

START-3 Calculations of SUPER-RAMP (FUMEX-III) Cases

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1. START-3 FUMEX Exercises History

1. FUMEX 2 cases were calculated;
2. FUMEX 3 SUPER-RAMP cases were calculated;
3. Recalculation FUMEX 2 Simplified cases.

2. SUPER-RAMP

The Studsvik SUPER-RAMP [1] Project, an internationally sponsored research project, investigated the failure propensity of typical LWR fuel in the form of test rods when subjected to power ramps, after base irradiation.

The Project power ramped 28 individual PWR rods and 16 BWR rods. The PWR rods were all tested using high ramp rates. Due to different objectives for the BWR subprogramme, one set of the BWR rods was tested using a high ramp rate, and another set were tested with a very slow ramp rate.

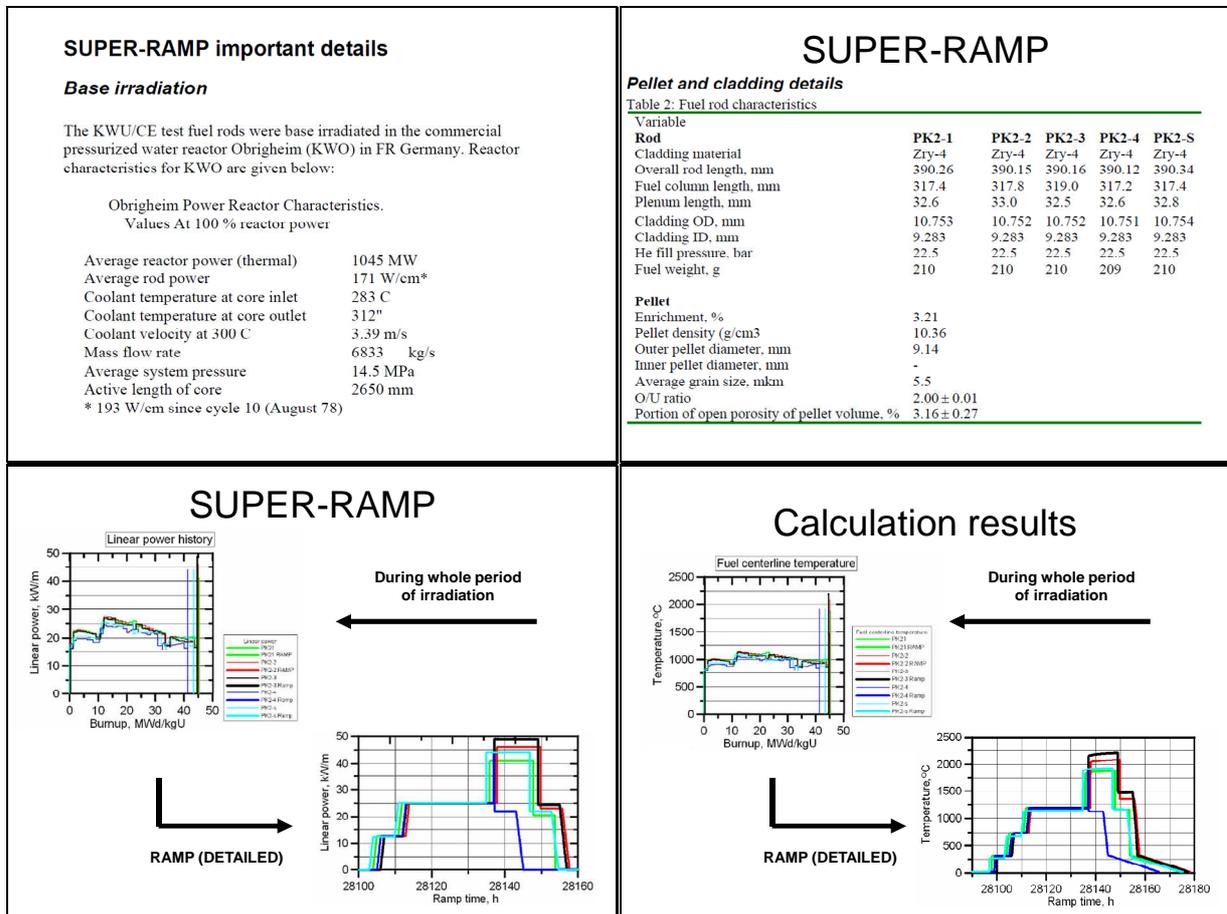
All rods underwent a thorough examination program, comprising characterization prior to base irradiation, examination between base and ramp irradiation and examination after ramp irradiation.

