Ad hoc Group of Governmental Experts to Identify and Examine Potential Verification Measures from a Scientific and Technical Standpoint

Distr.
RESTRICTED

BWC/CONF.III/VEREX/WP.47
24 November 1992

ENGLISH only

Second Session
Geneva, 23 November - 4 December 1992

UNITED STATES OF AMERICA

Nondestructive Evaluation Techniques for Chemical Weapons

Nondestructive evaluation (NDE) of the contents of munitions or containers generally involves using an energetic "probe", or signal, such as a beam of photons or neutrons or sound waves. Information about the interrogated device is obtained by measuring either the system response to the probe or reflected signal.

The United States has conducted several successful tests of NDE techniques on chemical weapons at the Tooele Army Depot in Tooele, Utah. NDE techniques are under development to provide rapid, safer, and cost effective alternatives/adjuncts to direct chemical sampling for the detection, and identification of chemical agent systems. At their current state of development, U.S. NDE technologies have limited application to biological materials.

System Descriptions

Ultrasound Pulse Echo

Ultrasound pulse echo can be used to distinguish liquid-filled munitions or containers from solid-filled, powder-filled, or empty munitions or containers. It is not capable of discerning elemental composition. For liquid-filled objects the method can determine fill level, the thickness of the fill, the speed of sound in the fill and its density and viscosity. The method can also be used to measure the wall-thickness of the interrogated device.

To interrogate an object, an acoustic pulse is introduced into the object through its outside wall. If liquid is present, the signal propagates through it and is reflected back from any obstruction, such as a burster in a munition or the opposite wall, and is picked up by one or more detectors. Solids will be detected as long as they are in good contact with the container wall and do not attenuate the sound wave below detectability (powders do not meet this condition). Fill level is detected by the absence of a reflected signal from the fill material as one moves up the container wall. The relative amplitude of the reflected signal gives information about the density and viscosity of the fill.

Dimensions are calculated by timing the arrival of the reflected signal, coupled with the knowledge of the speed of sound in the material. If neither the internal dimensions nor the speed of sound are known, both can be determined by triangulation, using two detectors. Measurements of internal dimensions are complicated when internal interfaces have complex curvature on a length-scale comparable to the wave length of the interrogating signal; in such cases, more than one detector will be required.

The method requires direct contact with munitions. Measurements can be made in a few seconds. There are no hazards associated with use of the method. Clearly, ultrasound techniques have very limited utility for determining the presence of biological material in an interrogated object.

Acoustic Resonance

Acoustic Resonance provides information about the contents of an interrogated object when its response is compared with a baseline obtained from a known object. Even without a baseline, differences in the responses of objects to the interrogating signal indicate differences in their internal composition.

Using this method, an object is excited with a range of acoustic frequencies. It responds with a resonant signature that is a function of its size, shape, and physical properties. Empty, solid, and liquid-filled containers (similar except for the fill) will all have a similar low-frequency component to their signature. The presence of liquid introduces high-frequency components to the spectrum. Frequency shifts in the spectrum give information about differences in level and density of the fill.

Use of acoustic resonance to positively identify an object depends on the consistency and uniqueness of classes of objects, since identification requires comparison with a baseline signal. Even without a baseline, structural differences in apparently similar objects will manifest themselves by differences in the resonant signature, and are thus detectable.

The current acoustic resonance device requires direct contact with the interrogated object, but work has been done in remote excitation and detection. Measurements require a few seconds. No hazards are associated with this method. At its current state of development acoustic resonance has limited application to BW, as it can only be utilized to determine fill level and to categorize items based on an existing baseline comparison.

Neutron Interrogation

Portable Isotopic Neutron Spectroscopy (PINS)

PINS provides information about the elemental composition and stoichiometry of materials. It can be used to identify chemical agents and to distinguish conventional from chemical munitions.

PINS involves irradiating an object with neutrons from a relatively low energy neutron source. The system being developed by the U.S. uses a californium source that produces neutrons with an average energy of 2 MeV. Those neutrons thermalize quickly and can either inelastically scatter from the target material or be absorbed. In the case of inelastic scattering, which is a resonant phenomenon, the transmitted neutron spectrum can be detected and will show sharp absorption lines which provide a signature of the elements in the interrogated object. In the case of neutron absorption, the nuclei are excited and emit gamma rays (photons) with energies characteristic of the elements of the interrogated object. Information about the type of fill is obtained from those elements which are detected in combination with those that are not. Stoichiometry can be determined by the relative amplitudes of the elemental responses.

The inelastic scattering cross-section for thermal neutrons is high for CW elements, which ensures strong transmitted signals and easy detection. Crosssections for neutron absorption are lower at these energies but still high enough to give statistically significant data for all CW elements.

The PINS system under development by the U.S. uses a gamma detector. No direct contact with the interrogated object is required. Measurements require on average between two and ten minutes. The hazards are minimal with the low-energy neutron source, whose transportation is routine under the IAEA.

The PINS system focusses on the presence of unique elements in sufficient proportions to give indications about the nature of an unknown fill. For example it is able to distinguish a mustard round from a high-explosive round by the presence of sulfur and chlorine. Biological materials are mainly composed of carbon, hydrogen, nitrogen, and oxygen. PINS would not be effective against biological materials because such material does not present a distinct fingerprint.

X-Ray

An X-ray of an object provides information about its internal structure. It would not provide a distinction between solid or liquid. X-ray is considered intrusive, since detailed structural information about the object under interrogation can be obtained, potentially compromising sensitive information.

Application to Biological Weapons Verification

Although the U.S. has not completed a comprehensive study of the application of NDE to biological weapons verification, it can be reasonably asserted that these techniques would be of limited utility to a BW inspector. Biological materials possess neither the elemental composition nor the physical characteristics necessary to permit the effective use of NDE. In fact, some of the equipment associated with the production and storage of biological materials would make the use of acoustic NDE impossible. Acoustic systems are not usable on containers with discontinuities between the outer surface and the interior mass, such as double-walled containers with an air gap between the walls (e.g., some fermenters, spray tanks and submunitions). Neutron techniques, at their current state of development, do not positively identify biological materials because biologicals contain no tell-tale elements, such as phosphorus, chlorine and/or sulfur common in chemical weapons or the high concentrations of nitrogen in conventional high explosives.