Developing a New Criticality Safety Hands-On Training Utilizing ZPPR Plates

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INTRODUCTION

Nuclear criticality safety is an extremely important part of the work at Los Alamos National Laboratory (LANL). As part of the work LANL performs to continue to keep criticality safety a top priority, LANL has developed and regularly teaches nuclear criticality safety training classes for both the United States Department of Energy Nuclear Criticality Safety Program as well as internal trainings for LANL employees.[1] A portion of the training classes is comprised of hands-on demonstrations, where students get the opportunity to handle special nuclear material at the National Criticality Experiments Research Center (NCERC).[2]

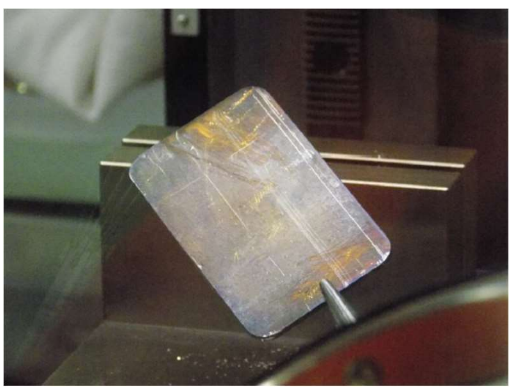

Figure 1: The Plutonium Core of a ZPPR Plate.

One hands-on demonstration uses the “Class foils”, thin HEU foils which are stacked with lucite moderator plates.[3] A hand-stack is performed until the multiplication reaches the “three-quarters rule”, where the demonstration is continued remotely on a vertical lift assembly up until the system is critical. This hands-on demonstration eventually achieves a critical configuration and follows the ANS-1 guidelines on an approach to critical. Another hands-on demonstration involves handling clad plutonium and neptunium spheres, and follows procedures using criticality safety evaluations to ensure that the hands-on demonstrations remain subcritical. This hands-on demonstration also involves the use of polyethylene shells around the plutonium sphere to demonstrate how additional reflector increases the criticality of a system. This paper is focused on developing a new hands-on demonstration using Zero Power Physics Reactor (ZPPR) plates,[4] shown in Figure 1. This new hands-on demonstration will follow the ANS-8 standards as it is not desired to achieve criticality with the ZPPR plates during the hands-on demonstration. A hands-on demonstration using multiple plutonium parts will likely be more applicable to personnel who handle plutonium on a daily basis, such as LANL glovebox operators.

NUCLEAR CRITICALITY SAFETY TRAINING AT NCERC

Nuclear criticality safety training at NCERC consists of a multi-day course with presentations, hands-on demonstrations, and a tour of NCERC, located at the Device Assembly Facility (DAF) in the Nevada National Security Site (NNSS). Instructors discuss and teach everything from the fundamentals of nuclear interactions to the most important concepts in nuclear criticality safety.

One of the main objectives of the training is to educate the students on basic parameters of nuclear criticality safety. These parameters can be summarized by the acronym MAGIC MERV: Mass, Absorption, Geometry, Interactions / Spacing, Concentration / Density, Moderation, Enrichment, Reflection and Volume[5]. These nine physical parameters determine the criticality of a system: understanding how each of them can change the criticality of a nuclear system (sometimes in counter-intuitive ways) and the underlying physics of why those changes occur is an essential part of the training. The hands-on demonstration helps to reinforce the concepts taught during the classroom portions of the training.

DESIGNING THEN ZPPR HANDS-ON DEMONSTRATION

Using the Monte Carlo N-Particle (MCNP)[1][6] transport code, six different configurations of ZPPR plates will be

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modeled. These six configurations will be used to demonstrate how the MAGIC MERV parameters can change the criticality of a system. For each configuration, the neutron leakage and the dose rate will be simulated. He-3 detectors will be modeled and the simulated neutron count rates will be calculated. Each simulation will also include a human phantom to calculate approximate dose rates experienced by the operators.

