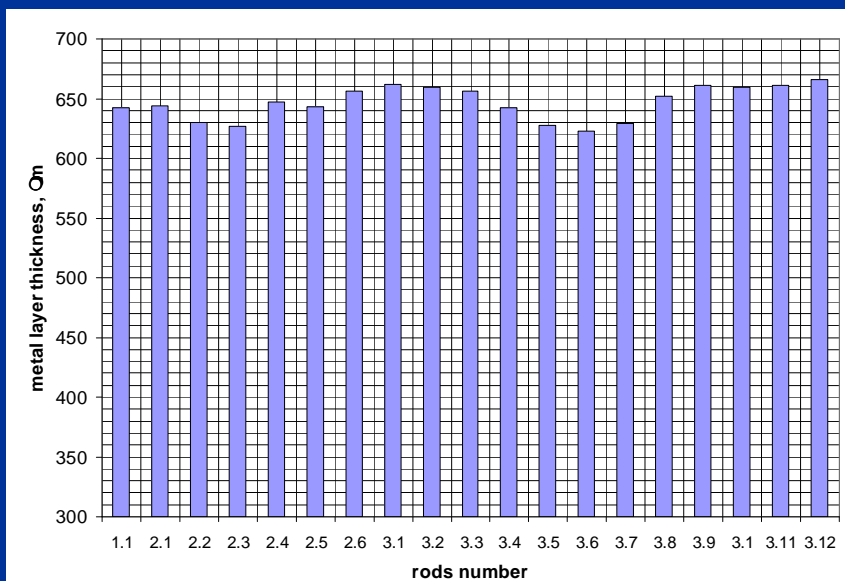
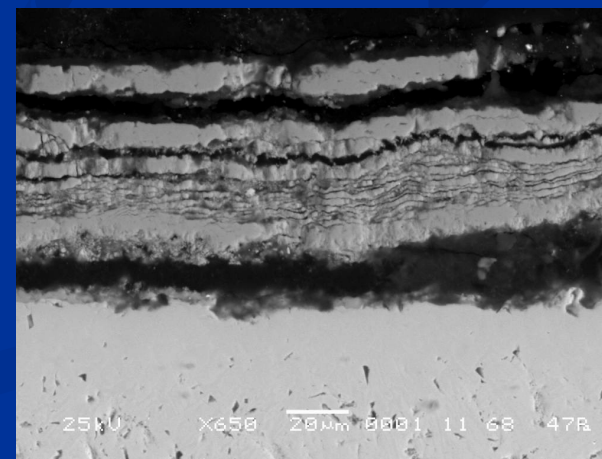
Metallographic examination of the cross - section at Z=513 mm



Rod 2.1



Rod 2.3



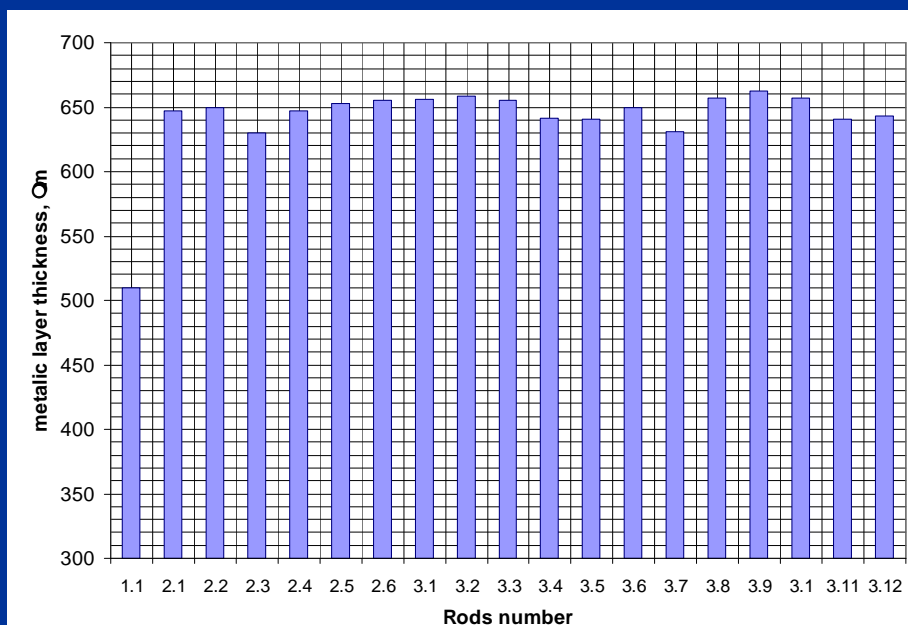
Metallographic examination of the cross section at Z=702 mm



