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Survey of Commercially Available Explosives Detection Technologies and Equipment 2004

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For:

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This document is an updated version of a document originally published in 1998. The objective of the original document was to help the law enforcement community understand the many options in commercially available explosives detection methods and technologies. In the intervening six years, the explosives detection field has seen enormous growth, fueled by the threat of terrorism and the emphasis on homeland security. Since the document was originally published, some of the commercial companies no longer exist, new companies have entered the field, product lines have changed, and technology has advanced.

Without the contributions of these individuals, the relevant chapters would be much less informative and complete than they now are. We are also grateful to the vendors of commercial equipment listed in this document who have in many cases provided us with detailed information and fruitful discussions over the years. The authors of this document are solely responsible for any errors contained herein, and any opinions that are expressed are those of the authors alone.

Some information included within this survey on commercially available explosives detection systems and technologies is derived from information received in response to a request for information placed in the Fed Biz Opps (formerly Commerce Business Daily) in March 2004. Sandia National Laboratories does not warrant, guarantee, or endorse any of the products mentioned in this survey.

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Chapter 1. Introduction

Document Purpose, Scope, and Structure

Document Purpose

This document provides an overview of currently available explosives detection methods and technologies to aid the law enforcement community in the selection of explosives detection equipment for various applications.

This document was originally published in September 1998 and has been updated to provide the most recent information on commercially available equipment.

Sponsor

Funding was provided by the National Institute of Justice (NIJ) through the National Law Enforcement and Corrections Technology Center (NLECTC)–Rocky Mountain Region. Sandia National Laboratories (SNL) authored this document and is the Department of Energy's technology base for the physical protection of facilities.

Buyer Beware

This document is intended to inform law enforcement agencies about relevant aspects of explosives detection for making procurement decisions. This document is **not** intended to be a procurement guide and does not make specific recommendations. Each reader must reach his or her own conclusions, based on the unique needs of the agency seeking information. All detection methods and technologies have advantages and disadvantages; the buyer must determine which aspects have the most relevance for the buyer's application.

Further Information

Law enforcement agencies that have questions or comments about explosives detection equipment are encouraged to contact the authors of this document and any of the commercial vendors listed for additional consultation. This document provides basic and practical information with some technical information describing principles of operation of the individual technologies.

Document Structure

The document provides an overview of

- purchase considerations and explosives detection applications (chapter 2)
- trace explosives detection technologies (chapter 3)
- bulk explosives detection technologies (chapter 4)
- terminology (glossary)

Major Types of Explosives Detection

Definitions of Trace and Bulk Explosives Detection

Explosives detection methodologies are divided into two major categories: trace detection and bulk detection methods (see Figure 1.)

- ***Trace explosives detection*** involves the chemical detection of explosives by collecting and analyzing tiny amounts of explosive vapor or particles (a microscopic amount of explosives.) Trace detection includes several different technologies using chemical sensors. Canine detection is considered a subset of trace detection; however, that topic is outside the scope of this document, which focuses on technological solutions.

  NOTE: Sample collection methods and the presence of a background of explosives material at a site can profoundly affect the usefulness of trace detection methods.

- ***Bulk explosives detection*** involves the detection of a macroscopic mass of explosives material (a visible amount of explosives), usually based on either imaging or on nuclear (molecular) properties of the explosive. Bulk detection methods are less dependent than trace detection methods on sampling techniques (sample collection), and are not affected by the presence of an explosive background. However, equipment costs associated with bulk detection are often higher, and some bulk detection techniques ─ especially those based on imaging, such as x-ray imaging ─ may have a lower degree of specificity than trace detection methods.

Trace and Bulk Have Complementary Strengths

Because trace and bulk explosives detection methods are sometimes complementary and have different strengths, it may be worth having the capabilities of both detection techniques. The feasibility of having both techniques available is usually constrained by cost and by the operational needs of the facility. The different technologies and methods utilized in trace and bulk explosives detection systems are discussed in greater detail in *Chapter 3—Trace Explosives Detection* and *Chapter 4—Bulk Explosives Detection*.

Distinguishing between Bulk and Trace

A few final thoughts on distinguishing between bulk and trace detection:

- Bulk detection seeks the *actual explosive material*.
- Trace detection looks for *residue or contamination* from handling or being in proximity to explosives materials. However, trace contamination may reveal a bulk source. For example, if a terrorist with explosives strapped to his body walks through a personnel portal, the portal may detect the trace amounts of the explosives present on the terrorist's skin or clothing from handling the bomb. The magnitude of the detection does not necessarily relate to the quantity of bulk explosive that may be present.

