Westinghouse – U. of Cambridge – Georgia Tech – INL – Morehouse – PoliMi – VirginiaTech – U. of Tennessee – U. of Michigan – U. of Idaho – SNOC –

I²S–LWR

Status on Spent Fuel Pool Task

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Update on I²S-LWR – Panel

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Outline

- Objectives and Tasks
- Connection to Other Working Groups
- Schedule
- Preliminary Results

Objectives

- Design a passively safe and secure spent fuel pool (SFP)
  - considering passive safety (maintaining subcriticality, cooling and shielding),
  - monitoring systems for determination of neutronics and thermal hydraulics parameters, and
  - addressing safeguards concerns.

Approach

1) Develop a reference pool fuel pool (SFP) with special features for passive safety and effective monitoring,

2) Examine the performance of the SFP for the I^2S fuel during normal operations

3) Develop a set of accident scenarios and examine performance of the SFP during accident situations including natural events such as earthquakes.

How?

- Use the INSPCT-S code system (developed by Walters and Haghighat) will be used for on-line determination of subcriticality and detector response.

- The necessary databases for INSPCT-S will be created by performing thermal-hydraulics and neutronics calculations:
  - For thermal-hydraulics calculations, we will choose a code system following testing different types of code systems such as FLUENT CFD code and TRACE system code.
  - For neutronics codes, we will use the ORIGEN-ARP, PENTRAN deterministic code system (Sjoden and Haghighat), and MCNP5

Connection to Other Working Groups

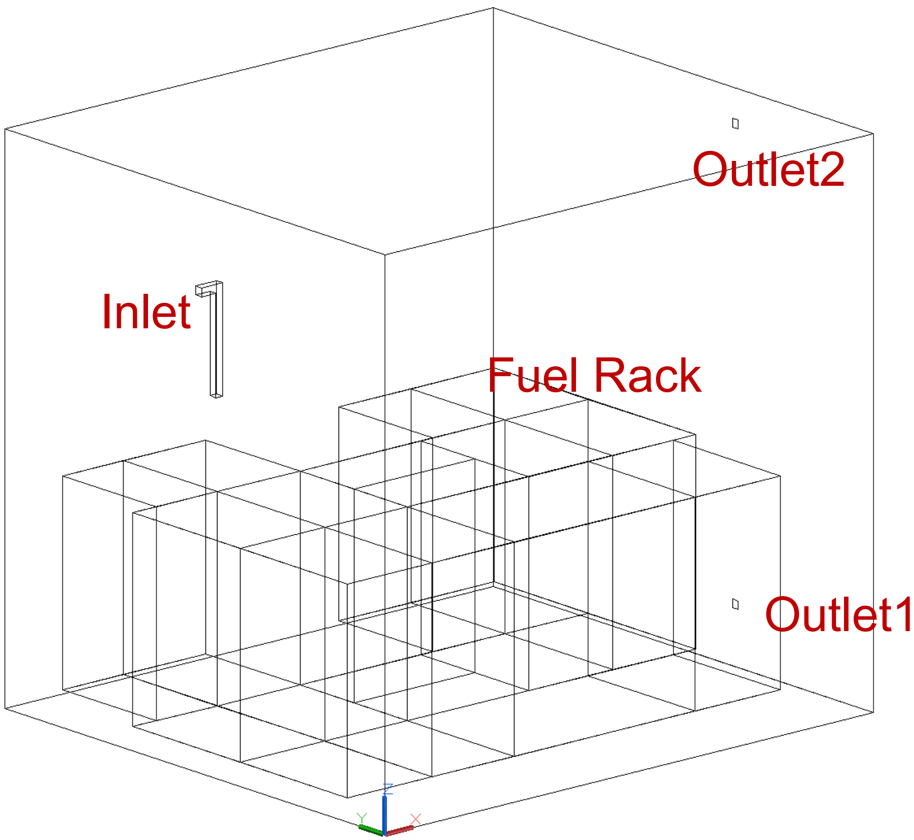
- Reactor/Core Design
  - Fuel design (number of assemblies; geometric dimensions; material composition and density; power distribution/burnup; load pattern)
  - Cycle length
- Spent Fuel Pool Design and Capacity and Dry Storage
- Reactor Building/Containment and SFP Positioning
- Safety System
  - Cladding tolerance (chemical reaction, melting point)
    - Possibility for air cooling and radiation heat transfer
  - Interaction with TH/safety working groups
    - SFP water could be a source for core cooling
- Instrumentation and Control
  - Implementation of newly developed sensors (water level, temperature, void, gamma and neutron)
  - Adoption of wireless technology