Rod 1.1



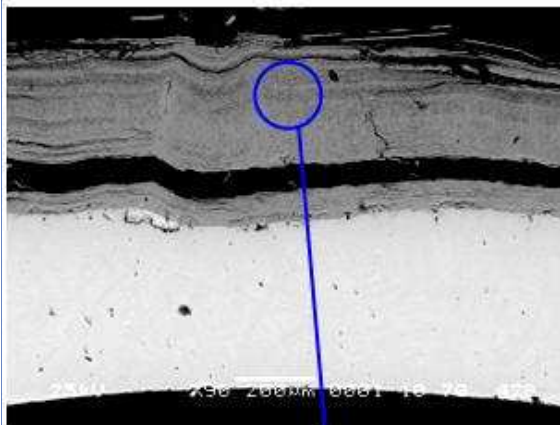
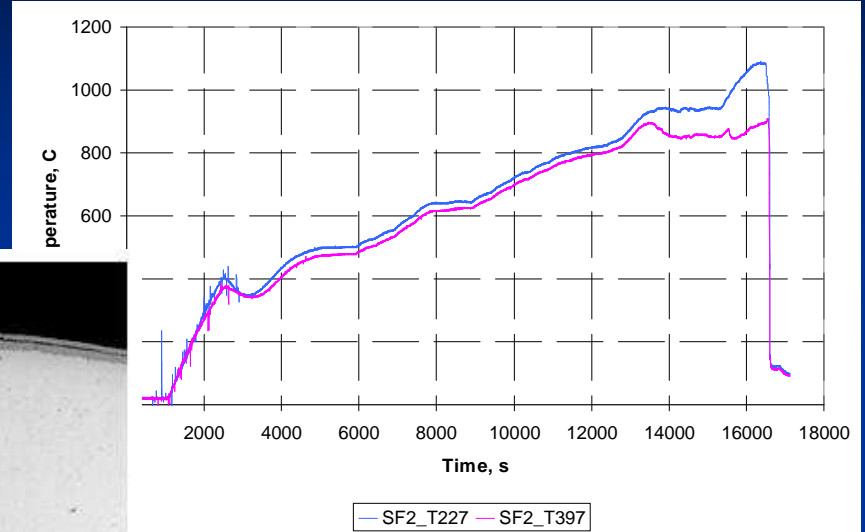
Rod 2.1



