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Small threat and contraband detection with TNA-based systems

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Abstract

The detection of small threats, such as explosives, drugs, and chemical weapons, concealed or encased in surrounding material, is a major concern in areas from security checkpoints to UneXploded Ordnance (UXO) clearance. Techniques such as X-ray and trace detection are often ineffectual in these applications. Thermal neutron analysis (TNA) provides an effective method for detecting concealed threats. This paper shows the effectiveness of Ancore's SPEDS, based on TNA, in detecting concealed liquid threats and differentiating live from inert mortar shells.

keywords: Thermal neutron analysis; Explosive detection; UXO clearance; Chemical weapon detection

1. Introduction

Ancore's small parcel explosive detection system (SPEDS) was developed to address an important niche in the security arena, namely, the inspection of items carried by people onto airplanes, into courthouses and other government buildings, or through other security checkpoints. It has additionally been adapted to more specific targets including detection of liquid threats, such as explosives and chemical weapons, and the determination of the contents of unfuzed (i.e. already fired) mortar shells.

Explosives range in density from the pure "plastiques" with density 1.6 g/cm^3 down to that of water, 1.0 g/cm^3. They have been made in many shapes: cast as toys, molded into briefcase walls, shaped as computer batteries, flattened in thin letters, poured as liquid into bottles, etc. They have also been sealed in closed containers from metal tins to toiletry products. Chemical weapons have been concealed in containers of many shapes and sizes as well diluted with various inert materials.

The two most common methods of inspection, namely X-ray (including CT) and trace detection, have clear and well-known weaknesses. The latter attempts to detect the presence of trace amounts of threat material by collecting particulates or via the vapor emitted by the material on the external surface of items. Such vapor will not be present on well-sealed and prepared threats. The former looks for shapes and densities, while modern explosives have a large variety of densities and indistinct shapes as mentioned above. Many chemical weapons have densities similar to other benign liquids, and they are invariably held in well-sealed containers.

SPEDS automatically detects military, commercial, and homemade explosives, as well as chemical weapons including nerve, blister, blood, and choking agents, regardless of shape, container, and concealment method. It does so by directly detecting the elemental constituents of the explosive or chemical weapon material. The detection is via the well-established thermal neutron analysis (TNA) method (Gozani and Shea, 1991;

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Gozani, 1994, 1995). The item to be inspected is loaded into a cavity and "bathed" by thermal neutrons. The deeply penetrating thermal neutrons are absorbed, through the thermal neutron capture process, by the elemental constituents of the item. Most elements, including those essential to most explosives and many chemical weapons, then emit gamma-rays characteristic of the elemental constituents. An array of detectors surrounding the cavity detects the emitted gamma-rays, producing a spectrum characteristic of the inspected item. The spectra are processed to produce an automatic "yes/no" decision on whether the inspected item contains the threat or threats which the system has been calibrated to detect. As mentioned above, the system can be calibrated to detect a large variety of threats and contraband.

SPEDS is fast, automatic (no human interpretation necessary), and very sensitive. The system is compact, comparable in size to current security checkpoint X-ray systems, and would fit in current airport security checkpoints and most government and commercial lobbies. It is transportable and movable. System calibration and use is very simple, requiring only the touch of a resistive touchscreen user interface.

2. Mortar shell inspection

Currently, there is an extensive effort in many parts of the country geared towards cleaning areas which were once used for military training in an effort to make them suitable for public use. In particular, there is a large area in Massachusetts called the Massachusetts Military Reservation (MMR) which is littered with artillery shells. Most of these are inert shells, filled with a waxy substance, which were used for artillery practice. However, some of the shells are live, in other words, contain explosive material. Since the shells have, in general, been buried under the soil for years, even decades, they are corroded and all markings indicating whether or not they contain explosive material have disappeared. Determining whether or not the shells are live, and disposing them off as explosives, is a laborious and expensive process, costing between $500 and 1000 per shell.

Ancore was contracted by the Environmental Division of the National Guard Bureau (NGB), through Ogden Environmental and Energy Services Co., Inc., to non-intrusively inspect a large number of mortar shells at the MMR. SPEDS was sent to the MMR in July 2001. From 16 to 27 July 2001, SPEDS inspected over 800 mortar shells and found them clear of any explosive material with a very high level of confidence. Following this success, Ancore was again contracted by the NGB, through Environmental Chemical Corporation, to deliver a mobile system capable of inspecting mortar shells. A system was developed by modifying a SPEDS unit for this application and mounting it in a 14 ft trailer with a power generator, lighting, air-conditioning, and all necessary electronics.

The system was calibrated by constructing reference shells, both inert and filled with explosive simulant, for each type of shell likely to be encountered in the field. The advantage of having reference shells is that any shell found in the field need only be compared to the two (inert and explosive simulant filled) reference shells of the same model, and the reference shells have to be scanned at most once daily.

An example of the gamma-ray spectra from an inert and explosive simulant shell, an 81 mm model M374 shell) is shown in Fig. 1. The obvious difference between the two spectra at energies between about 10 and 11 MeV is due to the nitrogen, contained in the explosive simulant, which produces gamma-rays of energy 10.8 MeV.

Based on spectra from inert and explosive simulant filled shells of various models, algorithms were developed to automatically detect live mortar shells found in the field. One of the methods we use to describe the performance of a given algorithm is through a parameter called FOM, which is defined as

$$FOM \equiv \frac{\mu_S - \mu_B}{\sqrt{\sigma_S^2 + \sigma_B^2}},$$

where μ_S and μ_B are the means of the algorithm output, and σ_S and σ_B are the variances of the explosive simulant and inert shell distributions, respectively. Table 1 lists the estimated FOMs from the five shell types for which we have developed algorithms, along with the number of scans, N, of live mortar shells which would need to be done before one of these scans resulted in a single missed detection at a false alarm rate of 0.01%. The results are for a scan time of 60 s. These are laboratory results on a limited number of shells, but

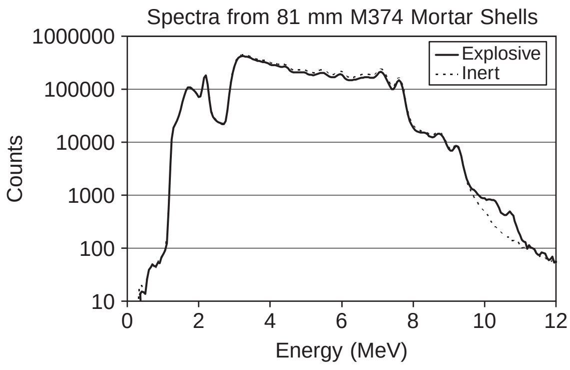

Fig. 1. Gamma-ray spectra from inert and explosive simulant filled M374 mortar shells.