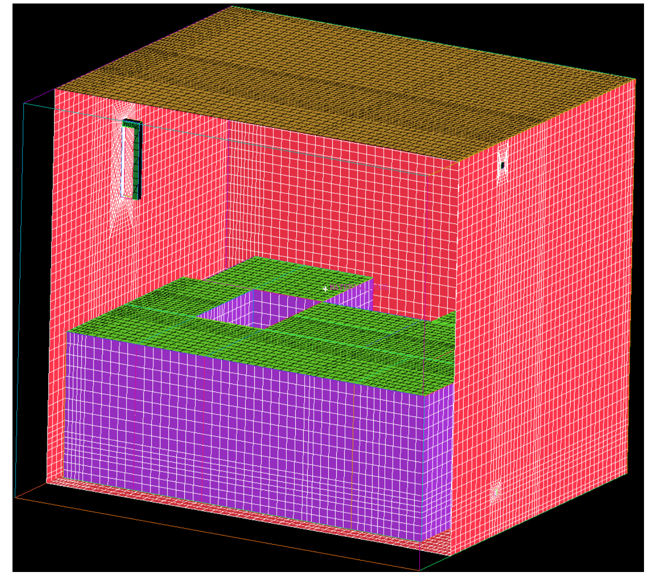
Schedule

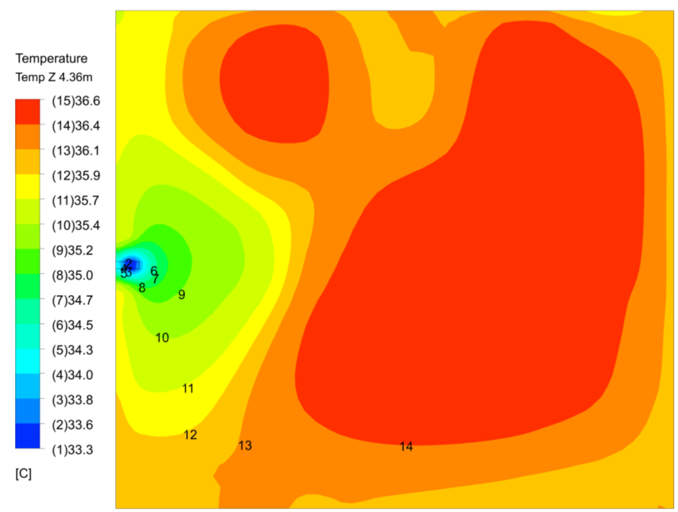
- Year 1
  - 1) Review of the existing pools and development of a reference pool
  - 2) Perform thermal-hydraulics and neutronics calculations to prepare the necessary databases for INSPCT-S
  - 3) Determine safety and safeguards parameters/issues of the reference pool
  - 3) Consider measures which can be passively activated and operated by natural causes such as an earthquake
- Year 2
  - 1) Prepare input parameters for I2S-LWR fuel (neutronics and TH)
  - 1) Perform detailed neutronics and thermal-hydraulics calculations to prepare the necessary databases for INSPCT-S
  - 2) Determine pool subcriticality multiplication factor and neutron and gamma detectors
  - 3) Examine safety and safeguards features of the I2S-LWR pool
- Year 3
  - 1) Based on available literature, develop time evolution of different accident scenarios an consider corresponding water, temperature and density distributions
  - 2) Perform detailed neutronics and thermal hydraulics calculations to prepare databases for different accident scenarios
  - 3) Determine pool subcriticality multiplication factor and neutron and gamma detectors
  - 4) Examine safety and safeguards features of the reference pool during accident conditions