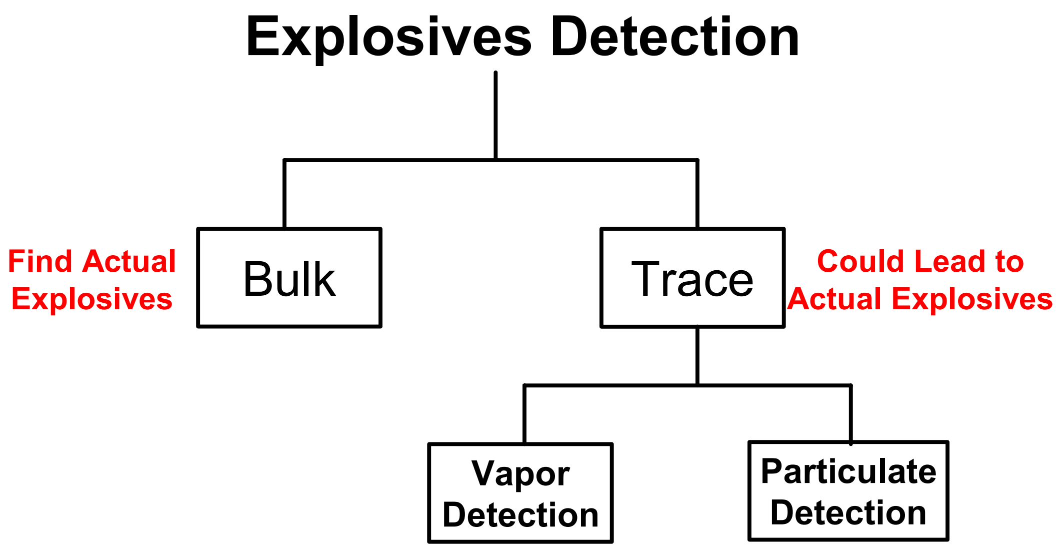

Figure 1. Main categories of explosives detection methodologies: trace and bulk

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Chapter 2. Explosives Detection System Purchase Considerations

Overview

Applications, Calibration, Maintenance, and Legal Issues

This chapter covers a wide range of topics that should be discussed before purchasing explosives detection equipment, including the following:

- applications for explosives detection
- operational considerations for explosives equipment
- explosives detection system performance parameters
- calibration and maintenance of equipment
- possible legal issues
- general advice for buyers

Key Words

P_d: Probability of Detection

The probability of detection (P_d) refers to the probability that an explosives detection system will detect a certain amount of explosive material under a given set of conditions.

LOD: Limit of Detection

The limit of detection (LOD) is the smallest mass of explosive that will cause an explosives detection system to alarm.

False Negative

A false negative occurs when a device fails to alarm in the presence of explosives.

False Positive

A false positive occurs when a device generates an alarm even though no explosives are present.

Applications for Explosives Detection

Define the Applications for the Proposed Equipment

Before acquiring an explosives detection system, ask the question, "How will this system be used?" The explosives detection application will influence system selection. Some potential applications for explosives detection include:

(1) ***Routine screening of large numbers of personnel***: Occurs primarily at the entrances to buildings or facilities when it is desired to screen all incoming persons to determine whether they have explosive materials in their possession. This screening could occur at building entrances, airports, or large event facilities. This application is characterized by screening large numbers of people routinely entering an area. Rapid processing is very important.

(2) ***Screening of large numbers of vehicles***: Occurs primarily at high-security checkpoints. Screening vehicles includes, by definition, the screening of people and packages contained within those vehicles. Rapid processing is very important.

(3) ***Screening of large numbers of hand-carried items***: This application will normally occur in conjunction with Application 1, and, in many cases, different explosives detection systems will be used to screen the people and their hand-carried items, including briefcases, backpacks, purses, suitcases, packages, etc.

(4) ***Screening of mailed and shipped items***: Screen letters, packages, and shipping crates arriving at a particular location, for example, at a judicial or legislative location. Special attention might be paid to items addressed to government officials, senior executives, or personnel involved in the discipline or termination of employees.

(5) ***Screening of small numbers of people, vehicles, or mailed/shipped items***: Investigating a suspicious item (for example, an abandoned package found outside a building where a bomb threat has been communicated.) In these cases, the volume of people/items to be screened is small, so more time can be spent screening a single person or item than in Applications 1 through 4.

(6) ***Bomb search***: Involves the screening of a room, building, or other area when there is reason to believe a bomb may be present (e.g., when a bomb threat has been communicated.) This application clearly places a premium on being able to screen a large area in a short period of time since the area to be searched potentially is much larger than any of the applications listed above.

