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Title: Test Plan for Cask Identification Detector

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Test Plan for Cask Identification Detector

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INTRODUCTION

This document serves to outline the testing of a Used Fuel Cask Identification Detector (CID) currently being designed under the DOE-NE MPACT Campaign. A bench scale prototype detector will be constructed and tested using surrogate neutron sources. The testing will serve to inform the design of the full detector that is to be used as a way of fingerprinting used fuel storage casks based on the neutron signature produced by the used fuel inside the cask.

OUTLINE OF TEST PLAN

The test plan can be explained in three parts: what will be tested, how it will be tested, and the objectives of the testing.

What to test:

The basic premise of the fingerprint identification method relies on two principles: multiplication in the fuel provided by the special nuclear material (which remains constant over the lifetime of the cask) and a neutron source that is primarily driven by spontaneous fission of ^{244}Cm and ^{242}Cm in the early post-irradiation life of an assembly (50 years). The identification method captures the shape of the neutron signal escaping the cask and uses the relative peaks and valleys of that signature to identify that cask. The bench scale test will assess 4 items of the identification method: collection methodology, identification methodology, count times, and reproducibility of the detector placement.

Collection Methodology

An easily reproducible method for collecting the signature will be important for the full design. It is unlikely that that same person or team collecting an initial signature would be collecting a confirmatory signature in a later re-measurement. The collection methodology must be well defined to ensure proper comparisons between signatures. For the bench scale test, the collection methodology will be tested in a variety of ways.

First, a method of calibrating the detector through the use of a single neutron source will be tested. A single source placed at the center of the detector ring at the mid-plane of the detector tubes will be used to ensure each detector tube has the same relative efficiency over a small sample of measurement counts. The preliminary proposal for the calibration procedure is:

1. Arrange detector with neutron source located at the center of the ring of detectors and at the axial mid-point for the active region of the detectors.
2. Take three 100 second totals counts. A totals count is a simple measurement where the total amount of neutron events within a detector is counted. Average the counts for each detector.
3. Adjust the gain on the amplifiers of each detector to obtain the same measurement response from each detector.
4. Repeat steps 2 and 3 until each detector can produce an average within 1 square root of initial average of the highest channel.

Changes to this procedure may be made to address changes in the bench scale prototype detector design. For each day of testing, the calibration will need to be performed at the beginning of the day and at half day. A final calibration measurement will also be performed at the end of the day to detect any drift in detector response.

After calibration, the collection methodology will assess detector placement on the bench scale detector apparatus. The test apparatus will be used as a surrogate for the cask. Most cask designs feature structural elements that could be used to reproducibly place the detector on the cask. The design of the test apparatus will include a feature to simulate a structural element that can be used to align the placement of the detector. Measurements will be made on the azimuthal location of the tubes and adjustments will be made to ensure tight tolerances for placement of the tubes on the test apparatus.

Another piece of collection methodology that will be assessed is the data collection itself. The final detector will likely be a self-contained unit with a simplified data acquisition system requiring minimal input from the user. The bench scale test will start with a simpler data acquisition system using off the shelf components. Eventually, testing of a cohesive tablet or smart device based data acquisition system will be done. Testing of this more advanced system is dependent on the detector design itself, so that will not be outlined here.

Signature Methodology

Assessment of the proposed signature is the main focus for the bench scale test. Multiple arrangements of surrogate neutron sources will be assembled and tested with the bench test apparatus. The same arrangement will be tested on a weekly basis for at least 4 weeks to generate a data set that can be used to help assess the validity of the assumptions and acceptance criteria that will be used to match signatures through time. Alternate versions of the same arrangements with substitute sources of different strengths will also be assembled to form a more complete data set.

Count Times

Count times for actual casks will largely depend on the observed neutron collection rate. If possible, counting statistics will be 2%. A method for estimating count times will be determined using known neutron source strengths in the test apparatus.

Detector Placement

Sensitivity to the azimuthal location of the neutron detectors will also be assessed. A series of adjustments will be made to the azimuthal location of the detectors, essentially rotating the detectors in various increments around the test apparatus and replicating the measurement at each increment.

How to test:

The bench scale test will require the following items: an assortment of surrogate neutron sources (~10-20 across a range of strengths), a custom-built source apparatus and calibration stand, and 10 detectors with associated off the shelf electronic components to run them. The surrogate sources should be available from the stock of neutron sources currently available onsite at LANL. If acceptable neutron detectors, preamplifiers, amplifiers and scalers are not available onsite, some will be purchased from outside vendor. The test apparatus and calibration stand will be fabricated after final design of the bench scale detector. Preliminary design work is shown in Figure 1 and Figure 2.

