

Shielding Fuel Assemblies & ATHENA

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1. Lifetime Limitation by Neutron Fluence

About Neutron Fluence

- Neutron production in active part of the core
- Neutron E > 1 MeV cause neutron embrittlement
- Sensitive areas: beltline welds, flanges
- Aging of reactor pressure vessel is life time limit
- Neutron cause activation, relevant for D&D



Neutron Fluence validation

- Neutron flux measured by detectors
- For RPV development dedicated capsules:
 - E.g. Fe, Nb detector
 - Activation over time
 - Recalculation of neutron flux
 - Capsules show future of RPV
 - Material analysis to valid RPV integrity



Neutron Fluence E > 1 MeV development

- Demonstration of fluence development
- Visualization of fluence increase
- Extrapolation for upcoming cycles
- Relevant for RPV maximum
- Also demonstrated for sensitive areas



2. Neutron Fluence Optimization

Low Leakage Core Design

- Applying fuel assemblies with high burn up at periphery
- Outer row acts like a heavy reflector
- Less neutron leave the active core
- Effective core size is decreased
- Core design optimization ensures flat power distribution
- Process is well known and today applied for lot of NPPs

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5	5	1	4	2	3	3
5	1	4	3	3	1	3
5	1	4	2	3	3	4

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Increase of Validation Fluence

- Increase of validation fluence
- Introduction of new or further irradiate surveillance capsules
- Requires sufficient time to
 - Prepare
 - Irradiate
 - Evaluate

The capsules

Already applied in some NPPs



Application of Shielding Fuel Assemblies

- Introduction of SFA in critical areas
- Rather low effort in licensing and introduction
- Have to be replaced after certain time
- Experienced shielding factor
 2.3 and 7.5 in Vattenfall plants



3. ATHENA concept

Coupling to Core Design Data

- Fuel Design is input for XS data in ARCADIA
- ARCADIA applied for Core Design + Safety Analysis + Interface Data
- ATHENA applies HDF Data for detailed Monte Carlo Fluence Calculations







Detailed 3d MCNP model

- Neutron source data full traceable
- Detailed 3D MCNP model containing all relevant
- Automatic data transfer to evaluate the effect on critical areas
- Can be applied with high time resolution
- Can be applied later for D&D calculations

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Cycle by cycle or higher time resolution



Neutron Flux of Detectors

- Time dependent behavior of the
- Interaction rate of ex-core detectors
- Activation rate of passive detectors
- Activation rate of Self-Powered-Neutron-Detectors
- Determination of lifetime of detectors input data for waste disposal



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Control Rod Fluence Calculator

- Monitor all RCCA
- Identify RCCA with high/low fluence
- Optimize RCCA core positioning
- Optimization RCCA operation mode
- Ensure long term operation of all RCCAs
- Input for waste package optimization

SE-ROD-41	SE-ROD-42	SE-ROD-43	SE-ROD-44	SE-ROD-45	SE-ROD-46	SE-ROD-47	SE-ROD-48
SE-ROD-33	SE-ROD-34	SE-ROD-35	SE-ROD-36	SE-ROD-37	SE-ROD-38	SE-ROD-39	SE-ROD-40
SE-ROD-25	SE-ROD-26	SE-ROD-27	SE-ROD-28	SE-ROD-29	SE-ROD-30	SE-ROD-31	SE-ROD-32
SE-ROD-17	SE+ROD-18	SE-ROD-19	SE-ROD-20	SE-ROD-21	SE-ROD-22	SE-ROD-23	SE-ROD-24
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4. Shielding Fuel Assemblies

Use of different Shielding designs

- Shielding Fuel Assemblies a combination of
 - Fuel Assembly (e.g. ordinary Uranium enrichment)
 - Shielding Assembly (e.g. Steel bars)
 - In a well establish Fuel Assembly design to reduce lenience effort
- In all cases, RCCA guide tubes replaced by steel bares
- Radial symmetric design allows rotation of Shielding Fuel Assembly
- Number of steel bars depends on the required shielding factor (ratio of flux reduction)



4.2. Axial or Radial Symmetric Design





4.2. Design Optimization

- To limit effect of core design parameters:
- Volume of core reduction to be limited
- Shielding should ensure sufficient "shadow"
- Axial segmentation of Shielding Fuel Assembly
- Optimization of shield length and fuel



Conclusions

- Detailed Neutron Fluence analysis
- Direct evaluation of core design regarding neutron fluence
- Fluence reduction techniques
- Shielding Fuel Assembly adaptable to required life time extension
- Long time experience in the field of fluence evaluation and optimization



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