Preliminary Thermal Hydraulics Results

FLUENT code is used to model the SPF in Main Yankee Nuclear Plant (Ref. 4)





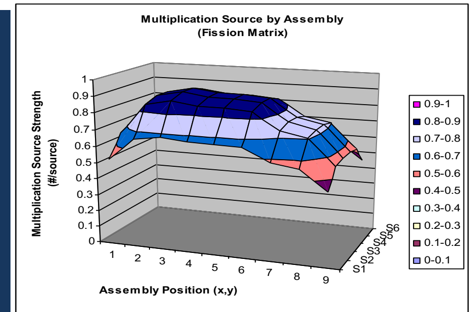


Overview of INSPCT-S (Inspection of Nuclear Spent-fuel-Pool Calculation Tool for Spreadsheet)

$$R_n = < S_n \phi_n^+ >$$

- **Source** (S = $S_{intrinsic}$ + $S_{subcritical\text{-}Multiplication}$)
  - **Intrinsic Source**
    - Spontaneous fission & (α, n) from fuel burnup calculation (ORIGEN-ARP)

  (Created a database)



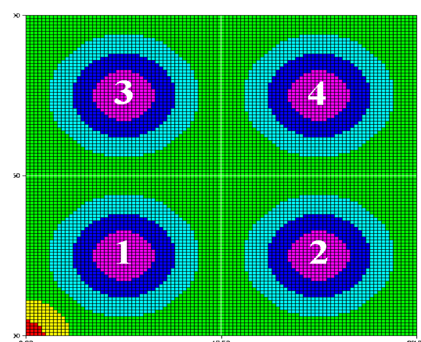
- **Subcritical Multiplication (Hybrid method)**
  - Simplified fission-matrix (FM) method
  - Use MCNP Monte Carlo to obtain $a_{i,j}$ *for each pool type*

(Created a database for coef. a_{ij})

$$F_i = \sum_{i=1}^{N} a_{i,j}(F_j + S_j^{\text{int.}})$$

- **Adjoint function**
  - **Is obtained using the PENTRAN transport code**

(Created a database for multigroup adjoint for different lattice sizes)



A demo of INSPCT-S

INPUT

	src file	C:\Users\Ali\Documents\misc\VT\LLNL\INSPCT-s\nu.dsrc	
COLUMNS 8	fm file	C:\Users\Ali\Documents\misc\VT\LLNL\INSPCT-s\nu.dfr	Response Tolerance
ROWS 6	imp file	C:\Users\Ali\Documents\misc\VT\LLNL\INSPCT-s\nu.dir	5.00%

Burnup

(x,y)	1	2	3	4	5	6	7	8
1	4000	4000	4000	4000	4000	4000	4000	4000
2	5000	5000	5000	5000	5000	5000	5000	5000
3	6000	6000	6000	6000	6000	6000	6000	6000
4	7000	7000	7000	7000	7000	7000	7000	7000
5	8000	8000	8000	8000	8000	8000	8000	8000
6	8000	8000	8000	8000	8000	8000	8000	8000

Cooling time

(x,y)	1	2	3	4	5	6	7	8
1	1	2	5	10	15	20	30	40
2	1	2	5	10	15	20	30	40
3	1	2	5	10	15	20	30	40
4	1	2	5	10	15	20	30	40
5	1	2	5	10	15	20	30	40
6	1	2	5	10	15	20	30	40

Response (experimental)

(x,y)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5
0.5									
1.5		1		0.8		0.75			
2.5									
3.5									
4.5					3				
5.5									
6.5									

