WPEC Subgroup 46 Activity on “Target Accuracy Requirements (TAR)”

April 14th 2021

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Core physics validation

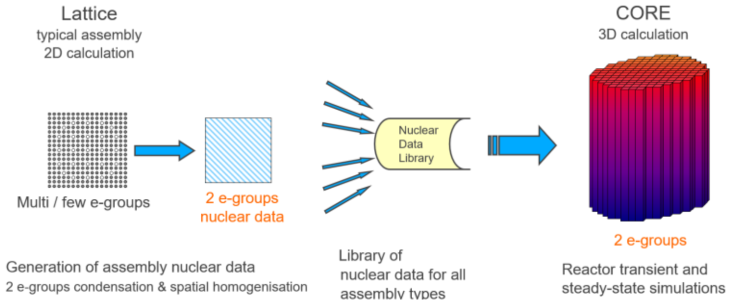
- Codes and Methodologies approval process

Assembly

- Verification
  - Code structure
  - Numerical models
- Validation
  - Code comparisons
    - Deterministic
    - Monte Carlo
    - Analytical solutions
  - Comparisons with experimental results
    - Reactor type
    - Experiment type

Core

- Justification of numerical models
  - Derivation of neutronic (nuclear) data
  - Neutronic calculations
  - Derivation of T-H data
  - T&H models
- Accuracy of approximations
  - Benchmarks problems
    - Steady-state neutronics
    - Transient neutronics
  - Code comparisons
    - Steady-state neutronics
    - T-H models and data
  - Plant comparisons with operating reactors
    - Steady-state
    - Transient

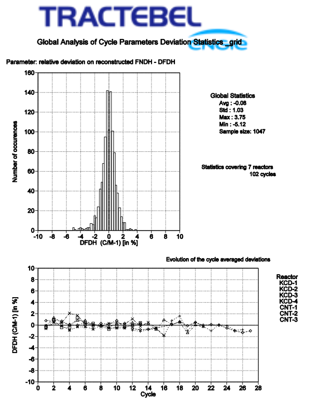


Calculation route… from ND to simulation of flux distribution in a given medium

Unique calculation route for all units

P-M codes suite performance matches acceptance values for PWR safety applications

Core physics validation



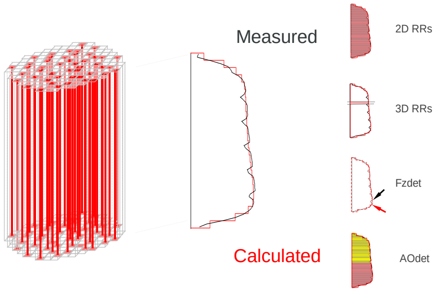
- Typical validation results for current PWR route based on JEF2.2
  - Start-up tests
  - Cycle depletion & 3D-distribution of neutron flux

Parameter	Calculated - Measurement Mean	1σ	Valid range
HZP			
Critical boron conc. [ppm]			
ARO	-8	25	±50ppm
Rod banks (global) [ppm]	-21	19	
D	-15	27	
C (Din)	-21	28	
B (DCin)	-21	26	
A (DCBin)	-26	24	
Rod bank worths Δ_r[%]	0.5	4.7	±10%
D	-1.4	4.4	±10%
C (Din)	0.7	4.5	±10%
B (DCin)	0.5	4.4	±10%
A (DCBin)	2.4	4.6	±10%
MTC [pcm/°C]	-2.4	1.3	±5 pcm/°C
Boron worth Δ_r[%]	-2.1	4.8	±10%

where Δ_r denotes a relative (Calculated/Measurement -1) discrepancy

Parameter	Calculated - Measurement Mean	1σ	Valid range
HFP			
Critical boron concent. [ppm]	-16	32	±100 ppm
2D RRs Δ_r[%]			
Unfiltered	0.1	1.5	-
Power_gt1.00	0.0	1.3	±5%
UO2	0.1	1.6	-
Fresh Gd	0.6	1.4	-
3D RRs Δ_r[%]			
Without grids, unfiltered	-1.2	2.4	-
Fz_d Δ_r[%]	-1.2	1.2	-
Fz_{detp} unfiltered Δ_r[%]	-1.5	1.4	-
AO_d [%]	-0.1	1.0	-
AO_{detp} unfiltered [%]	-0.2	1.2	-
Natural cycle length [MWd/t]	-208	311	-

where Δ_r denotes a relative (Calculated/Measurement -1) discrepancy



sub-populations of FAs to detect specific trends or behaviors (Gd poisoned, position in core, …)