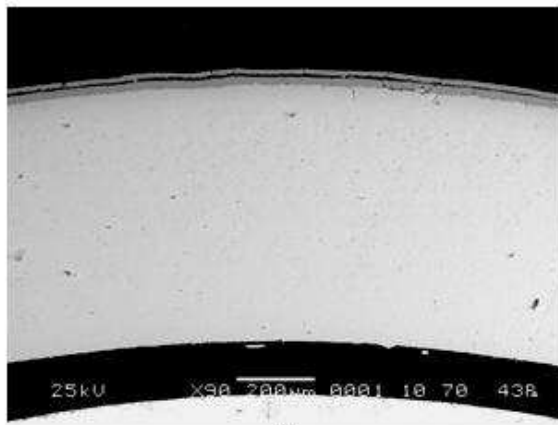
Layers structure at Z=702 mm

Rod 1.1

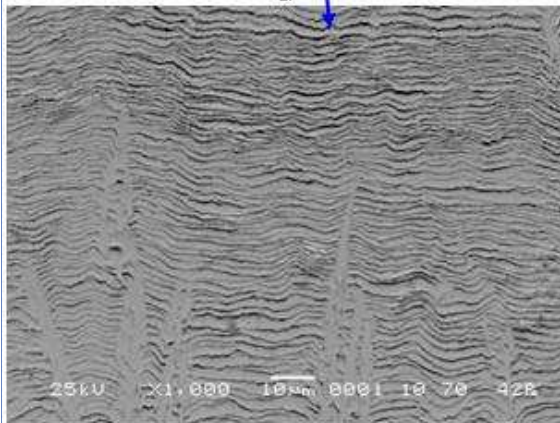
Rod 2.1



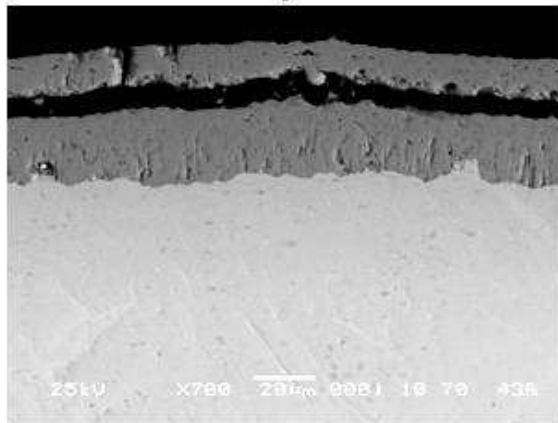
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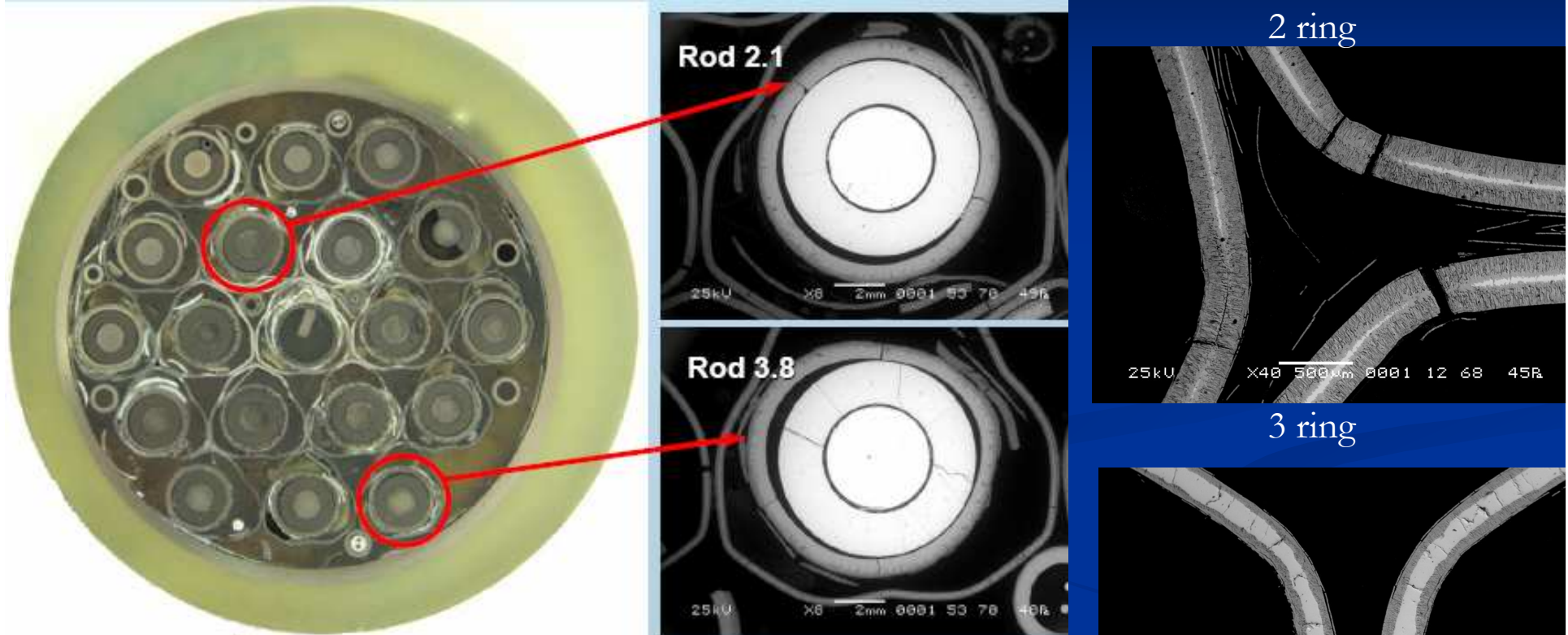
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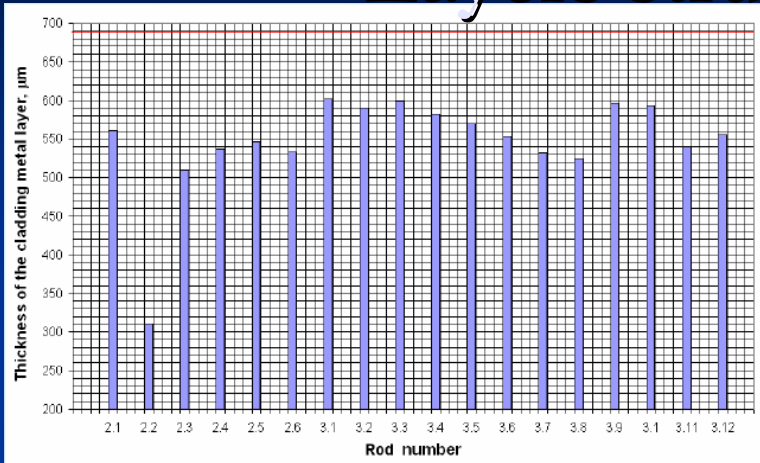