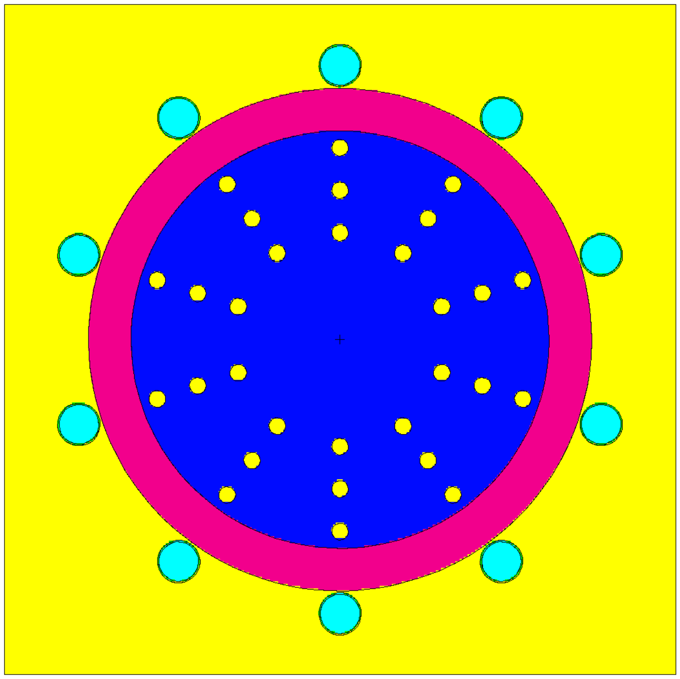

Figure 1: XY view of preliminary design of test apparatus

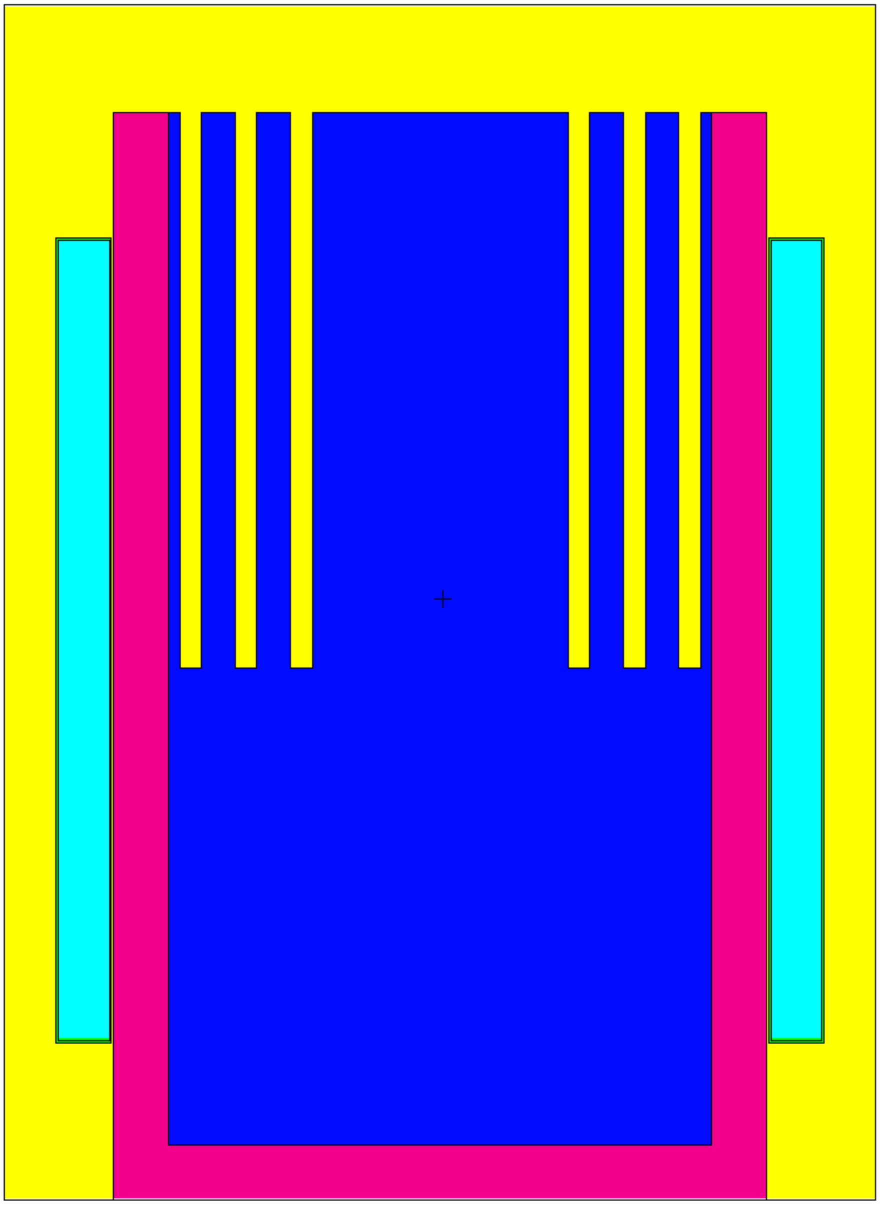

Figure 2: YZ view of preliminary design of test apparatus

The figures show the basic concept of the test apparatus. The test apparatus will consist of a cylindrical block of polyethylene, surrounded by a 1 inch thick steel case. The source locations are concentric rings of holes drilled into the polyethylene. Each azimuthal location has 3 radial positions for a source to generate different signatures. With 10-20 sources, hundreds of different signatures are possible. A subset of these will be assembled and assessed. The holes are designed so that the sources can sit at the mid point axially of the detectors on the outside of the steel case. The steel used for the case will be similar to steel commonly used in cask construction.

The electronics required to operate the detector tubes could be available from other R&D projects or could be purchased for this bench test. The advanced data acquisition system providing a comprehensive command and control system for the detector would be one of the last things to build. As it is more aspirational in nature, and not a necessity to achieve the goals of testing, it would be optional provided enough time and chance of success.

Objectives of Testing

The main objective of the bench scale test is to prove that a neutron signature fingerprint can be collected in a repeatable, reliable way and to identify areas of potential issues for a full detector. The bench test should offer a way to test the fingerprint method and work around potential issues in a full detector before design and construction of the full detector.

The signature method itself will be tested with the substitution of sources to change the signature in small ways. The data acquisition system will also be assessed and enhanced to give a reliable data set for every measurement.

CONCLUSION

The plan outlined in this document serves as a starting point for testing. As the work package is performed and a prototype detector is designed, built, and assessed, new facets of its operation could open themselves to assessment. The results of these assessments could impact future refinement of this test plan as well.