(7) ***Special situations or events***: Includes any significant event that may require increased security measures with regard to explosives detection. Examples include visits by legislative persons, foreign dignitaries or the President and also events with significance to potential terrorist groups.

(8) ***Protection of special infrastructure***: Includes structures such as utility plants, dams, and communication facilities that may need explosives protection.

Determine Applications

In some situations, several of these explosives detection applications may need to be performed. In these cases, determine which applications have the highest priority, and to what degree the applications can use the same explosives detection equipment.

Explosives Equipment Operational Considerations

Purchase Considerations

Once the explosives detection application has been identified, the following operational factors need to be considered:

(1) Type of explosives to be detected
(2) Working environment
(3) System cost
(4) Consumables Cost
(5) Health/public safety issues
(6) Privacy issues
(7) Ease of use
(8) Portability
(9) System speed (throughput rate)

Determine Which Explosives Need to be Detected

1. Which explosives need to be detected?

Although it is obviously desirable to be able to detect every type of explosive, some explosives are more commonly encountered than others. For example, mail bombs that have been sent in the U.S. have traditionally used black powder, rather than plastic explosives. Thus, if mail screening is the primary application, a detection system that works well for black powder may be adequate, even if it does a poor job with plastic explosives. Almost always, particularly with trace explosives detection systems, some types of explosives are more easily detected than others.

Working Environment

2. What is the current working environment where the explosives detection system will be installed?

Some environments have a high background level of explosives material, such as propellants at a practice firing range. Explosives material contamination may be present on the ground, nearby surfaces, or on an individual's clothing, which could result in an alarm. If explosives detection is being performed in an area that already has a high explosives background level, then the sensitivity of the explosive detection system may need to be modified. To account for the explosives contamination in the environment, operators will need to set the alarm level on the system higher than normal (thereby lowering sensitivity) for explosives detection.

Other environmental factors may influence which explosive detection system would be best when operating in an outside environment. These factors include temperature, humidity, dust, and wind.

Consider Both Purchase and Maintenance Costs

3. What are the system costs?

Depending on the type of system and the desired degree of sophistication, commercial detection system purchase costs can range from approximately $20,000 to more than $1,000,000. It may be necessary to choose between the purchase of one very sophisticated system and the purchase of several cheaper and less sophisticated systems. Cost normally has a bearing on some of the other parameters listed in this section, such as system sensitivity and ease of use, though higher cost is certainly no guarantee of a "better" detection system.

Consider both purchase and maintenance costs. Maintenance costs can vary depending upon the complexity of the system, the number of explosives detection systems in use at a location, and the maintenance plan chosen.

Consumables Cost

4. What are the consumables cost for a system?

Consumables cost is harder to quantify than an explosives detection system's initial cost. Some explosives detection systems have more consumables (disposables, reagents, etc.) associated with them than other systems. Therefore, the cost of consumables should be evaluated and should be a purchase consideration, especially in a high-volume application.

Health/Public Safety Issues

5. What are the health and public safety issues?

If the explosives detection application will involve screening people for explosives, then the potential health effects of the screening technique need to be considered. Even if there is no known hazard to human health, the public perception that a hazard exists may present a significant barrier to the use and acceptance of a technology. The prototypical example is the use of personnel screening systems that use low-dose backscatter x-ray technology to detect bombs and other contraband items. Although the x-ray dosages involved are extremely low and the Food and Drug Administration has approved such systems for sale in the U.S., the public's dread of X rays has thus far limited the use of such systems. In the U.S., these systems have been restricted primarily to use in correctional facilities, where the inmates or visitors are screened. In these applications, the persons being screened are required to submit to the screening process. Extensive public education and awareness may be necessary before the technology can be put into widespread use.

Privacy Issues

6. What are the privacy issues?

The privacy of an individual whose person or possessions are being screened can become a constitutional/legal issue in personnel screening applications. Screening people with low-dose backscatter x-ray scanners is a good example, since the x-ray image produced can show a rather revealing image of the person's body. The reactions of the people to be screened may need to be considered before a system is purchased.

Operator Ease of Use

7. How easy is it to use the system?

Explosives detection systems vary dramatically in their complexity and ease of use, from highly technical laboratory systems that will be used primarily by experts in performing forensic analysis to field-portable units that could be used by a police officer or security guard with a few hours of training. For most commercially available systems, the company that sells the system can provide some training when the unit is purchased.