Metallographic examination of the cross-section at Z=1033 mm

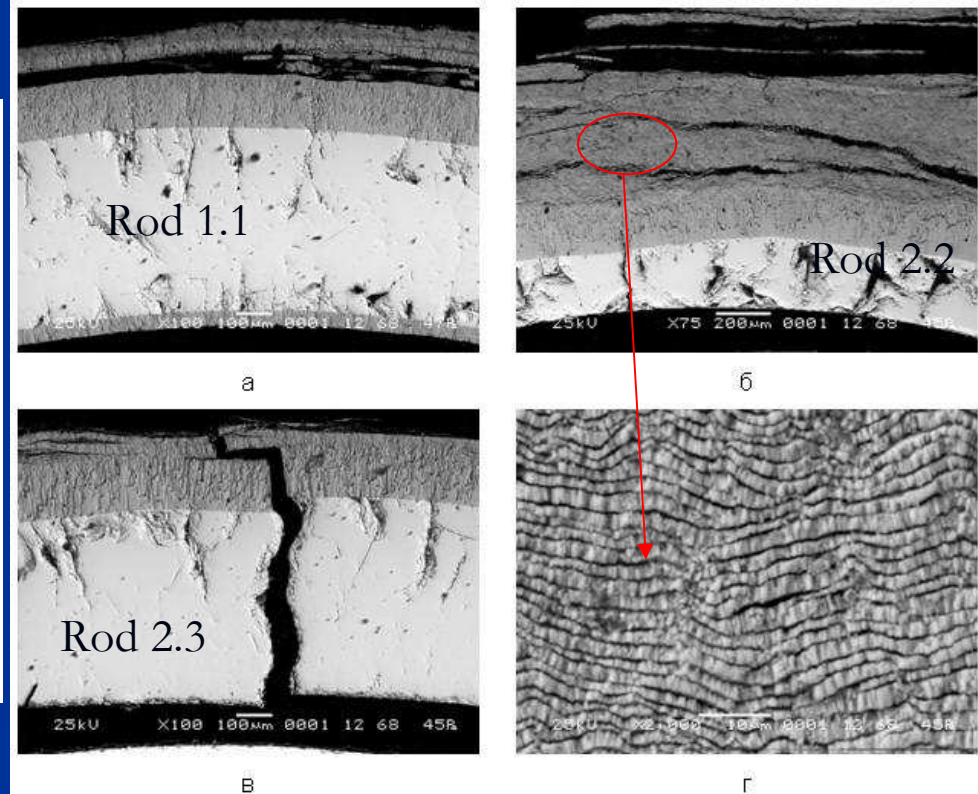
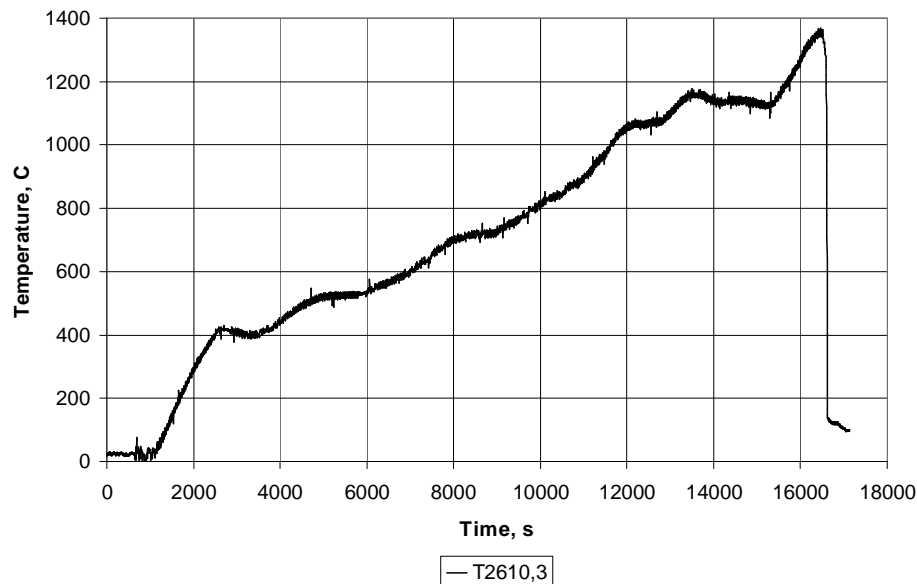


- A lot of oxide scale remnants and cladding fragments between rods
- Strong external and weak internal claddings oxidation
- Through wall cracks in the claddings and the spacer grid
- No cladding fragmentation

Layers structure at Z=1033 mm

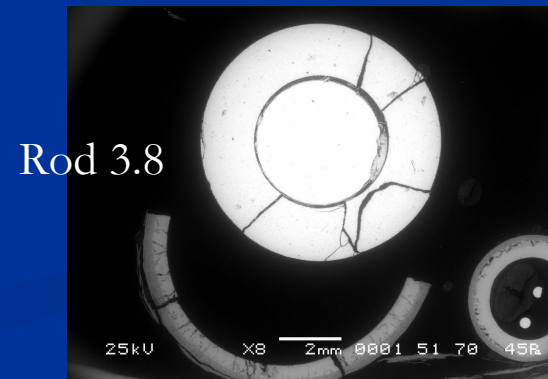
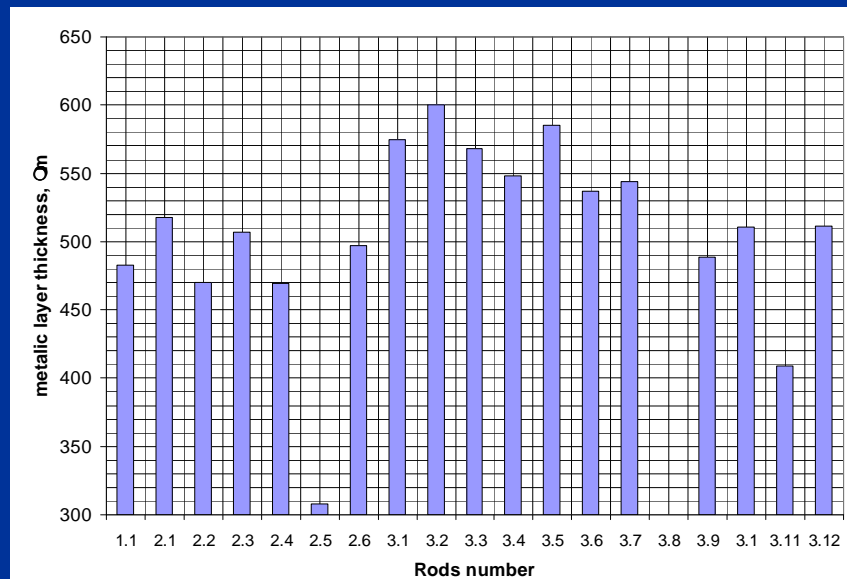
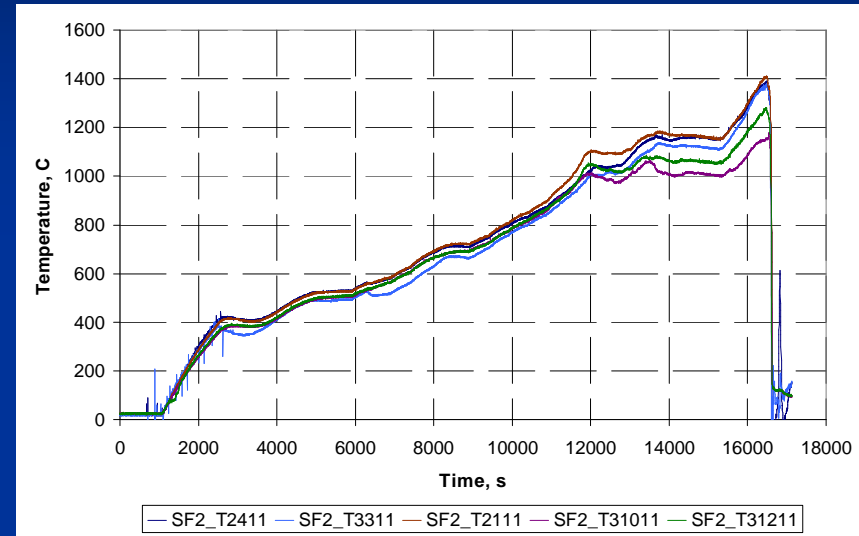


