Proposed Plutonium-Nickel Critical Experiment

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INTRODUCTION

The Los Alamos Critical Experiments Facility (LACEF) and subsequently its descendant, the National Criticality Experiments Research Center (NCERC) located at the Nevada National Security Site, have been performing critical experiments for over 75 years. The work done continues to build upon lessons learned from the past. It also builds upon knowledge gained from past experiments. The LACEF and NCERC experiments "provide nuclear criticality benchmark data for a wide variety of fissile and non-fissile materials in all neutron energy spectra systems". In 2014, a subcritical benchmark with plutonium surrounded by nickel was issued in the International Criticality Safety Benchmark Evaluation Project (ICSBEP) [1]. Two years later, a new benchmark experiment was performed, commonly known as Subcritical Copper Reflected α-Phase Plutonium SCRαP [2]. The uncertainties in the SCRαP experiment were significantly reduced from the Pu-Ni experiment and the methods were refined. Additionally, a Pu-lead critical experiment was performed in 2017 which followed different methods and with different objectives [3]. Now, an experiment is proposed that builds on both the subcritical nickel experiment and the critical lead experiment. The proposed experiment has interleaved nickel and plutonium, in a thermal arrangement. This particular experiment would support criticality safety at the Hanford Tank Farms, whose tanks contain a significant amount of nickel credited as a neutron absorber in the criticality safety evaluation.

HISTORY

Subcritical Nickel Benchmark

In 2012, subcritical benchmark experiments were performed which utilized a well-known sphere of weapons grade plutonium, known as the Beryllium Reflected Plutonium Ball (BERP Ball). The experiments included varying thicknesses of nickel, from none to 3 inches thick. The benchmark parameters included singles rate (R1), doubles rate (R2) and neutron leakage multiplication. This experiment was accepted into the ICSBEP in 2014. A lot was learned about plutonium and nickel nuclear data from this subcritical experiment.

Critical Lead-Plutonium Benchmark

In 2017, a critical experiment was performed on the Comet critical assembly machine which utilized plutonium plates and lead interstitial with a thick copper reflector. The experiment was targeting lead-void reactivity worth and built upon similar HEU and pseudo LEU versions using the Zeus configuration. Much was learned about void reactivity worth measurements from this series [4].

HANFORD TANK FARMS

The Hanford Tank Farms contain waste from processing operations conducted to extract plutonium from fuel irradiated in the Hanford reactors during the Cold War. The waste compositions vary significantly from tank to tank. The inventory estimates for each tank are subdivided into several "layers" that represent a particular waste stream or origin. The fissile material of concern throughout the tank farms is plutonium, though much larger quantities of uranium at near-natural enrichments are also present. Tank wastes are complex mixtures of many elements and compounds, a small subset of which are credited in the criticality safety evaluations.

Recent code validation efforts within Tank Farms criticality safety have pointed to a lack of available benchmark experiments that are applicable to tank conditions – specifically, thermal plutonium systems where neutron absorption reactions in the elements that are credited for criticality safety of tank waste (including iron, nickel, and aluminum) are the dominant contributor. Tank AN-101 has a particularly large reliance on nickel in comparison to the other absorber elements credited for criticality safety. Inventory estimates for selected elements in AN-101 are listed in Table 1 [5].

Table 1. AN-101 Tank Composition.

Pu	**100 kg**
Al	400,000 kg
Fe	61,000 kg
Ni	15,000 kg
U	57,000 kg
Cr	2,600 kg
Mn	7,300 kg
Si	43,000 kg
Zr	57,000 kg

PROPOSED EXPERIMENT

An experiment is proposed which builds directly upon lessons and knowledge (both operational and nuclear data) from the BERP/Ni subcritical benchmark and the Pu-Lead critical experiments. It aims to address unknowns associated with nuclear data validation which directly support criticality safety analyses of Hanford Tank Farms. The proposed experiment will utilize the general setup from the Pu-Lead critical experiments and include the benchmark uncertainty minimization work from the subcritical experiments.

The proposed experiments will have plutonium plates interleaved with plates of nickel, steel, aluminum, and PET. PET is a great material to use to mimic thermal configurations as it holds its shape, is easy to machine is less temperature sensitive relative to materials such as lucite or polyethylene. An overview of the Jupiter experiment, which will be the overall setup for the proposed experiment, is shown in Figure 1.

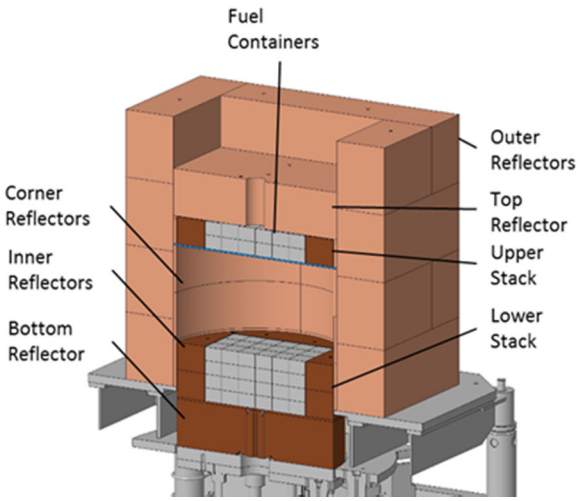

Figure 1. The full Jupiter Experiment. The proposed experiment will mimic this setup with a PET reflector.

CONCLUSIONS AND FUTURE WORK

An experiment has been proposed to support the Hanford Tank Farms. It includes reactor grade and weapons grade plutonium, interleaved with PET and nickel in varying amounts. This experiment will progress into full design and execution, followed by publishing in the ICSBEP.

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