Another important factor under ease of use is the explosives detection system setup time and complexity. If the system takes two hours to set up and assemble or needs to warm up one hour prior to use, these may be important considerations when purchasing an explosives detection system.

System Portability

8. What are the system portability constraints?

Some explosives detection systems, such as the smaller commercial trace detection systems, are easily portable, while others, such as portals and most x-ray baggage screeners, are large and are intended primarily for dedicated, repetitive use at a single location. Clearly, this constraint is an important consideration relating to the intended application of the new equipment.

System Speed (Throughput Rate)

9. How fast does the system work?

In high-volume applications (such as Applications 1 through 4 mentioned above), the ability to screen items or people quickly is very important. A system's "throughput rate" is expressed in units such as persons per minute, packages per hour, etc. In many high-volume applications, the need for a high throughput rate can be met by replacing 100 percent screening with screening a random selection of people (i.e., one out of five.)

Explosives Detection System Performance Parameters

Key Parameters

The following discussion describes parameters that help assess a system's overall performance. The operational considerations mentioned above define the system's performance requirements, which include:

1. Sensitivity (P(d) and LOD)
2. False alarm rates
3. Nuisance alarms
4. Interferents

1. Sensitivity

Sensitivity and Probability of Detection (P_d)

One way to determine an explosives detection system's sensitivity is to evaluate the probability of detection (P_d) when the system is presented with an explosive. The P_d refers to the likelihood that an explosives detection system will detect a certain amount of explosive material under a given set of conditions. The P_d could be an important parameter in the selection of a system, but it is difficult to determine.

Variables that Affect P(d)

In field applications (outside a laboratory), the value of P_d can depend upon a large number of variables, including:

- the explosives packaging
- the cleanliness of the person(s) packaging the explosive
- the way the package is scanned, swiped, or vacuumed
- the skill and motivation of the explosives detection system operator
- the measures taken by the adversary to prevent detection
- the environment of the explosive

Because of this complexity, the limit of detection (LOD) (see below) can be a better measure for comparing different explosives detection systems.

Limit of Detection (LOD)

The LOD is the smallest amount of explosive that will cause an explosives detection system to alarm. One should keep in mind that reported LODs usually represent the best-case presentation of an explosive to an explosives detector (e.g., the explosive is injected directly into a sampling port) and may not truly represent field conditions. The LOD is a good way to compare the sensitivity of different explosives detection systems for the explosives of interest.

2. False Alarm Rates

Two Types of False Alarms

The false alarm rate is a *critical* parameter to examine when looking at a particular explosives detection system. There are two types of false alarms: a false negative and false positive. Figure 2 illustrates possible false alarm scenarios. A desirable explosives detection system will have low false alarm rates. The vendor performs testing to determine the false alarm rates (sometimes just false positive) on its explosives detection systems and these numbers should be available.

False Negative Alarm

A false negative occurs when an explosive material is present, but the explosives detection system fails to detect it. The false negative rate is the number of times the system failed to detect an explosive when it was present, divided by the total number of tests performed.

False Positive Alarm

A false positive occurs when an explosive material is not present, but the explosives detection system alarms anyway. The false positive rate is the number of positive detections, when no explosives are present, divided by the total number of tests.

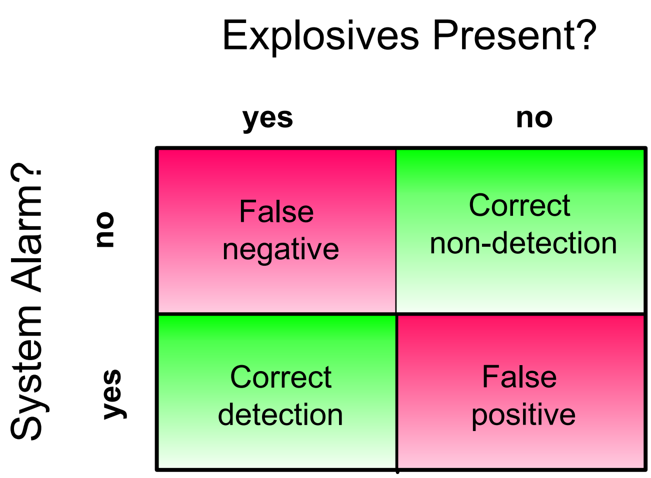


Figure 2. Possible false alarms are false negative and false positive.

Balancing Act

The false positive rate tends to increase when the sensitivity of an explosives detection system increases (i.e., the detector is set to alarm on lower amounts of explosives material.) An explosives detection system with a high false positive rate may lead the operators to set the detection limit higher to avoid false alarms. In some situations, this setting may be acceptable, but it may also lead to more false negatives (i.e., to the failure to detect a threat item when present.)