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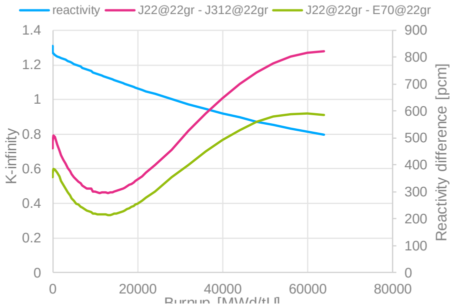
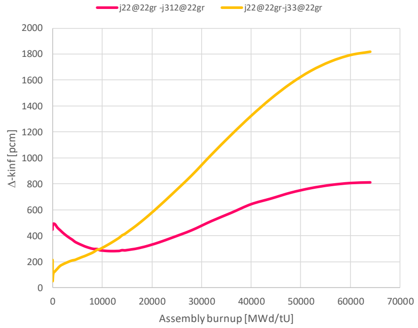
Core physics suite evolution
Impact of the nuclear data library

- Nuclear Data are treated by NJOY to generate a 172 e-groups library for reactor physics calculations
- Validation based on JEFF3.1.2 faced great impact on plant data comparison due to strong reactivity differences at assembly level
  - Assembly level difference between JEF2.2 / JEFF3.1.2 > 300 pcm
  - Plant validation results show much greater impact on reactivity for library choice than physics modelling options



- Validation based on JEFF3.3 did not improve JEFF3.1.2 performances
  - Huge (adverse) impact at assembly level (22 energy-groups)
  - Large discrepancies for plant data comparisons
    - In particular, strong underestimation of the core reactivity (HFP and HZP)



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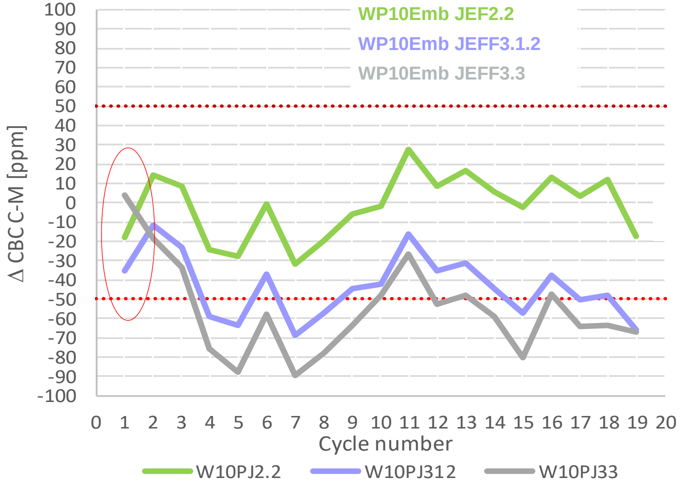
Core physics suite evolution
Plant validation/ Impact of the nuclear data library

- Example of library effects on plant data validation : Δ boron concentration HZP

Belgian test Unit



Fresh <> Depletion

NO CALIBRATION

- New models and methods for Core Physics move towards higher fidelity
  - The more recent libraries have all a huge impact on the global reactivity and do not match the accuracy targets using a unique calculation route

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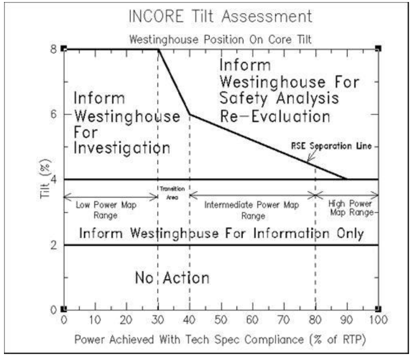
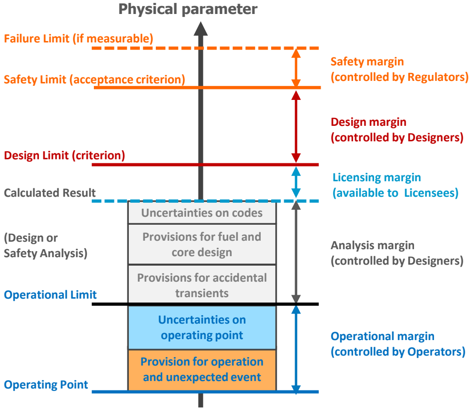
Some thoughts

- On a pure PWR Utility point of view
  - Acceptance criteria for plant operation and technical specifications are based on pratice, instrumentation performance and operational feedback
  - Always possible to “calibrate” to get closer to measured quantities but it should apply consistently for all cores/units and only applicable within calibration and validation range
- On a Neutronics point of view
  - Calibration should lead to constructive evolution of Codes and Methods (Why? correct and get better)
  - Trust the code capacities relying on almost spot on predictions < acceptance criteria is always better
  - Demonstrated uncertainties play an important role of safety and operation





Some thoughts

…"A real system can be apprehended by means of a model only. Any validation of the calculations is therefore necessarily limited to the scope and the validity of the model. This limitation is the very reason for having a model rigorously defined and validated from the outset, as complete and as coherent as possible through all phases of the multi-step demonstration "…

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