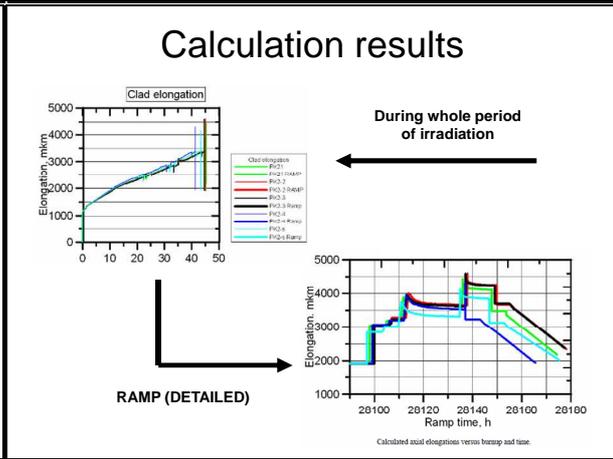
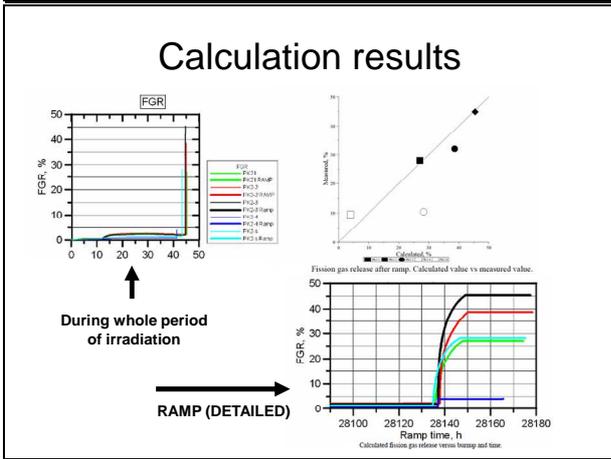
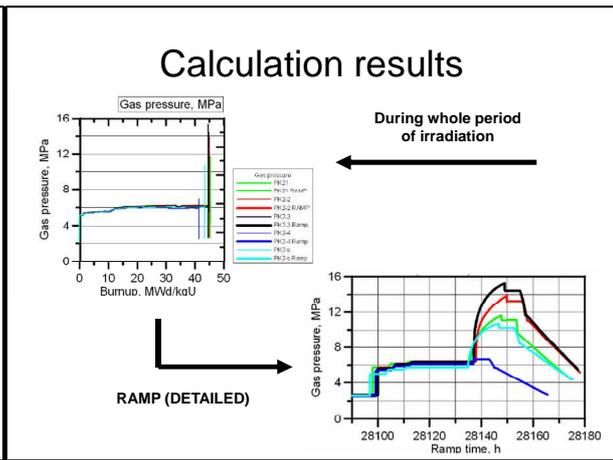
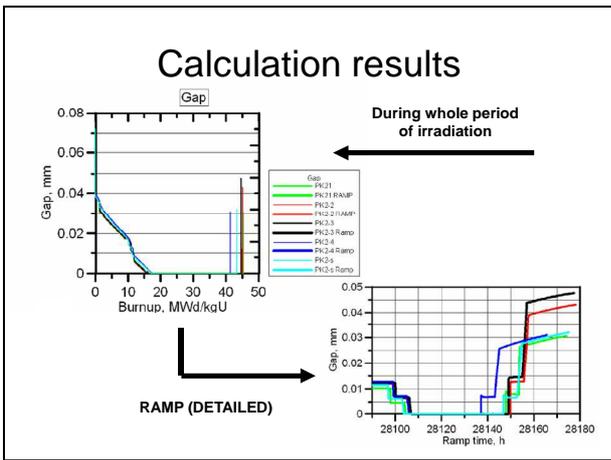
There were 6 groups of rods with variations in design and material parameters.

The rods were base irradiated in a power reactor environment KK Obrigheim or BR-3 at time averaged heat ratings mainly in the range 14-26 kW/m to peak bum-ups in the range 33-45 MWd/kgU and were subsequently ramp tested in the research reactor R2 at Studsvik, Sweden.

In this presentation some calculations are made on the PK2 group fuel rods. The rods were standard rods manufactured by Kraftwerk Union AG/Combustion Engineering (KWU/CE).

All these rods sustained ramping to power levels in the range 41 to 49 kW/m and power changes 16-24 kW/m without failure, in spite of large deformations, fuel restructuring and fission gas release particularly for the PK2 rods.