3. Nuisance Alarms

Real Alarms, but Not Threats

Nuisance alarms are the result of the trace system detecting actual, but non-threatening explosive materials. The source of the explosives is a non-threat item such as heart medication and not a bomb or other contraband. Nuisance alarms are different from false alarms, because no explosive materials are present in a false alarm.

4. Interferents

Non-Explosive Chemicals Can Mask Explosives or Generate False Positive Alarms

Interferents (sometimes also called interferences) are non-explosive chemicals that may interfere with the detection of explosives using a trace detection system. Interferents could be naturally occurring compounds in the environment or they can be compounds that have been intentionally added to the object in question or brought in proximity to the equipment.

The interfering substance could hide or cover up the presence of an explosive, thereby generating a false negative. Interferents can also interfere with the explosives detector and generate a false positive (an explosives detection alarm occurs when no explosive is present.)

Consequences of Interferents

Important consequences of having too many false positive alarms include:

- the operator may decide to decrease the sensitivity on the explosives detection system or
- the operator may discontinue using the equipment.

Calibration and Maintenance of Equipment

Manufacturers Should Supply Manuals and Hands-On Training

Explosives detection systems that are purchased from reputable companies should always have accompanying user's manuals that provide detailed information concerning required calibration, maintenance, and operational procedures. Ideally, a condition of any purchase agreement should include that the company send a qualified individual to the site to install and set up the equipment initially. At that time, at least one of the operators (several are recommended) should be present and discuss the calibration and maintenance procedures in detail with the company representative. Such hands-on training can save time, money, and operator effort.

Perform Calibration and Maintenance Regularly

While calibration and maintenance procedures are always specific to the particular instrument one is using, it is generally easy to perform for commercial systems. Users do need to be aware of when it is necessary to re-calibrate equipment. Be sure to discuss with the vendor (at length) any circumstances that may require re-calibration of the instrument.

A few generalizations can be made about calibration procedures for different types of instruments. For example, trace detection systems based on ion mobility spectrometry (IMS) are sensitive to ambient pressure (atmospheric pressure), and the system may require re-calibration if operated during inclement weather or moved to a new location at a different altitude.

Maintenance Contracts

Some companies offer maintenance contracts for their detection systems. These contracts can be very worthwhile if a system needs major repairs before the contract expires or if the application requires minimal down-time (such as in an airport.) However, it may often prove cheaper not to purchase a maintenance contract and to pay for repair work on an as-needed basis. Buyers need to consult vendors and consider their own specific circumstances before making a decision on maintenance contracts. In some cases, repairs can be performed relatively cheaply if the equipment is shipped back to the manufacturer.

Possible Legal Issues

Disclaimer

The following discussion on possible legal issues associated with explosives protection is brief and does not imply any explosives protection policy.

Consult Legal Staff

Due to the wide variety of circumstances in which explosives detection systems may be used, the exact legal consequences of its use are difficult to predict. If legal questions are anticipated, legal staff should be consulted for specific guidance applicable to the specific explosives detection system prior to its use.

Authority for Searches

The location where the explosives detection equipment is set up and in use is important. Whether the explosives detection equipment is on private, public, or government property has ramifications for "authority to search". Determine any legal issues on authority to search prior to equipment placement in a location.

Imaging the Body or Using Ionizing Radiation

Explosives personnel screening detection systems that use backscatter X rays or any other technology that creates an image of the human body may raise constitutional right-to-privacy issues. Also, the use of X rays, even in extremely low doses, may raise health and safety issues by exposing personnel to ionizing radiation. Additionally, there may be health and safety issues about how to screen expectant mothers. Obtaining advice from qualified legal professionals is recommended before the use of any explosives detection system that results in a body image or uses ionizing radiation in screening individuals.

General Advice for Buyers

Talk to the Vendor

1. Talk to the vendor of the product(s) you want to buy

Reputable vendors are the most knowledgeable sources of information on the products that they sell, and can give advice on applications. Vendors should also be able to refer you to similar customers who have purchased and use their product. Ask the vendor what makes their product superior to their competition and who their competitors are. Discussions with the competitors can be useful. Refusal of a vendor to provide any information on their competitors *might* be a warning sign that the vendor is being less than totally candid. Bear in mind that the vendor is not a disinterested third party.

Consider All Costs: Initial, Maintenance, Consumables, and Long-Term

2. Always consider maintenance, consumables, and other long-term costs in addition to initial purchase cost

Maintenance and consumables costs have not been heavily emphasized in this document, because

- they tend to be minor for many trace and bulk explosives detection systems, and because
- they are variable and are more difficult to define than purchase cost.

