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Classifying threats with a 14-MeV neutron interrogation system

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Abstract

SeaPODDS (Sea Portable Drug Detection System) is a non-intrusive tool for detecting concealed threats in hidden compartments of maritime vessels. This system consists of an electronic neutron generator, a gamma-ray detector, a data acquisition computer, and a laptop computer user-interface [Strellis et al., 2003, Proceedings of the 2003 ONDCP International Technology Symposium, San Diego, CA].

Although initially developed to detect narcotics, recent algorithm developments have shown that the system is capable of correctly classifying a threat into one of four distinct categories: narcotic, explosive, chemical weapon, or radiological dispersion device (RDD). Detection of narcotics, explosives, and chemical weapons is based on gamma-ray signatures unique to the chemical elements. Elements are identified by their characteristic prompt gamma-rays induced by fast and thermal neutrons. Detection of RDD is accomplished by detecting gamma-rays emitted by common radioisotopes and nuclear reactor fission products. The algorithm phenomenology for classifying threats into the proper categories is presented here.

Keywords: Neutron generator; 14-MeV neutron; Thermal neutron analysis; Fast neutron analysis; Neutron activation; Explosive detection; Chemical weapons detection; Drug detection; Dirty bomb

1. Introduction

Sea Portable Drug Detection System (SeaPODDS) was developed to detect narcotics concealed in hidden compartments onboard fishing vessels. Since the September 11 tragedy, detecting additional bulk threats has become a high priority to authorities securing our borders. To counter the added threat, new algorithms were added to the SeaPODDS capability. SeaPODDS will now detect a wide variety of targets including narcotics, explosives, chemical weapons, and nuclear materials.

Detecting threats behind hidden compartments onboard marine vessels requires the system to be man-portable, rugged, water resistant, and user friendly (see Fig. 1). The sensor must be able to probe through thick walls and provide an automatic decision in a relatively short period of time. These requirements can be reasonably well met by using an appropriate configuration of a neutron source, neutron spectrum tailoring, gamma-ray detector type, and shielding material. The underlying technology uses both TNA® (thermal neutron analysis) and FNA™ (fast neutron analysis). These technologies measure, in a complementary way, elemental (hence material) specific signatures. Usability

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is further enhanced by automatically classifying the inspection as benign or suspect. If suspect, then the algorithm further classifies the suspect as an explosive, narcotic, chemical weapon, or RDD. Knowing the nature of the threat allows the inspector to take appropriate action to clear the suspected area.

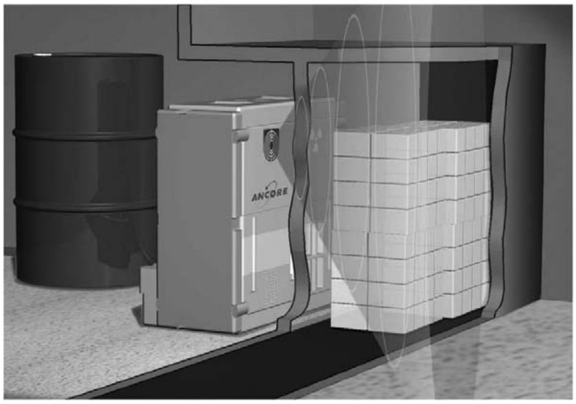

Fig. 1. Rendering of SeaPODDS inspecting a hidden cavity.

2. Material signatures

Nuclear techniques detect the presence of materials of interest by detecting signatures of specific nuclei through their unique nuclear structures. Narcotics, explosives, and chemical weapons are unique and different from most benign materials because of their elemental compositions (Gozani, 1981, 1991; Gozani et al., 1989; Vourvopoulos et al., 1991; Bendahan et al., 1999) as shown in Table 1.

Table 1 clearly shows that a narcotic like cocaine hydrochloride can be efficiently measured with TNA using a combination of H and Cl features. Combining TNA with FNA to measure C and/or O will further enhance the measurement.

Explosives can be efficiently measured with TNA using the N and H features. Combining TNA with FNA to measure oxygen will further enhance the measurement.

Chemical weapons have inherently different signatures because they vary greatly in elemental composition. Nerve agents, blister agents, and blood agents contain chemicals that are designed to attack very

Table 1
Elemental composition of common substances, narcotics, explosives, and chemical weapons

Substance	Density (g/cm^3)	%H	%C	%N	%O	%Cl	% Other elements	Examples of elemental siqnatures			
								C/O	N/O	Cl/C	Cl/H
Benigns											
Salt	0.77	0	0	0	0	60	40	0	0	0	0
Sugar	1.2	7	42	0	51	0	0	0.8	0	0	0
Sand	2.3	0	0	0	53	0	47	0	0	0	0
Water	1	11	0	0	89	0	0	0	0	0	0
Wood	0.62	6	47	0	44	0	3	1.1	0	0	0
Petroleum	0.87	14	86	0	0	0	0	0	0	0	0
Cement	2.3	0	0	0	35	0	65	0	0	0	0
PVC	1.32	5	38	0	0	57	0	0	0	1.5	11.5
Polyethylene	0.94	14	86	0	0	0	0	0	0	0	0
Fiberglass	1.7	3	46	0	35	0	16	3	1.3	0	0
Sea water	1.02	10	0	0	88	1.2	0.8	0	0	0	0.03
Explosives											
PETN	1.76	2.4	19	17.7	60.8	0	0	0.3	0.3	0	0
TNT	1.63	2.2	37	18.5	42.3	0	0	0.9	0.4	0	0
Dynamite	1.18	4.2	14.8	18.5	62.4	0	0	0.2	0.3	0	0
C4	1.65	3.6	21.9	34.4	40.1	0	0	0.6	0.9	0	0
Narcotics											
Heroin hydrochloride	~0.87	6	62.1	3.5	19.7	8.7	0	3.2	0.2	0.1	1.5
Cocaine hydrochloride	~0.87	6.5	60.1	4.1	18.8	10.4	0	3.2	0.2	0.2	1.6
Heroin	~0.87	6.3	68.2	3.8	21.7	0	0	3.2	0.2	0	0
Cocaine	~0.87	6.9	67.3	4.6	21.1	0	0	3.2	0.2	0	0
Chemical_weapons											
Hydrogen cyanide		3.7	44.5	51.8	0	0	0	0	0	0	0
Mustard gas		5	30.2	0	0	44.6	20.2	0	0	1.5	8.9
Sarin		7.1	34.3	0	22.9	0	35.7	1.5	0	0	0