Proposal

VT^{3}G-SNFP (Spent Nuclear Fuel Pool) benchmark, a loosely coupled system

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For presentation at the OECD Workshops on Benchmarks and Uncertainty Quantification , May 18-22, 2015, Universidad Politecnica de Madrid (UPM), Madrid, Spain

Purpose

- Recent public and regulatory concerns about safety and security of spent nuclear fuel pools (SNFP) has resulted in the utilization and/or development of best estimate techniques that have to be benchmarked

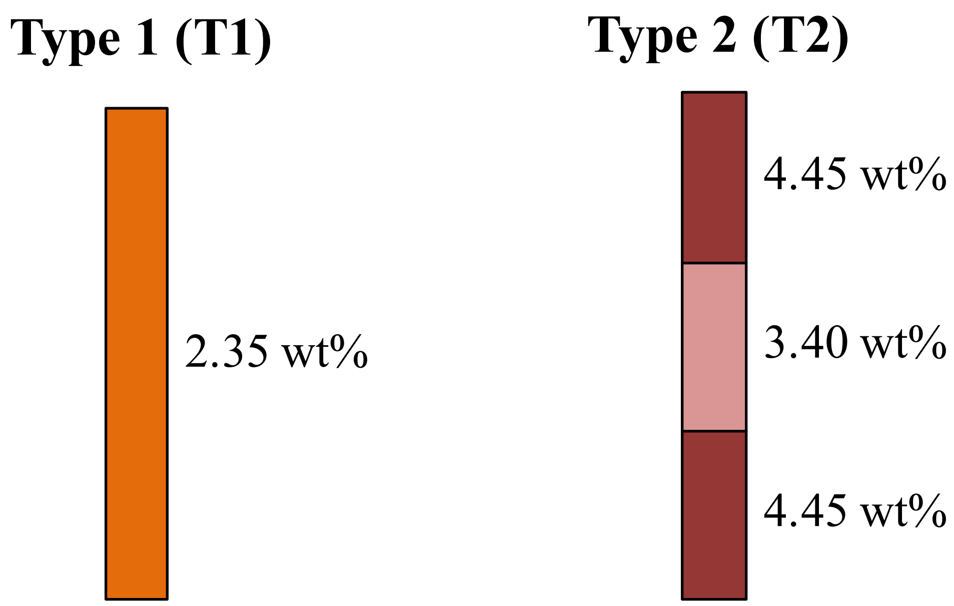
- Determination of accuracy and efficiency of different methodologies, e.g., Monte Carlo criticality calculation vs. Fission Matrix (FM) approach

Background

- Since 2006, VT^{3}G (Virginia Tech Transport Theory Group) has been engaged in the development and testing of accurate and fast methodologies for simulation and analysis of SNFP with applications to criticality safety and nuclear safeguards. two software tools have been developed based on the Multi-stage Response-function Transport (MRT) methodology :
- INSPCT-s (Inspection of Nuclear Spent fuel-Pool Calculation Tool ver. Spreadsheet) (Refs. 1 and 2) and uses pre-calculated databases for identification of fuel diversion and/or placement mishaps.
- RAPID (Real-time Analysis for spent fuel Pool *in situ* Detection) (Refs. 3 and 4) developed for determination of detailed fission density throughout a SNFP in addition to the pool eigenvalue and subcritical multiplication
- Based on above experience, we are:
  - Organizing a workshop entitled *1st Workshop on Spent Nuclear Fuel Pool Simulation, Safety and Security*, from June 23-25, at the Virginia Tech Research Center (VTRC) in Arlington, VA, USA.
  - Proposing the VT3G-SNFP benchmark problem (identify tools, their accuracy and efficiency, and obtain information on the range of variations of different parameters and their sensitivity to problem detail and complexity)

Proposed Problems

- Two problems, made of two types of assemblies, which made of the following fuel pin types



