Future Industry Hotlab Needs
- AREVA NP View -

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AREVA NP

> Introduction

> Milestones in the development of AREVA NP Fuel Assemblies

> Areas of hot cell support and examples of achievement

  - Fuel assembly
  - Water chemistry

> Future trends

> Conclusions
Average Assembly Burnup Achieved as of 2007/12/31

Year of First loading

Average assembly burnup (GWd/t)

BWR
PWR
### Milestones in the Development of PWR Fuel Assemblies of AREVA NP

<table>
<thead>
<tr>
<th>Year</th>
<th>AGORA® fuel ass.</th>
<th>M5™ structure</th>
<th>MONOBLOC™ guide tube</th>
<th>PCI remedies (Concerto)</th>
<th>Low Gd design</th>
<th>4.4 w/o U235</th>
<th>AFA™ 2G fuel assemblies</th>
<th>M5™ spacers and guide tubes</th>
<th>FOCUS™ fuel assemblies</th>
<th>AFA™ 2G fuel assemblies</th>
<th>4.0 w/o U235</th>
<th>M5™ cladding</th>
<th>ERU fuel assemblies</th>
<th>HTP™ fuel assemblies</th>
<th>Mark-BW™ fuel assemblies</th>
<th>AFA™ fuel assemblies</th>
<th>Gd2O3, full-low-leakage cores</th>
<th>Zircaloy spacers and guide tubes</th>
<th>Partial-low-leakage cores</th>
<th>MOX fuel assemblies</th>
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Milestones in the Development of PWR Fuel Assemblies of AREVA NP
Design of Modern AREVA NP Fuel Assemblies

BWR

- Internal water channel
- Fuel rods
- Part-length fuel rods
- Spacer grids

PWR

- Guide tube
- Fuel rods

FUEL
Objectives of Hotcell Work for the Fuel Manufacturer

- Provide data for design and modelling
- R&D, development of advanced materials
- Provide rodlets for test or for further examinations (E.g. RIA, LOCA, PCI)
- Investigation of incidents or special cases, i.e. new or unexpected phenomena
- Fuel backend studies
Survey of Key Design Data from Hotcell Examinations
- Fuel Assembly -

> Fuel rod (reactor operation and transient tested rodlets):
  - Dimensions (length, diameter),
  - Fission gas analysis,
  - Fuel density
  - Microstructural information (grain, porosity, rim, distribution and characterization of fission products)
  - Thermal annealing experiments
  - Isotopic analysis

> Rod cladding
  - Corrosion behaviour
  - Hydrogen concentration
  - Mechanical data (strength, thermal creep, …)
  - Crud characterization

> FA structural data (spacer, guide tube, water channel, fuel channel)
  - Corrosion behaviour
  - Hydrogen concentration
  - Mechanical data

> Control rods
  - Swelling
  - Mechanical data
Improvement of Corrosion Resistance
-PWR Cladding Corrosion (from metallographies)-

- Corrosion resistance is mainly determined by Sn and Nb
Reduction of Hydrogen Uptake
- PWR Cladding Data (as measured) -

![Graph showing reduction of hydrogen uptake vs. burnup]

- PCA-2
- AFA20
- M5/Zr1Nb
Analysis of Fission Gas Release up to High Burnups

![Graph showing fission gas release versus fuel rod burnup](image-url)
Optimization of the Fuel Density Behaviour

![Graph showing fuel density vs. burnup]

- Old standard fuel
- Modern stable fuel
- $\text{UO}_2$ / AUC
- $\text{UO}_2$ / stable fuel
- $\text{UO}_2$ / PuO$_2$

Burnup [MWd/kgHM]

Fuel density
Long Term Thermal Creep Tests on Irradiated Samples

Electrical furnace
- Double-wall tube

Diameter measuring device
- Axial adjustment
- Measuring head
- Circumferential adjustment
- Fuel rod sample

Gas filling station
- Gas inlet
- Pressure gauge

Results of qualification tests

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Double-wall tube

Circumferential adjustment
Refabrication of Rodlets for Transient Testing
Ramp testing in the OSIRIS reactor:

Linear power variation (W/cm) vs. Burnup (GWd/MTU)

- Zy-4 No Failure
- Zy-4 Failure

CONCERTO ramp tests
« On the characterization of plutonium distribution in MIMAS MOX by image analysis »
G. Ondinet et al., IAEA-TECDOC-1416, October 2004, p 221
AREVA NP’s Perspective of Future Hot Cell Work

> Further optimization of AREVA NP’s FAs is a continuous task (Budget!).

> Technical and economical optimization of the lab techniques is a continuous task, too.

> Burnup increase tends to saturate due to limited potential of a further U235 increase. Tendency of an increase of the plant power for different customers, opening up of operational margins by improved fission gas retention, optimization of structural behaviour with regard to corrosion and mechanical behaviour.

> Growing importance of coolant chemistry topics (power increase, dose rate reduction, life time of components); techniques, such as Li and B measurements in the oxide, characterisation of the crud (chemical composition, porosity,…)

> Refabrication of rodlets for transient testing and their subsequent analysis remains interesting (e.g. mechanical properties of cladding and fuel).

> PCI remedies in the new operational conditions (burnup, power increase)

> MOX fuel in the new operational conditions (burnup, power increase)
CONCLUSIONS

> In the last two decades, burn-up and reliability of PWR and BWR fuel could be increased considerably. It would not have been possible without comprehensive analysis performed in hot cells all over the world.

> In future, hot cell work will be needed to further optimize the fuel for the existing fleet of reactors, but also for the advanced LWRs still to come. As their basic technique remains essentially unchanged, existing hot cell techniques can also be utilized for a while.

> For the near future, a lowering of budget for hot cell investigations can be expected. As a result, all doers, i.e. fuel manufacturer and hot cells, will have to focus on more economic processes.