Nevertheless, these long-term costs need to be considered when purchasing a system. In some cases, maintenance efforts can be substantial. Vendors can provide maintenance and consumables cost information.

Talk to Customers That Have the Product You Want to Buy

3. Talk to current users of the product(s) you want to buy

Ask the vendor for a list of customers who have used the system you want to buy to compare their experiences concerning long-term costs, equipment failure rates, and maintenance requirements. Talking to the owners of the explosives detection system in question can give a less biased opinion from someone with hands-on experience with the vendor's product. Make sure that the customers you talk to have been using the equipment in question (same model number) long enough to have a good grasp of the pros and cons of the system Ask the customer if they are satisfied with their explosives detection purchase and the company's service. For example, if 4 out of 5 customers report significant equipment failures, equipment downtime, or are not receiving assistance or adequate service from the vendor, exercise caution and gather more information prior to purchasing equipment.

Ask Third-Party (non-biased) Experts

4. Seek advice from a disinterested third party who has expertise in explosives detection

This advice could be sought by consulting documents similar to this one, or through personal correspondence or phone conversations. Such advice is particularly important if discussions with vendors and other customers leave you with important questions still unanswered. Possible sources of information include the National Institute of Justice (NIJ), the FBI, other law enforcement agencies, and the authors of this document. (The authors have developed prototype explosive detection technology, and therefore may not represent a totally disinterested third party.)

Consider Possible Market Changes

5. The market for explosives detection equipment evolves rapidly

Market changes are especially rapid for trace and combined technology detection systems. Always determine your key needs and then choose a system that can meet those needs as well as possible for several years. Furthermore, question vendors about any new products in the works. Perhaps, by delaying a purchase for 6 months or a year, a product that is better suited to your needs and application may become available.

Buyer Beware

6. Be wary of unknown companies selling radically new technologies that seem to make unprecedented claims about detection capabilities

Unusual and radically new technology claims may prove to be correct, but other claims may be erroneous or, in extreme cases, fraudulent. It is critical to talk to a wide variety of people, including vendors, the vendor's customers, and outside experts, before a purchase is made. Discussions with other customers may be less useful if the product is new and if those customers do not fully understand the technology. Try to find out if the equipment has been independently tested by a government laboratory or university, and discuss the matter with the people who performed the testing. If a piece of equipment seems too good to be true, exercise caution.

Conclusions on Purchase Considerations

Tradeoffs Usually Occur During System Selection

In summary, tradeoffs in a system's capabilities may be necessary to arrive at a **best** decision on which explosives detection system to purchase. In some cases, system sensitivity and speed improve with increasing cost. Portable systems may have less sensitivity as compared to a larger, dedicated, single-location system. How these factors are weighed during the selection process is arbitrary and may vary with each individual situation. Most often, a single overriding factor such as cost or throughput rate sets some initial bounds that limit the available choices. Nevertheless, it is highly desirable to think about all of the issues listed in this section before purchasing a system.

For expert advice, consult with several of the prospective companies about their system prior to selecting an explosives detection system. Also, consider contacting the subject matter experts and authors at Sandia National Laboratories if the vendors are unable to answer the question satisfactorily. The authors' contact information is listed in the acknowledgements.

Chapter 3. Trace Explosives Detection Technologies

Introduction to Trace Detection

Overview

This chapter provides an overview of trace explosives detection technologies (as shown in Figure 3) and the factors that affect trace detection methods. The topics in this chapter include:

- Principles of trace explosives detection
- Explosives vapor detection
- Explosives particulate detection
- Vapor vs. particulate detection—which is more appropriate?
- Trace detection technologies
    - Ion mobility spectrometry
    - Chemiluminescence
    - Thermo-redox
    - Surface acoustic wave (SAW)
    - Chemical reagent
    - Ultraviolet fluorescence
    - Mass spectrometry
    - Canine detection
- Summary of vendors and equipment

Before discussing the capabilities of current trace explosives detection systems, the following section provides an understanding of some of the challenges in trace explosives detection.