Problem 1

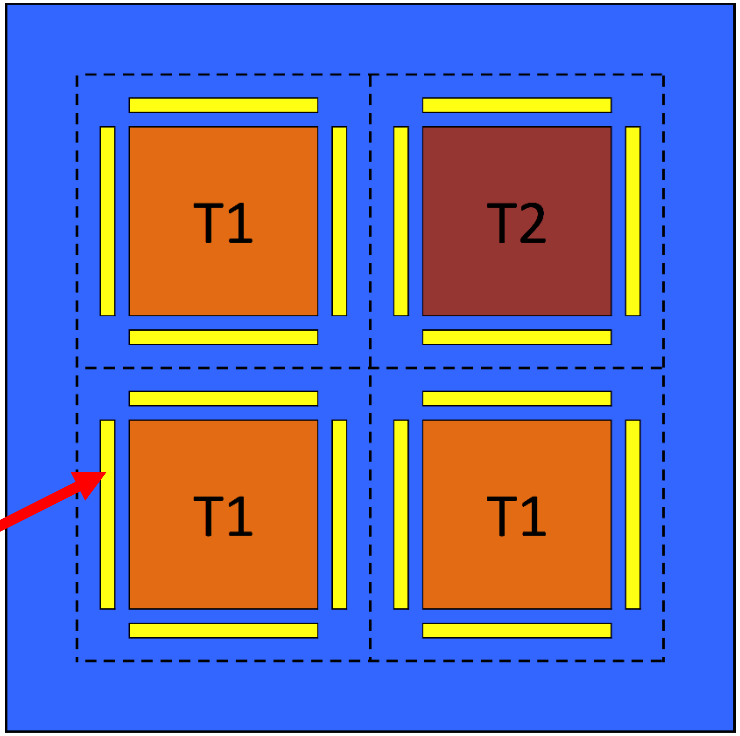
4-Assembly with axial variable enrichment (4A-AVE);

The four assemblies are placed in a pool of water and separated by *Metamic* neutron absorbers.

Two types of *Metamic*:

18.92 wt% B_4C

43.30 wt% B_4C



Benchmark Results

- Pin-wise fission density for all four assemblies
- *K* value for the system
- Pin-wise, axially dependent fission density for assembly *T1* and *T2* using Table A.1

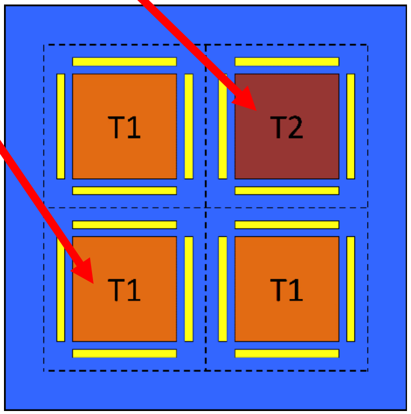


Table A.1 - Axially-dependent pin-wise fission density

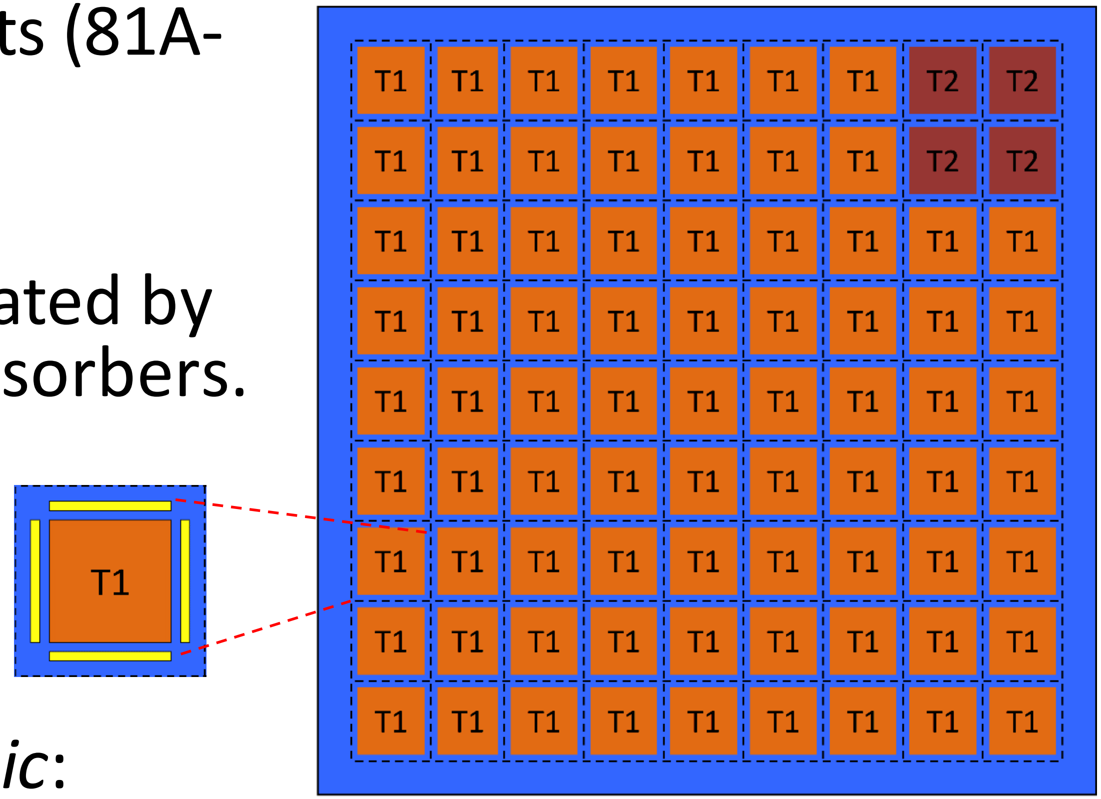
B_4C Conc. = 18.1 wt%	K_{eff} =				
Assembly-wise, Pin-wise, axially-dependent fission density					
A-ID[a];P-ID[b]	A-ID; P-ID	A-ID; P-ID	A-ID; P-ID	A-ID; P-ID	A-ID; P-ID
(1,1; 1,1)					
1					
2					
3					
…					
24					
(1,1; 1,2)					
1					
2					
3					
…					
24	…				
(1,1; 1,3)					
1					
2					
3					

