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Quarterly Report for Dry Storage Safeguards -Q3-2018-LLNL

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WBS # – Project Title: 24.1.3.1.1 – **Verification of Spent Fuel Inside Dry Storage Casks by Fast/Epi-thermal Neutron Mapping**

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Summary Statement of Work: The objective of this study is to develop a novel methodology for verification of spent fuel inside dry storage casks by analyzing fast/epi-thermal neutrons coming from the top surface of the dry storage casks. In FY2018, data required for MCNP modeling will be gathered, prepared and used to perform MCNP simulations of the system to validate the effectiveness of the verification methodology. Once the methodology is demonstrated to be effective and valid, parameters that affect the detector system sensitivity will be studied as well as the study of diversion scenarios and partial detect.

Major Highlights:

Various parameters that can affect the performance of the conceptual detector system have been identified and studied using the MCNP model. The parameters that we investigated are neutron energy to be used for detector threshold, the need and thickness of a collimator that shields the detector, and distance of the detector system from the top surface of the dry storage cask. Among the parameters, the choice of neutron energy for measurements is most crucial as it dictates the selection of effective neutron detector for the verification system. The modeling results show that use of neutron energy greater than 2 MeV would be most effective, and thermal neutron detector would not work to identify a missing assembly. The results also show that partial detect testing (50% diversion) is even possible of course if a previous measurement result is available.

A literature survey was conducted to identify potential fast neutron detectors that would be applicable for the verification system to be developed. The most important factor for the ideal detector would be the high cross section to fast neutrons while not being sensitive to thermal or epithermal neutrons as the incoming neutron will have a mix of thermal, epithermal and fast neutrons.

Progress (by task)

Task 1 – Spent fuel source term evaluation for Monte Carlo Techniques (completed)

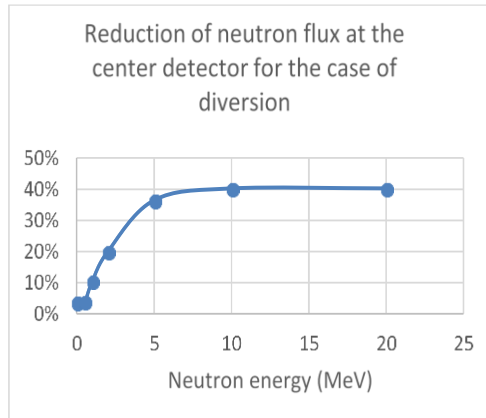
Task 2 – Development of a neutron transport model with geometry of a realistic dry storage cask for performing Monte Carlo simulations. (completed)

Task 3: Parameter Study of the detector system sensitivity

Parameters that affect the verification system are modeled and investigated. These are neutron energy to be used for detector threshold, the need and thickness of a collimator that shields the detector, and distance of the detector system from the top surface of the dry storage cask.

- Neutron energy: the neutron energy of 2-5 MeV was shown to be most optimal in the modeling study. This result suggests that a fast neutron detector that can have a threshold of 2 MeV would be ideal for the conceptual verification system.

Neutron Energy (MeV)	Reduction of neutron intensity in the case of a diversion
0.0 – 1.e-04	3.8%
1.e-04 - 0.5	3.9%
0.5 -1.0	10.5%
1.0 -2.0	20.0%
2.0 - 5.0	36.5%
5.0 - 10.0	40.3%
10.0- 20.0	40.3%



- Collimator and shielding for the detector: the modeling study shows that there is slight advantage if a collimator was adopted into a verification system. As the verification system is envisaged with multiple detector system, the thickness of the shielding in this design concept will be limited in size.
- Distance of the detector system from the top surface of the dry storage cask: no significant improvement was apparent as the detector system moved up. The detector position at 10 cm above the dry storage cask was found to be optimal.

Task 4: Realistic diversion scenarios study

Three potential diversion scenarios of spent fuel diversion have been identified. The first scenario is partial diversion of spent fuel occurrence even prior to the spent fuel's placement into the dry storage casks. This is a plausible scenario as spent fuel is not verified to the level of partial defect when they are introduced into the dry storage casks. The second scenario is that one or more seals are intentionally broken, and then diversion of a spent fuel assembly occurs. As the IAEA does not have capability to verify non-diversion of spent fuel assembly in the dry storage casks, the IAEA is most likely to qualitatively or visually check the integrity of the dry storage cask and apply new seals without discovering the diversion of a spent fuel assembly. The 3rd scenario is diversion of a spent fuel assembly through a side or bottom of the wall of the dry storage casks. This is the least plausible scenario, but it is still a possible scenario when a government or a large organization is involved in the diversion of spent fuel.

Task 5: Partial Defect Study

- A MCNP study was performed for the possibility of detecting partial defect diversion of spent fuel. Two limited cases of partial defect were investigated. One initial case of 25% diversion showed that there was reduction of 2-5MeV signals only by 5%. The MCNP modelling result with 50% diversion showed inconsistency which needs to be understood and resolved. The partial defect scenarios are still being investigated.

Task 6-1: Literature review, evaluation and selection of suitable fast neutron material/detectors

- There are multiple fast neutron detectors available, but not all of them are suitable for this particular application as we need to measure neutrons with 2 MeV or more while ignoring those neutrons with energies less than 2 MeV. [Note that use of 1 MeV as the threshold is still workable, but 2 MeV is more desirable.] The desirable characteristics for the ideal detector would have low or no sensitivity for neutrons with energies less than 2 MeV, low sensitivity to gammas, cost-effective, and ruggedness. The detector should be available commercially as well. The fast neutron detectors being studied are Stilbene, EJ-410, diamond detector, SiC and He-4 detector. The hydrogen detector is not selected for consideration as it is also sensitive to thermal neutrons. Liquid scintillator is not selected as it flammable although its flash point 144 C.   All of those 5 detectors listed above are commercially available. By the end of next quarter we will reduce our choice to 2 or 3 detectors for procurements/experiments and will get price quotes.

Publications: None

Issues: None

Project Performance:

- **Change Management:** no change since the last quarter
- **Budget Performance:** No issue with budget, but it would be nice to purchase at least one cheap fast detector not to delay any procurement in the next fiscal year
- **Schedule Performance:** The project proceeded within the schedule. The project schedule can be expedited by integrating tasks in FY19 and FY20. The delivery of the tool to IAEA can materialize earlier as the need for this tool at IAEA has been urgent as the number of dry storage casks has been rising rapidly around the world.

- **Milestone and Deliverable Performance:** No issue
- **Disposition and Transfer:** The technology developed out of this project is to be used for IAEA at the end of this project, as the project addresses one of the IAEA's most needed issues to be solved. The technology can be potentially applicable to confirm loading of spent fuel assemblies in the US nuclear industries, and of course to identify any missing assemblies or dummy assemblies.
- **Carryover: None**