Available online at www.sciencedirect.com
ScienceDirect
Applied Radiation and Isotopes 65 (2007) 1293–1299
Applied Radiation and Isotopes
www.elsevier.com/locate/apradiso

Fissile material detection using a prompt fission neutron chamber system

Raymond P. Keegan, Leo Van Ausdeln*

Idaho National Laboratory, 2525 North Fremont Street, P.O. Box 1625, Idaho Falls, ID 83415, USA

Received 21 February 2007; received in revised form 23 June 2007; accepted 25 June 2007

Abstract

The calculations supporting the design of a chamber system to detect and verify fissile material in items such as mail packages or luggage are described. Stimulated neutrons from fission are separated from those produced by the system 14 MeV neutron generators by time delay. The proposed system design has a chamber volume of $60 \times 60 \times 90$ cm. It is anticipated that at least 1 g of fissile material could be detected in as little as 5 s of interrogation.

Keywords: Prompt fission neutron; Fissile; Interrogation; Nondestructive; Package; Luggage

1. Introduction

This paper describes the calculations supporting the design of a prompt fission neutron (PFN) chamber system that uses two deuterium–tritium (D–T) neutron generators each producing 14 MeV neutrons at a yield of 10^8 neutrons/s to interrogate packages placed inside it. The technique is based on the work described by Bivens et al. (1976) and Caldwell et al. (1983, 1984). This work is still in the design phase and no fabrication has been completed. Induced fission neutrons radiating from fissile material present are detected using ^{3}He thermal and epithermal detector sets. The system calculates a normalized response that is independent of generator yield and directly related to the amount of fissile material inside its chamber.

This system could be deployed for example at shipping centers, such as airports or national laboratories, to detect smuggled fissile material in items such as mail packages and luggage. Items would move through the chamber on a conveyor belt. The presence of fissile material or anomalous neutron capture shielding within the package would trigger an alarm if the response is above a predetermined threshold. The system operator could then separate the item from the stream for closer examination. Candidate users include package delivery companies, airport luggage processors, domestic or foreign US military installations.

Other applications such as environmental remediation could be explored where the chamber with some geometrical design modification could be converted into an assay system to measure fissile material content in soil removed, for example from waste burial pits. Bogolubov et al. (2004) and Moss et al. (2005) recently described similar active neutron interrogation systems. Neutron-gamma techniques (see Gazani, 2004) are usually used to reveal the presence of fissile material or explosives.

2. Concept description

The system shown in Fig. 1 uses two D–T neutron generators that produce synchronized neutron pulses that interrogate the package and form a sea of thermal neutrons in the chamber. The generators each produce 14 MeV neutron pulses at 100 Hz at a yield of 10^8 neutrons/s. This thermalization process takes place both within the package and the polyethylene lining of the chamber. Epithermal neutrons occurring after the thermalization of the burst are detected. They arise from thermal fission within any fissile material present. The use of two generators is recommended in order to minimize spatial non-uniformity.

*Corresponding author. Tel.: +1 208 526 2031; fax: +1 208 526 5432.
E-mail address: leo.vanausdeln@inl.gov (L. Van Ausdeln).