- $T_{\text{max}} \sim 1350^\circ\text{C}$
- Internal oxide of columnar structure with multi-layer films spalled off
- No oxidation of cracks

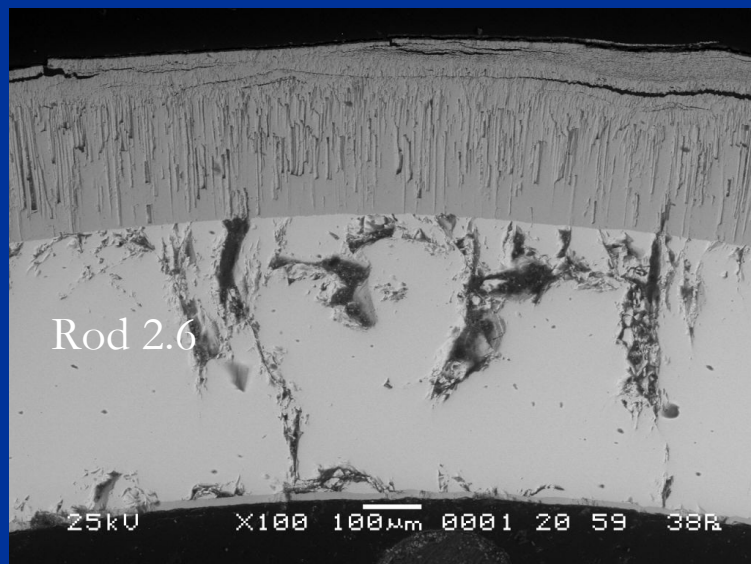
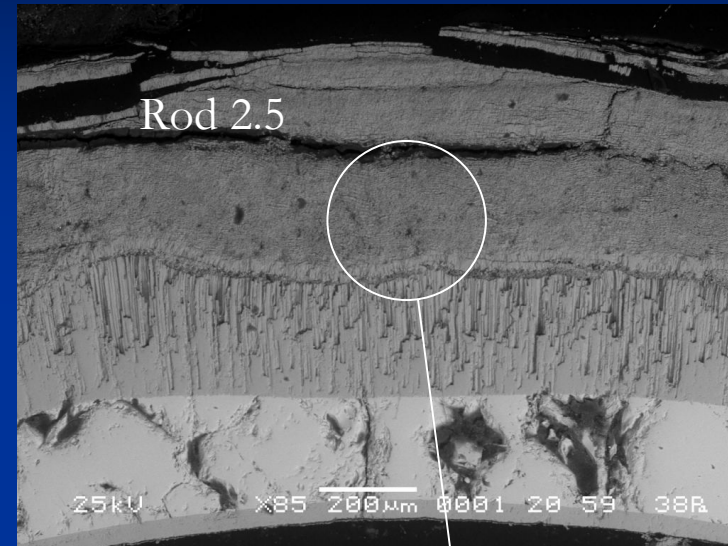
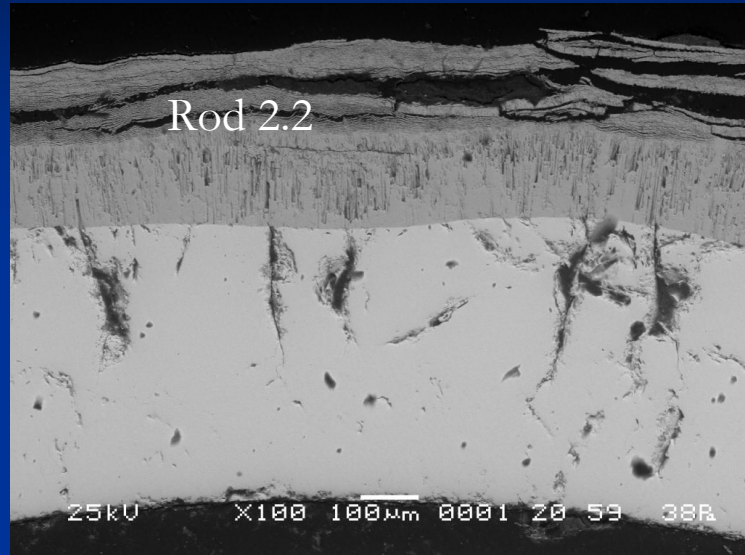