OUTPUT

Detector Normalization

7.63547E-09

run

Independent Source

(x,y)	1	2	3	4	5	6	7	8
1	5.11E+06	3.38E+06	2.93E+06	2.93E+06	2.92E+06	2.92E+06	2.89E+06	2864889.1
2	9.25E+06	6.00E+06	5.04E+06	4.86E+06	4.71E+06	4.57E+06	4.35E+06	4181874.3
3	1.59E+07	1.06E+07	8.78E+06	8.14E+06	7.64E+06	7.15E+06	6.45E+06	5947613.2
4	2.60E+07	1.80E+07	1.49E+07	1.34E+07	1.23E+07	1.11E+07	9.49E+06	8354144.2
5	4.10E+07	2.99E+07	2.50E+07	2.19E+07	1.96E+07	1.72E+07	1.40E+07	11767615
6	4.10E+07	2.99E+07	2.50E+07	2.19E+07	1.96E+07	1.72E+07	1.40E+07	11767615

Fission Source

(x,y)	1	2	3	4	5	6	7	8
1	5.62E+06	6.50E+06	6.08E+06	5.68E+06	5.37E+06	5.02E+06	4.45E+06	3150771.3
2	1.08E+07	1.24E+07	1.15E+07	1.05E+07	9.70E+06	8.85E+06	7.62E+06	5275026.4
3	1.75E+07	2.00E+07	1.82E+07	1.63E+07	1.46E+07	1.30E+07	1.08E+07	7317292.6
4	2.57E+07	2.91E+07	2.62E+07	2.29E+07	2.00E+07	1.73E+07	1.41E+07	9435484.3
5	3.21E+07	3.58E+07	3.18E+07	2.73E+07	2.35E+07	2.00E+07	1.61E+07	10711350
6	2.66E+07	2.93E+07	2.58E+07	2.21E+07	1.90E+07	1.60E+07	1.29E+07	8627113.8

Response(Calculated)

(x,y)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5
0.5	0.20	0.37	0.35	0.33	0.31	0.30	0.28	0.24	0.11
1.5	0.55	1.03	0.97	0.89	0.83	0.78	0.71	0.59	0.27
2.5	0.98	1.82	1.71	1.53	1.39	1.27	1.12	0.90	0.41
3.5	1.56	2.90	2.71	2.39	2.13	1.89	1.62	1.26	0.57
4.5	2.26	4.20	3.89	3.39	2.95	2.57	2.16	1.65	0.73
5.5	2.49	4.59	4.20	3.63	3.14	2.72	2.26	1.72	0.76
6.5	1.25	2.28	2.08	1.79	1.55	1.34	1.11	0.85	0.38

Response Difference

(x,y)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5
0.5									
1.5		**-3.05%**		**-10.08%**		**-3.65%**			
2.5									
3.5									
4.5					**1.54%**				
5.5									
6.5									

Appendix - Literature Search - Sample references

- AP 1000 Standard Combined License Technical Report - Spent Fuel Storage Racks Criticality Analysis, APP-GW-GLR-029, June 2006.
- Summary of the EPRI Early Event Analysis of the Fukushima Daiichi Spent Fuel Pools Following the March 11, 2011 Earthquake and Tsunami in Japan (updated May 2012)
- A Critical Review of the Practice of Equating the Reactivity of Spent Fuel or Fresh Fuel in Burnup Credit Criticality Safety Analyses for PWR Spent Fuel Pool Storage, J.C. Wagner and C. V. Parks, Nuclear Technology, Vol. 136, Oct. 2001.
- Spent Fuel Pool Analysis using TRACE Code, F. Sanchez-Saez*, S. Carlos, J. F. Villanueva, and S. Martorell, Proceedings of PHYSOR2012, April 15-20, 2012.
- Industry applications for license or license amendment for spent fuel pools expansion by using new rack designs, e.g., Turkey Point Nuclear Generating Unit No. 3 , Attachment to License Amendment No. 23 , 1977.