0969-8043/$ - see front matter
doi:10.1016/j.apradiso.2007.06.011

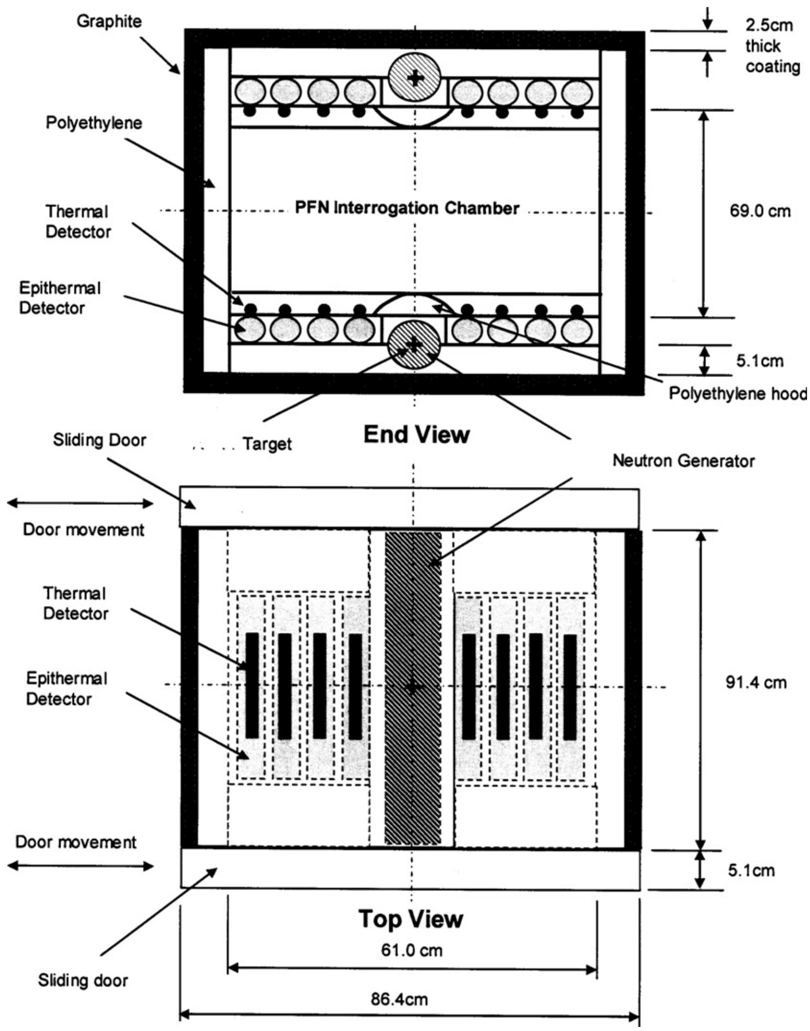

Fig. 1. Sketch of the chamber looking from the one end and the top. The sliding doors are opened for placement and removal of the package (not to scale). The system has 2 neutron generators and 16 thermal and epithermal detectors each. These components are evenly split between the top and bottom of the chamber.

Data collection begins after each generator pulse using a multichannel scaler to form a time distribution graph. Fission neutrons are produced after the generator pulse, and can be distinguished by time delay from generator pulse neutrons. The number of these delayed neutrons is proportional to the fissile mass in the chamber. A sketch of the time distribution response for the thermal and epithermal sets is shown in Fig. 2. In addition to the epithermal neutron detectors, a set of thermal detectors are used to gauge the effect of the material in the chamber on the thermal neutron flux.

The fissile material concentration is related to the PFN response by the following relationship:

$$[Q_{\mathrm{Fissile}}] = C_{\mathrm{a}} \times \frac{C_{\mathrm{epi}}}{C_{\mathrm{th}}}, \quad (1)$$

where Q_{Fissile} is the fissile material quantity, C_{a} the calibration factor, C_{epi} the net epithermal neutron count and C_{th} is the thermal neutron count. The thermal and epithermal neutron counts are summed over the same time window. This response is independent of variations in the neutron yield of the generator. The ratio of C_{epi} to C_{th} is the normalized response of the system.

The system, see Fig. 1, consists of a chamber that is 60 cm high × 61 cm wide × 91.4 cm deep into which packages are placed. The system shown here has sliding doors to facilitate the insertion and removal of the package. The process involves placement of the package into the system followed by closing the doors. Such doors are needed to optimize the performance of the system by minimizing neutron leakage. A version with reduced sensitivity could be produced without doors.

The chamber has two neutron generators with one on top and the other on the bottom located on the centerline. The generators are synchronized to pulse together or separately at 100 Hz. These neutrons are thermalized in the polyethylene hood that covers each generator, the walls of the chamber and in the package contents. The chamber