Thermocouple reading located into a spacer grid cell

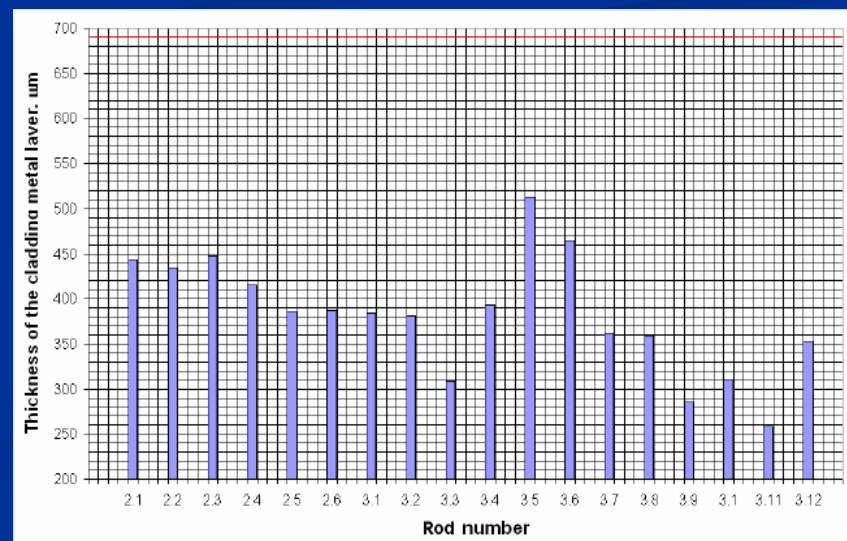
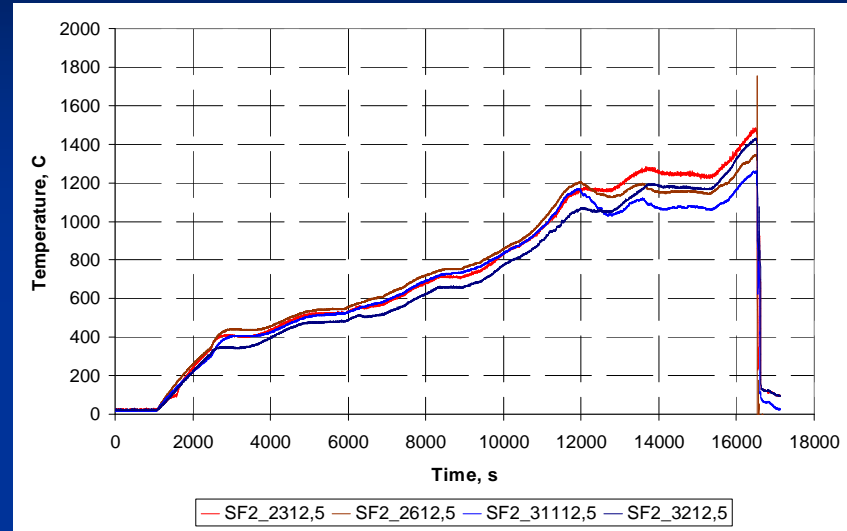
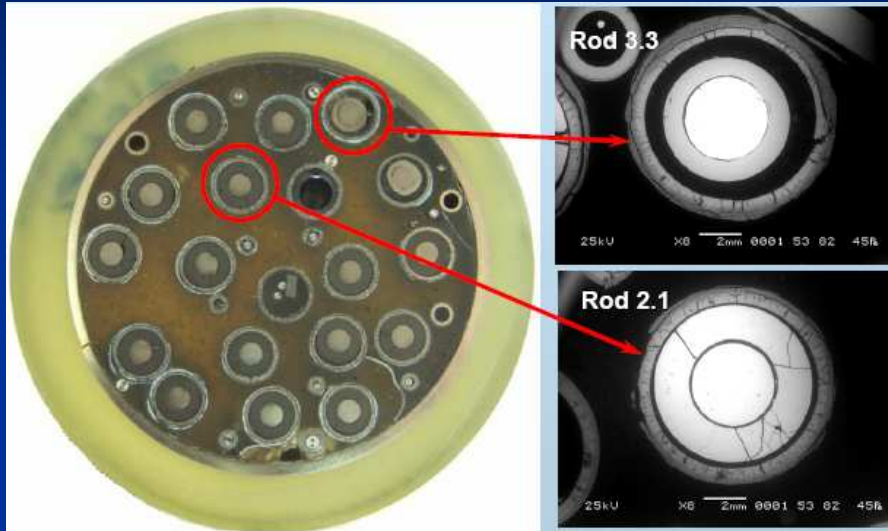
Metallographic examination of the cross section at Z=1103 mm