The objective for each configuration is to produce a system that is subject to change in one of the nine MAGIC MERV parameters. When each configuration is altered to change reactivity, there should be a measurable and noticeable change in the detector count rate. It is also desired that the count rate change is primarily due to the change in criticality of the system, not some other phenomena. Other reasons that the count rate could change includes higher detector efficiency, source-to-detector changes, an increase in the neutron source strength, etc. The configurations will have to be designed in such a way that phenomena like these do not affect the count rate considerably, and instead highlight the change in criticality due to the MAGIC MERV parameter alteration.

To demonstrate how each MAGIC MERV parameter affects criticality, the possible configurations that could be modeled include the following. One configuration could simulate adding more plates to the system to demonstrate how adding mass affects criticality. Another configuration could add a neutron absorber to show the influence absorption has on criticality. Another configuration could have the ZPPR plates rearranged from a flat layout to a cuboid to display the effects of geometry. To illustrate how spacing can change criticality, a configuration could contain two subcritical assemblies spaced apart and then these assemblies could be slowly moved closer together. To demonstrate moderation, a configuration could have moderator placed between ZPPR plates which originally have zero moderation. Another configuration could have a thin reflector surrounding a stack of ZPPR plates to exhibit how a reflector increases reactivity. These configurations would be analyzed and optimized to ensure the safety of the workers is upheld while maintaining ease of use.

Work is ongoing to design configurations which would demonstrate the effects concentration, volume and enrichment have on criticality. As these parameters are harder to change for ZPPR plates, it may not be possible to include demonstrations that highlight these parameters.

The main hazard to the instructors and students is the dose received from the special nuclear material. The plutonium in each ZPPR plate is radiologically hot. This is primarily due to the spontaneous fissions that occur in the plutonium and the relatively large leakage rate associated with the plate geometry. When dozens of plates are used in a single experiment, dose rates can get substantially high.

To help minimize the dose that instructors and students will receive, the number of ZPPR plates used in each configuration will be kept to a minimum. However, it is still important to maintain a high enough count rate to satisfy the goals of the operation. This is an optimization problem that will be resolved using MCNP. Once a configuration is designed, MCNP will be used to simulate the count rate at the set of detector as well as the dose rate to nearby personnel. The simulated count and dose rates will be recorded and analyzed to determine if they are adequate. If the results are not optimal, the design will be modified (perhaps by adding or removing ZPPR plates, etc). Using this method, an optimal design will be simulated for each proposed configuration.

RESULTS

Development of the simulations of each configuration are ongoing. Below in Figure 3 there is an image of a ZPPR plate modeled in MCNP. The blue portion is the Pu core, the green is the steel cladding, and the yellow is the gas (50/50 He/Ar at 7.8 psia) that fills the gap between the two.

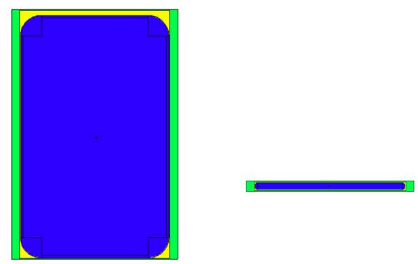

Figure 3: MCNP model of a ZPPR plate with cladding.

Final results will include the dimensions and layouts of the different configurations to be constructed at NCERC, which will inform the experiment plan and nuclear criticality safety evaluation. Along with each configuration will be a detailed explanation on what MAGIC MERV parameter is highlighted and how to alter the assembly to adjust said parameter. Each configuration will have an estimated count rate, change in count rate and dose rate.

CONCLUSIONS

The inclusion of a hands-on demo that uses ZPPR plates will be a valuable addition to the current set of demonstrations. It will provide workers and students with more experience on handling plutonium which is slightly lacking from today's demonstrations. This hands-on demo will also be able to highlight and demonstrate the effects on criticality of more MAGIC MERV parameters than the other demonstrations.

ACKNOWLEDGMENTS

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