3. Conclusion on PK Calculations

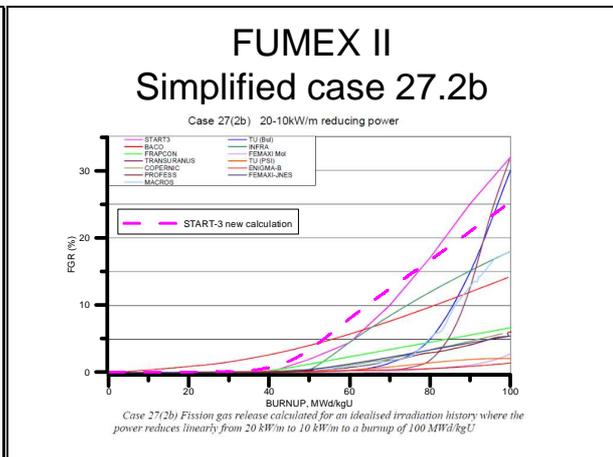
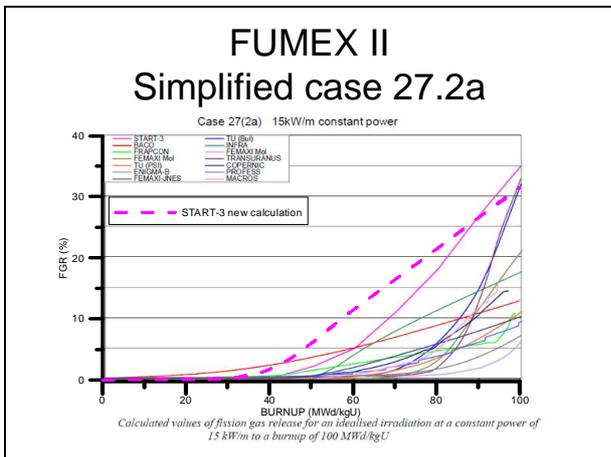
- Calculations have shown reasonable coincidence of calculated and experimental FGR.
- Reasonable prediction of dimensional behavior of fuel rod.

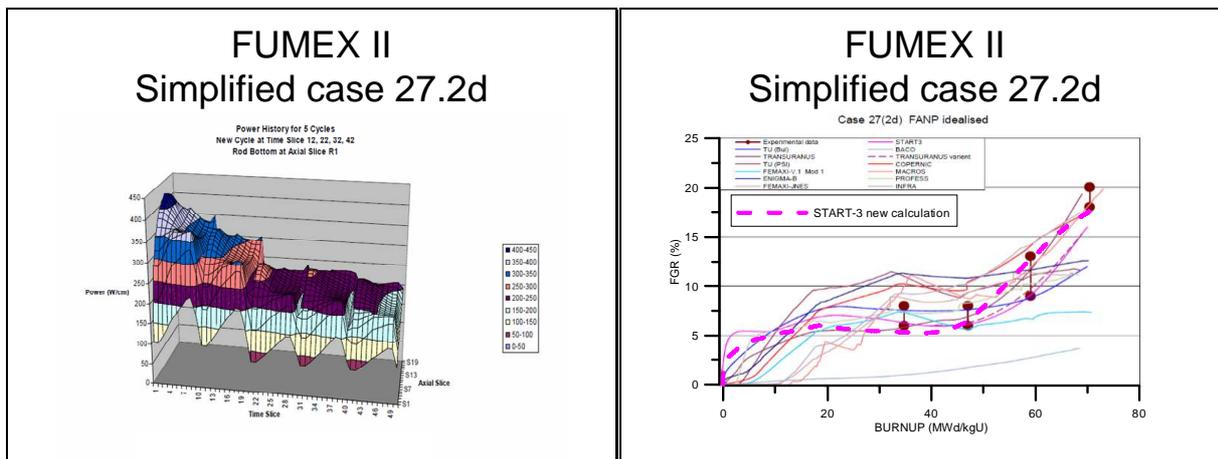
4. FUMEX II

The FUMEX-II [2] co-ordinated research pro-

gramme (CRP) was initiated by the IAEA following a recommendation of the IWGFPT. It was conducted over the period 2002-2006. Seventeen countries took part.

The FUMEX-II programme continued the work of the former CRP on "The development of computer models for fuel element behaviour in water reactors" (D-COM), which started in 1982 and was terminated in 1984, and the FUMEX CRP "Fuel Modelling at Extended Burnup" which started in 1993 and concluded in 1996.





Following the lead taken in the original FUMEX CRP, a number of simplified cases were constructed in order to investigate mathematical stability and more easily compare model and code predictions without the vagaries of real power histories. In this section, each case is outlined together with the reason for its inclusion before presenting the results and comparing the predictions.

The second idealized case was to illustrate code predictions of FGR as a function of burnup up to 100 MWd/kgU. There were four separate idealised cases for this task:

- 27(2a) a constant power of 15 kW/m from BOL to 100 MWd/kgU;
- 27(2b) a linearly decreasing power from 20 kW/m at BOL to 10 kW/m at 100 MWd/kgU;
- 27(2c) more realistic power history supplied by G Rossiter of BNFL;
- 27(2d) idealized 'real' history supplied by F Sontheimer of FANP.

5. Conclusion

FUMEX-III SUPER-RAMP exercise included up to 49 kW/m power ramps of fuel rods with burnup up to 45 MWd/kgU. START-3 calculations of this exercise are in reasonable agreement with the experiment.

The corrections made into the code are related with the cladding material properties and UO₂ diffusion parameters.

To verify the changes made into the code, the corrected version of the code was then used to recalculate the FUMEX-II simplified cases.

References

- [1] Final Report of the Super-Ramp Project. Seved Djurle, STUDEVK-STSR-32.
- [2] J. Killeen. Fuel Modelling at Extended Burnup (FUMEX-II). IAEA Report of a Coordinated Research Project 2002-2007.