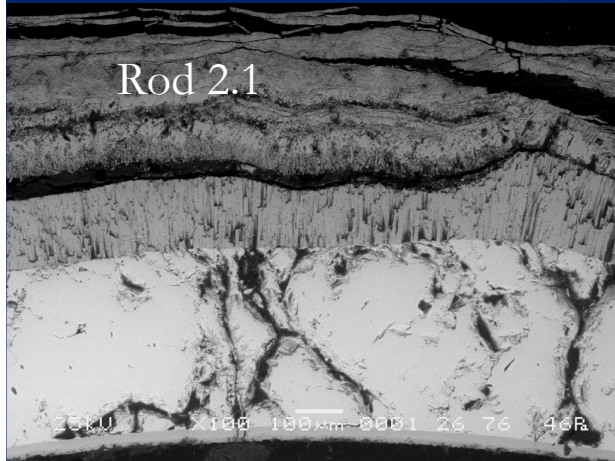
Layers structure at Z=1103 mm



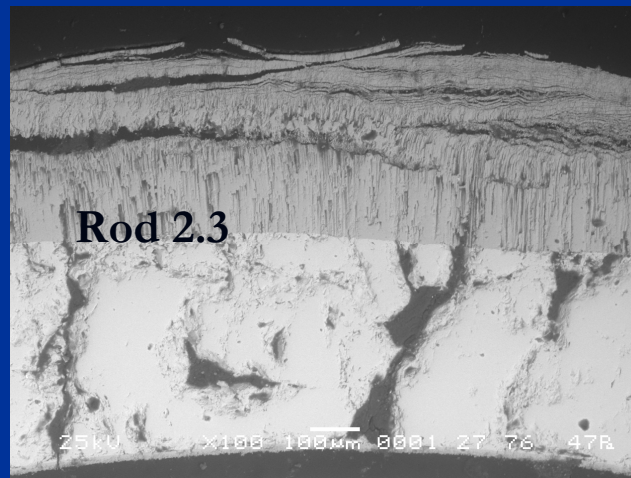
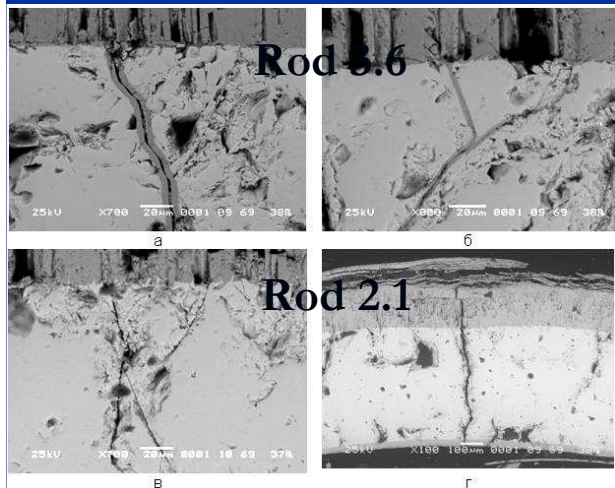
Metallographic examination of the cross section at Z=1250 mm



