Framatome`s Experience with 18/24 Month Cycles

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CONTENT

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1. Requirements for 18/24 Cycles

Cycle Length vs. Effort

- Comparison of 12, 18, and 24 month cycle

Cycle Length	Refuel	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Summary
12-month	20%	Outage 1	Outage 2	Outage 3	Outage 4	Outage 5	Outage 6	6 outages in 6 years
18-month	33%	Outage 1	Outage 2		Outage 3	Outage 4		4 outages in 6 years
24-month	45%	Outage 1		Outage 2		Outage 3		3 outages in 6 years

- Assuming 1 month for outages, this means

Cycle Length	EFPD / 6 a	Core Reloads	Outage Effort
12-month	2012	1.20	6
18-month	2072	1.30	4
24-month	2102	1.35	3

Topics on cycle length modification

Less outages

More effort during single outage

Update of safety studies

Higher effort in fuel purchase/backend

Less risk for longlasting authority approvals

More time for electricity production

preparation for outage

Modification and risk for short term outage

Risk on larger rod bow

Less risk in damaging during outages

Several Fq Maxima

Less outage effort

More reload volume

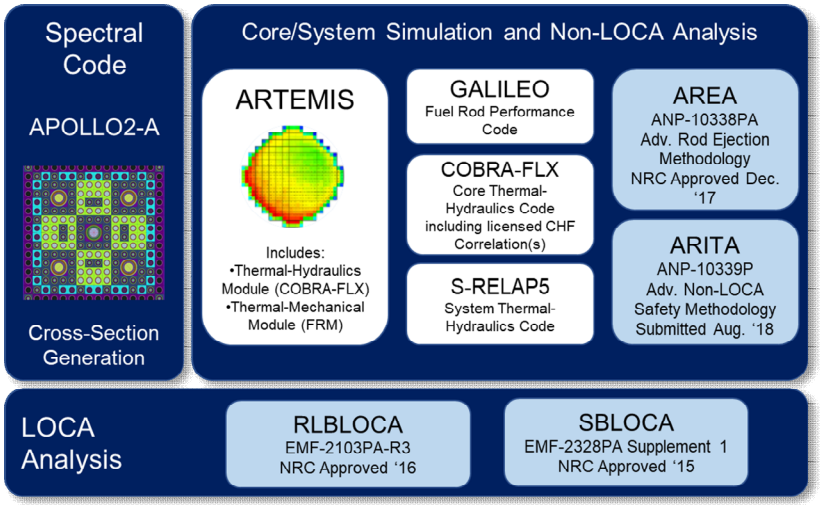
Customer requirements

- Cycle Length
- Number of reloaded fuel rods
- Burn up targets
- Operation flexibility
- Enrichment level
- Gd enrichment level
- Gd rod length
- Number of Gd rods
- Plant specific requirements

2. Core Optimization / Safety Limitations

Cycle Design and Licensing Methods

- Framatome is capable to calculate long cycles
- In case of PWR ARCADIA package is providing the interface
- In Case of BWR COMPASS package is providing the interface



3. Plant Experiences

PWR Plants already operated with long cycles

- New plant designed for 12-, 18-, and 24-month cycles

- Older plants in last cycle operate 418 efpd (EOC_{nat}) + stretch-out (510 efpd)
  - No safety limitations
  - Last reload ~25% of fresh fuel incl. Gd

- In some countries only long cycles are applied
  - Cycle design: 540 efpd
  - Reload ~40%
  - Safety windows rather fixed designed
  - limited flexibility (plan specific approach)

PWR Plants already operated Gd rods

- Typically applied for all kind of cycle length
- No issues in operation or safety margin
- Core design ensures flat power distribution, low leakage
- Used or plant with long cycles

BWR Plants already operated with long cycles

- US
  - most plants run 24M cycles
  - some plants run 18M cycles
  - AFM studies ongoing on longer cycle lengths up to 36M