A-ID: Assembly ID; P-ID: Pin ID

Problem 2

81-Assembly Pool with Different Enrichments (81A-PDE).

All assemblies separated by *Metamic* neutron absorbers.



Two types of *Metamic*:

18.92 wt% B_4C

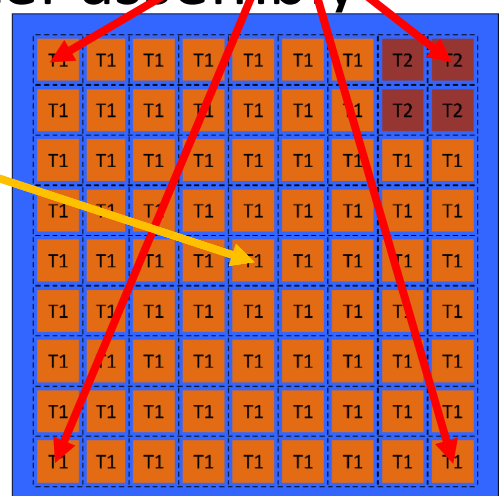
43.30 wt% B_4C

Benchmark Results

- Pin-wise fission density for all assemblies

- *K* value for the system

- Using Table A.1, provide pin-wise, axially-dependent fission density for the four corner assemblies, the center assembly



Sample Data

Table 1 - Assembly structure and dimensions

Item	Data	Comment
Assembly lattice size	17x17	
Rods per Assembly	264	
Guide Tubes per Assembly	25	
Rod pitch	0.4960 in	
Fuel pellet OD	0.3225 in	
Height (active)	168" (144")	12" of water is placed at top and bottom of active fuel
Clad OD	0.3740 in	
Clad Thickness	0.0225 in	
Guide Tube OD	0.4820 in	
Guide Tube Thickness	0.0200 in	
Neutron Absorber Length	168 in	
Neutron Absorber Width	7.5 in	
Neutron Absorber Thickness	0.106 in	

Table 2 - Materials information

Mixture	Mate rials	Density	Weight Fraction
Fuel	UO_2	10.74 g/cm^3 (97.5% theoretical density)	2.25 wt% 235U 238U – 0.8608 235U – 0.0207 O – 0.1185 3.4 wt% 235U 238U – 0.8515 235U – 0.0300 O – 0.1185 4.45 wt% 235U 238U – 0.8422 235U – 0.0392 O – 0.1185
Gap	void		
Cladding	Zircaloy	6.58 g/cm^3	Zr – 0.9824 Sn – 0.0145 Fe – 0.0021 Cr – 0.0010

Mixture	Mate rials	Density	Weight Fraction
Water		1.0 g/cm^3	H – 0.1119 O – 0.8881
Stainless steel, 316		7.94 g/cm^3	C - 0.000410 Si - 0.005070 P - 0.000230 S - 0.000150 Cr - 0.170000 Mn - 0.010140 Fe - 0.669000 Ni - 0.120000 Mo - 0.025000
Metamic absorber	B_4C	2.664 g/cm^3 2.619 g/cm^3	18.92 wt% B_4C Al – 0.8108 11B – 0.1209 10B – 0.0271 C – 0.0411 43.30 wt% B_4C Al – 0.5670 11B – 0.2768 10B – 0.0621 C – 0.0941

Thanks!

Questions?

Completed June 2011