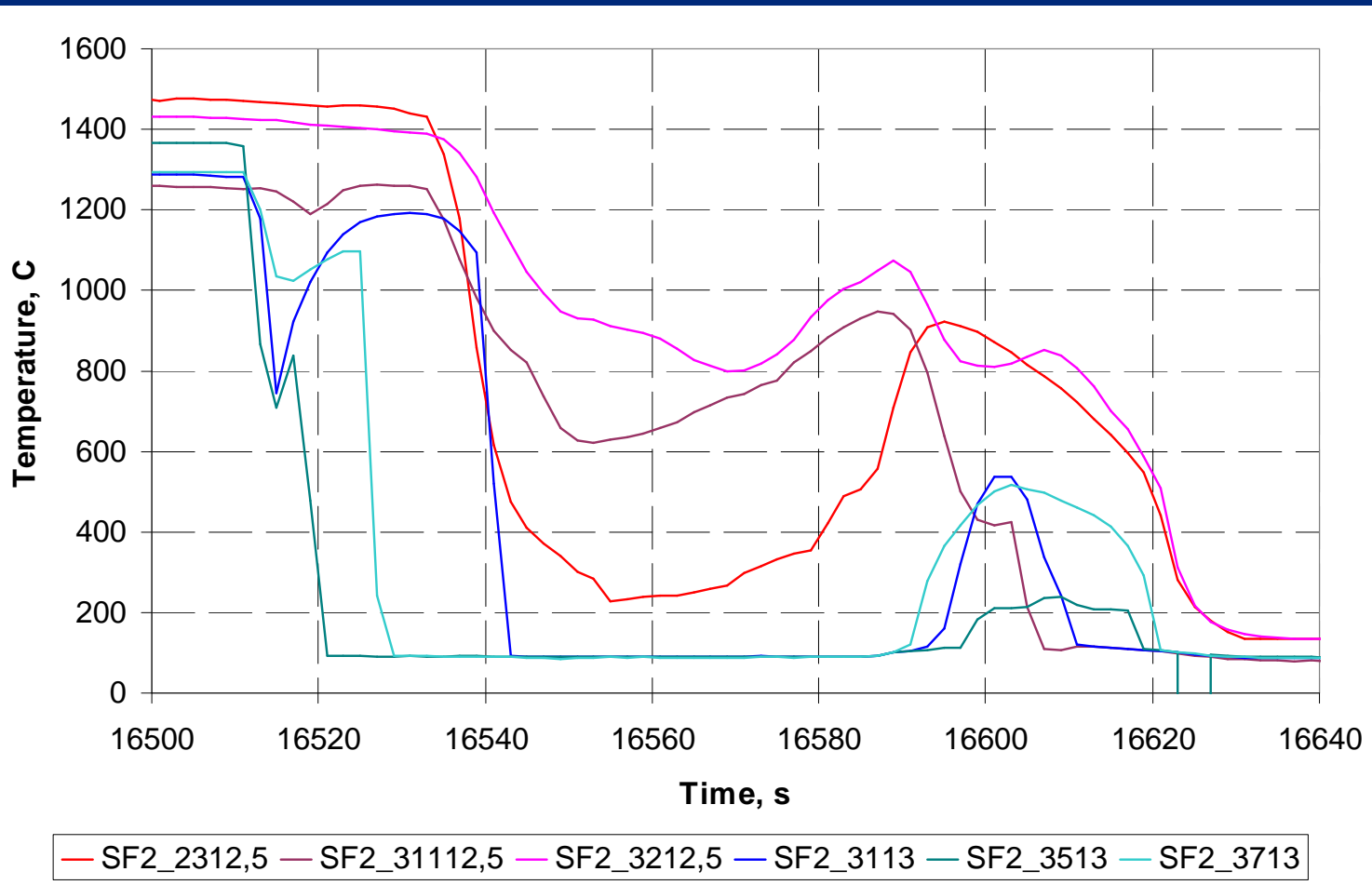
Layers structure at Z=1250 mm



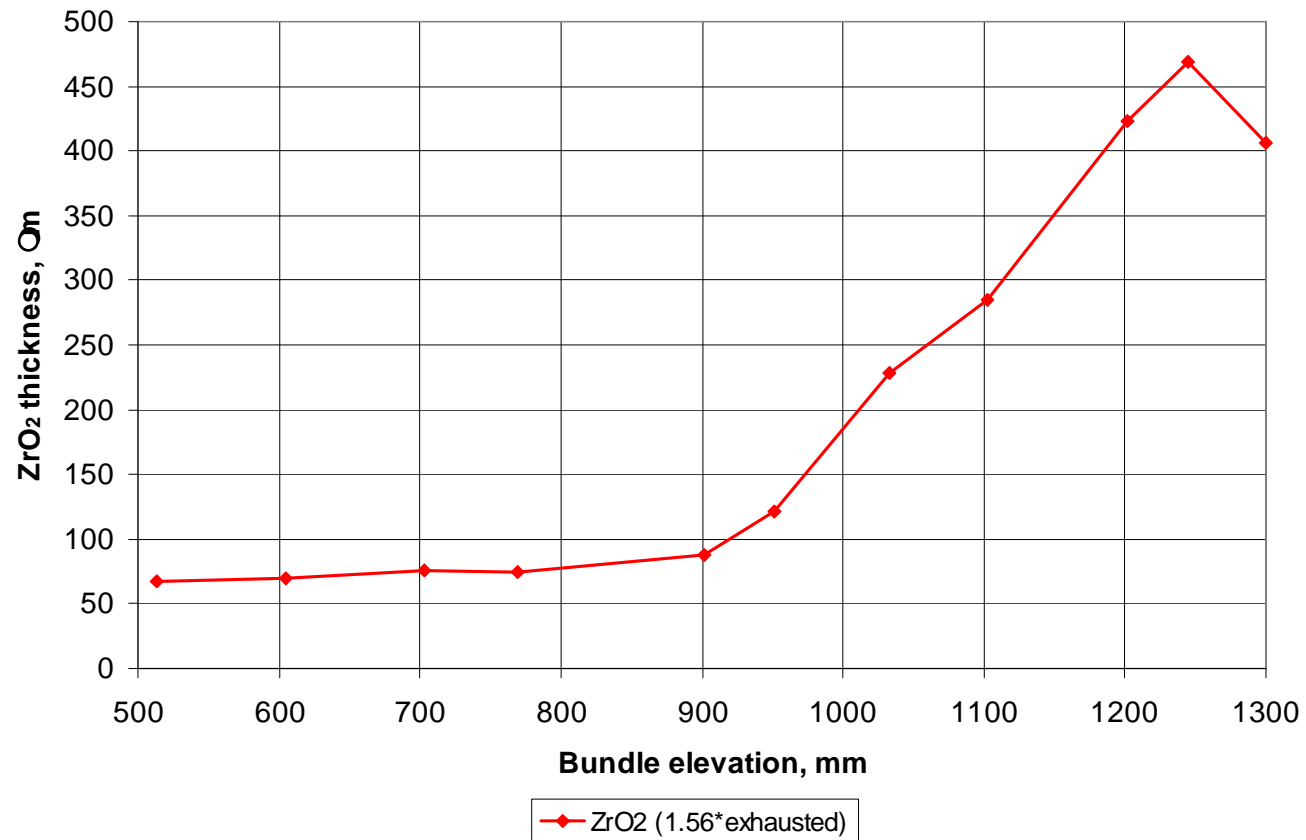
- split inner compact oxide with columnar structure and spalled off layered outer oxide
- weak inner cladding oxidation of some rods (30-50µm)
- complete $\beta \rightarrow \alpha$ transformation
- no fuel relocation or fuel-cladding interaction



Temperature evolution during quenching



Averaged oxide scale thickness



Summary

- SF2 bundle reveals pronounced breakaway oxidation over 500-1300 mm;
- cladding oxide scale over 900-1300 mm includes inner compact oxide with columnar structure on the metallic layer and external multi-layer spalled off oxide;
- over 1100-1300 mm inner compact oxide is split or tends to split; possible reason could be cool down and heat up cycle during combined quenching
- maximum calculated cladding oxide scale thickness corresponds to the hottest elevation (1250 mm);
- inner cladding oxidation over 900-1300 mm is weak;
- cladding fragmentation is non-pronounced;
- no fuel relocation.