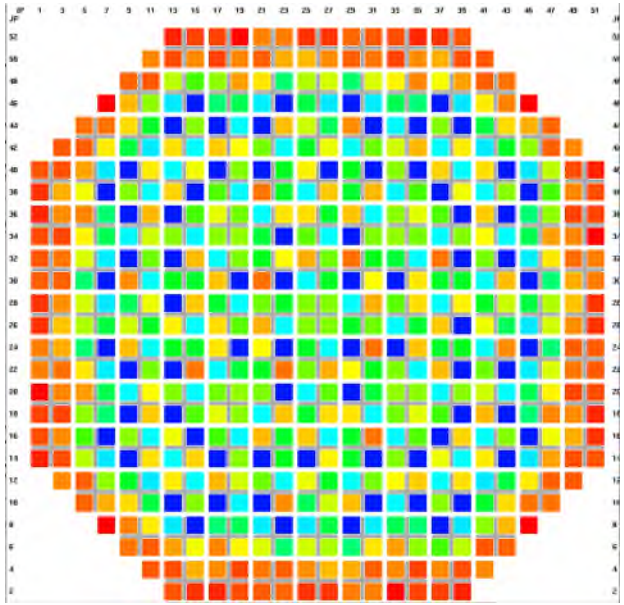
- EU
  - Spanish plant runs 24M cycles
  - German plant did run 15M and 18M cycles

Loading Pattern Effects

- loading pattern: from CCC pattern to „checker board“ pattern
- design work: from core design to FA design

