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Reactivity Simulation for Criticality Safety Training and Future Projects at LANL

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Additional reactivity introduced to a system of fissionable material, through reflection from the human hands, body, or other material, is a well-known concept in the nuclear community. However, individuals working at a nuclear facility do not necessarily come from a nuclear background. As such, it becomes necessary to acclimate workers to the fundamentals involved with operating with or near fissionable material, including reflection effects that their own bodies may have on reactivity.

I. PURPOSE FOR A REACTIVITY SIMULATOR

Criticality safety is included as part of training for fissile material handlers (FMHs) at Los Alamos National Laboratory (LANL). In order to provide additional insight into the neutronics involved with handling fissionable material, the Nuclear Criticality Safety Department (NCSD), with the assistance from LANL's Technology Applications team, has developed a reactivity simulator (Fig. 1). The simulator is a tungsten ball, similar in size and weight to a sphere of ^{239}Pu with a k_{eff} of 0.95.

FIGURE 1. Demonstration of increased reactivity due to reflection using the reactivity simulator.

I.A. How it Works

The reactivity simulator utilizes Theremin technology to simulate effects that the hands have on reactivity. Theremin is a musical instrument invented by Leon Theremin, Soviet scientist and musician, which utilizes the performer's body as an electrical control. The concept involves utilizing a performer's hand as a grounded plate of a variable capacitor which varies based on proximity to the pitch antenna. As capacitance is manipulated, the oscillator frequency of a tuned circuit is varied, which produces an audible tone.[1] Similarly, the reactivity simulator user's hands manipulate the capacitance about a tungsten ball. Essentially the hand and the tungsten ball act as a variable capacitor. The device is calibrated to produce a clicking sound, which increases as the operators move closer to the simulator.

I.B. Intended Use for Training

The reactivity simulator, coupled with a poster explaining the effects of reflection on nuclear reactivity, is intended to reach multiple audiences at LANL. While incorporation into FMH training is the primary focus, the simulator and the poster will serve as edification for individuals who may passively or inadvertently interact with nuclear material while accomplishing (Fissile Material Operation) FMO adjacent tasks. These individuals may include craft workers, Radiological Control Technicians, or simply anyone working near substantial quantities of fissionable material. Added reflection is possible for more than just the individual working directly with the material.

II. FUTURE SIMULATION PROJECTS

In order to expand worker knowledge of criticality safety, investigations are currently taking place, and prototypes for additional training tools are under development. Some of these tools are outlined briefly in the following sections. The intent is to highlight the effects of interaction, mass, and geometry in addition to reflection.

II.A. Changes in Reactivity Due to Interaction of Multiple Units

The goal for this project is to introduce two to three ^{239}Pu units into a system, and examine the audible click-rate from their interaction with one another. The intent here is to use a 2-dimensional light curtain array in order to identify the location of each unit. An example of a one-dimensional light curtain can be observed in Figure 2. The click-rate will be calibrated to match the units' proximity to each other in order to examine the effects of interaction. A strategy is still under development as to how to incorporate a third dimension to eliminate or reduce the effects from shadowing.

FIGURE 2. Example of a 1-D light curtain.

II.B. Recreation of 1978 Siberian Pu Ingot Accident

The 1978 Siberian Pu ingot accident involved a breakdown in conduct of operations, which resulted in a criticality accident after too much mass was accumulated in a single location. The operator suffered an amputation of both arms up to the elbow as a result of the criticality.[2] The recreation of this will involve some Hollywood trickery utilizing a small blue flash and ejection mechanism rigged to simultaneously go off at the moment of contact with the previously stacked third ingot. This exercise will help illustrate the dangers of over-massing a specific location.

II.C. Recreation of 1946 LANL Slotin Accident

The 1946 Slotin accident was an experimental accident where Slotin was using a screwdriver to keep an outer beryllium hemishell separated, keeping the assembly subcritical. When the screwdriver accidentally slipped, the hemishell closed completely around the Pu, resulting in a prompt-critical assembly (Fig. 3).[2]

The recreation of this accident will include a video that will be displayed for criticality safety training courses as well as a replicated assembly to be used for live demonstrations. Sensors will be located on the edge of the upper hemishell near where the screwdriver is making contact. As the outer hemishells are brought together, the individual will observe an increased click-rate. Once the hemishells completely encompass the "Pu sphere", a blue flash will occur, and the upper hemishell will be removed. For additional accuracy, a mechanism will be placed where the thumb is inserted such that the criticality (blue flash) will not be observed if the thumb is removed. The recreation will display the importance of geometry and leakage in a system. It will also highlight the additional hand reflection that was just enough to make the system prompt-critical.

FIGURE 3. Image of recreation of Slotin accident.

III. CONCLUSIONS

The use of hands-on reactivity simulations will help FMHs, along with other facility staff, better understand the importance of criticality safety.

REFERENCES

1. "The RCA Theramin Theory of Operation." Pavek Museum of Broadcasting. St. Louis Park, Minnesota.

2. McLaughlin, Monahan, Pruvost, Frolov, Ryazanov, Sviridov. "A Review of Criticality Accidents." LA-13638. Los Alamos National Laboratory (2000).