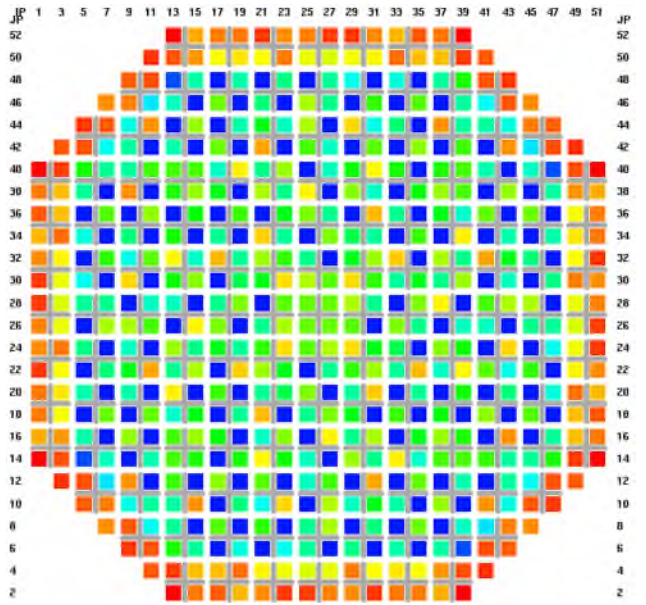
12M

13% reload fraction



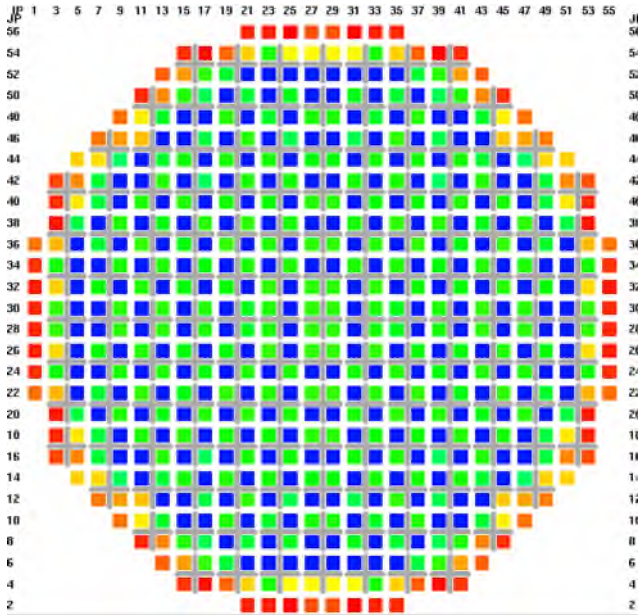
18M

24% reload fraction



24M

40% reload fraction



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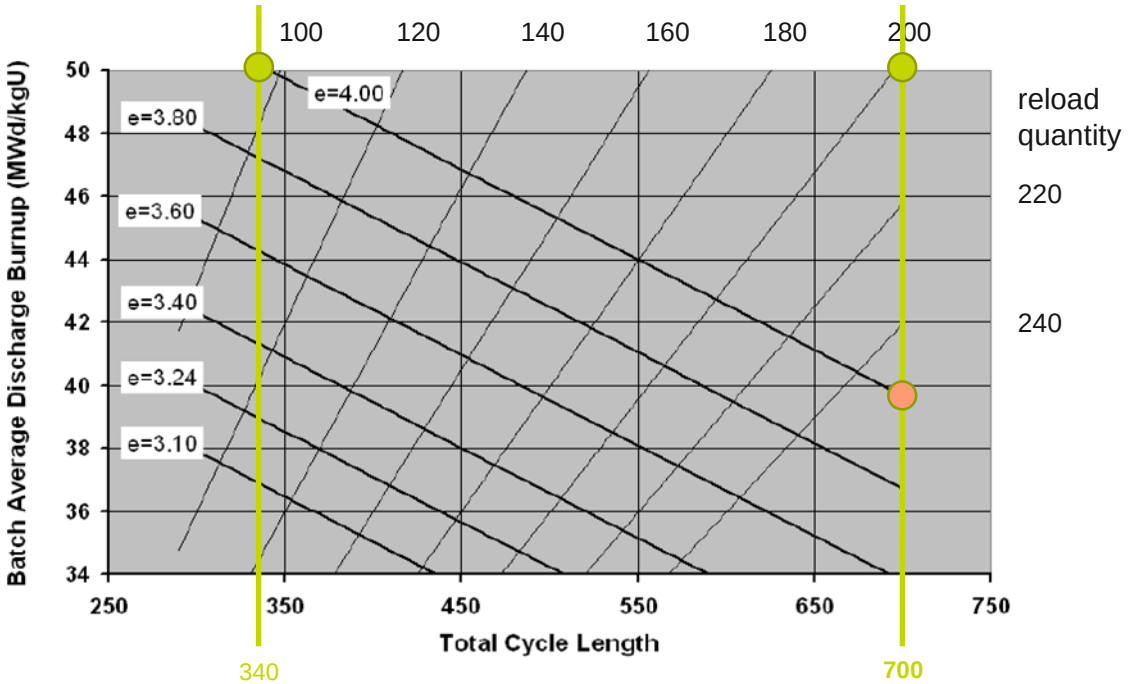
Challenges

To improve economics:

- increase cycle length
- reduce reload quantities

but this requires:

- higher bundle enrichment



4. Outlook Future Developments

Advanced Fuel Management (AFM)

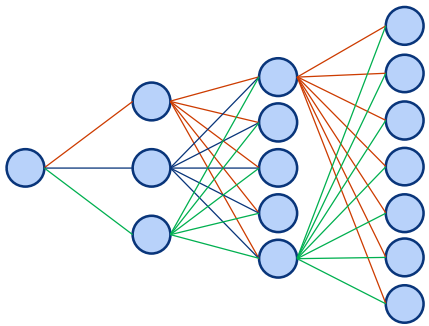
- Framatome is Implementing LEU+ Fuel Fabrication Capability
- PWR fuel assembly shipping containers approved for up to 8 wt% 235U enrichment
- The AFM project will establish a new max enrichment level for the HRR facility

Cycle Design	Fuel Fabrication	Enriched Uranium Product
• Reduced batch size designs • High burnup fuel design approval • Licensing methodology amendments	• Licensing for LEU+ receipt • Criticality protection upgrades • Shipping container relicensing	• New centrifuge cascades • New or relicensed UF6 cylinders • New or relicensed overpacks

Artificial Intelligence

- Optimization taking into account several parameters
- Optimize design on fuel rods: GD/U content, number of Gd rods, bot/top blankets

  number of fresh fuel, burn-up limitations, power limitations, operation flexibility, Margin to safety limits



- Getting set of loading patterns
- Getting branch of fuel rod designs
- Less effort in investigations
- Detailed results on several parameter effects

Conclusions

- Long Cycles possible and well experienced
- Core design optimization replaced by fuel design optimization
- Several parameters to be incorporate to optimize
- Longer cycle benefits in more productive time while less outage time
- Framatome can support in all steps from short cycle to long cycle
- Future handling will be improved by applying AI methodologies + AFM