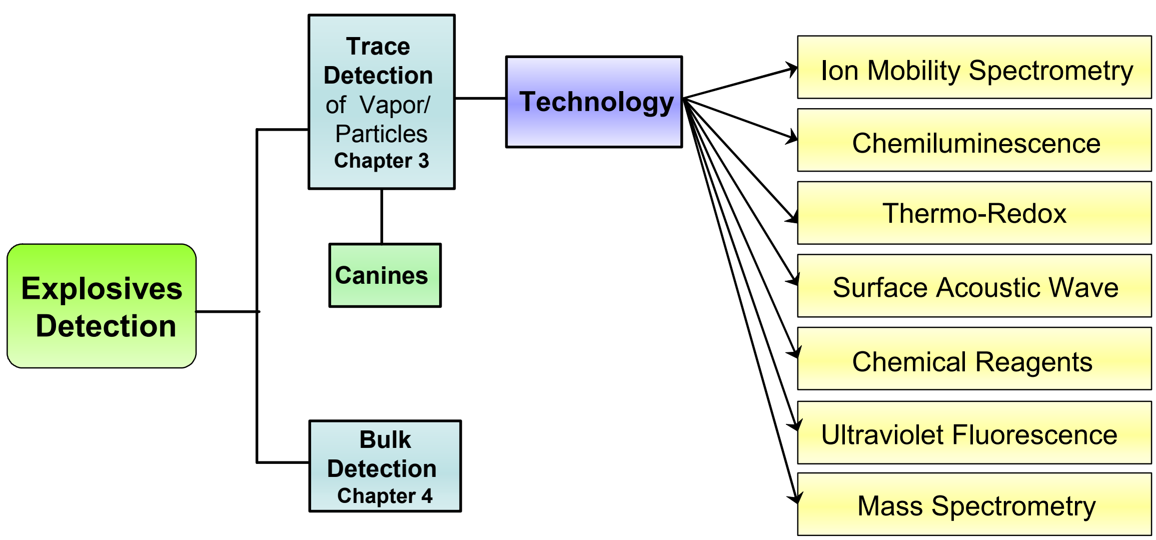


Figure 3. Explosives Detection Schemes with Trace Detection Technologies Highlighted

Definition

Trace explosives detection is the acquisition and analysis of microscopic residues of the explosive material.

Canine Trace Explosives Detection

Canine explosives detection is a very important trace detection method and will be mentioned briefly at the end of this chapter. Hand-held trace detection techniques cannot currently compete with canines in their ability to follow a scent to its source.

Principles of Trace Detection

The term "trace detection" refers to both vapor and particulate forms:

- ***Vapor***—Gas-phase molecules that are emitted from a solid or liquid explosive. The concentration of explosives in the air is related to the vapor pressure of the explosives material and to other factors such as the amount of time the explosives material is present in a location, its packaging, air circulation in the location, etc.
- ***Particulate***—Microscopic particles of the solid explosives material that adhere to surfaces (i.e., by direct contact with the explosive, or indirectly, through contact with someone's hands who has been handling explosives)

Vapor sampling requires no contact. Particulate sampling requires direct contact to remove explosives material particles from a contaminated surface. All trace detection systems have strengths and weaknesses.

Alarm Resolution is Critical

Not all alarms indicate a threat. A valid explosives detection alarm can occur if the object under inspection has been contaminated with trace amounts of explosives material for legitimate reasons. For example, when screening people, it is possible to generate a valid alarm for nitroglycerin, a frequently prescribed heart medication, even though no bomb is present. Alarm resolution is an important issue when using trace explosives detection technologies.

Explosives Vapor Detection

Definitions

Vapor pressure–All solids and liquids emit vapor in real-world environments. At a given temperature, the amount of vapor emitted is characteristic of that particular substance.

Vapor detection–The sampling and analysis of air-borne, gas-phase explosives material. The sample is collected without contacting the surface of the sampled item.

Explosives Tend to Produce Little Vapor

Most explosive materials do not evaporate readily. This tendency is a function of the materials' vapor pressure, which directly relates to the amount of the explosive material released into the air. Thus, sampling strategies are very important due to the usually small amount of vapor-phase explosives material emitted from solid explosives material.

Vapor Pressure

Vapor Concentrations of Explosives

Figure 4 shows the maximum vapor concentrations in air of several explosives at room temperature. Note that the vertical axis of Figure 4 has a logarithmic scale, so that each hash mark corresponds to a factor-of-ten increase in vapor concentration. In general, explosives can be categorized by their vapor pressures and vapor concentrations, as shown below:

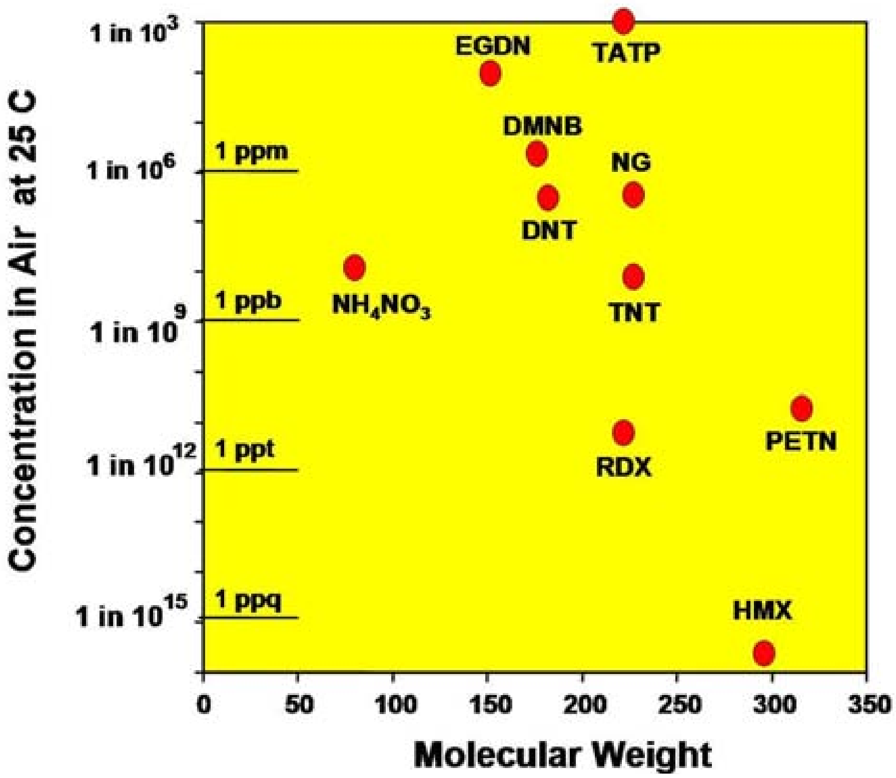


Figure 4. Vapor concentration of high explosives in saturated air at 25°C.

High, Medium, and Low Vapor Pressures

- ***High*** vapor pressure explosives include ethylene glycol dinitrate (EGDN), nitroglycerin (NG), and 2,4-dinitrotoluene (DNT.) These explosives have equilibrium vapor concentrations in air on the order of about one part per million (1 ppm), which means that there will be roughly one molecule of explosive vapor for every million molecules in the air.

- ***Medium*** vapor pressure explosives have equilibrium vapor concentrations in air near one part per billion (1 ppb.) The medium vapor pressure group includes TNT (2,4,6–trinitrotoluene) and ammonium nitrate (NH_4NO_3.)
- ***Low*** vapor pressure explosives have equilibrium vapor concentrations in air near or below the one part per trillion (1 ppt) level, an additional factor of approximately 1000 lower than the medium vapor pressure explosives. The low vapor pressure group includes HMX (octogen), RDX (hexogen or cyclonite), and PETN (pentaerythritol tetranitrate.) These vapor pressures are for pure materials. Vapor pressures for mixtures containing these explosives may be even lower.

The very low vapor pressures of some explosive materials present a challenge in the successful detection of trace amounts of explosives via a vapor sample.

Explosives Particulate Detection

Definition

Particulate detection–The acquisition and analysis of microscopic solid explosives material. The sample is collected by contacting the surface of the sampled item.

Bomb-building Spreads Explosives Contamination

Particulate (or particle) contamination consists of microscopic solid particles, often on the order of a few micrograms (1 microgram = 1 $\times 10^{-6}$ grams = one millionth of one gram.) Explosives in general tend to be sticky, and a person handling a piece of the solid explosives material will quickly transfer large amounts of contamination to his or her hands. Contamination with the explosives material will be transferred to any additional surfaces touched by the hands, which likely will include the person's clothing as well as doorknobs, tabletops, and other objects that were touched.

Careful handling of the explosive and the proper use of disposable gloves reduces the spread of particulate contamination; however, reducing it to zero is extremely difficult. Most bomb builders and carriers will not have the expertise to do a clean job and there will be particulate contamination present; thus, the particulate method of sampling has wide applications.

Swipe Method for Particulate Contamination

Particulate contamination is usually sampled by using a swipe pad (provided by the equipment manufacturer) to wipe the surface to be screened. The swipe pad is then inserted into a sampling port on the explosives detection system, and in seconds, it is analyzed for the presence of explosives.

Surface Swiping

Surface swiping works best with small packages, briefcases, and purses. Personnel screening is not usually performed with surface swiping because many individuals would find the method invasive. This technique can also be adapted to sampling small select areas on larger suspect items, such as vehicles.

Amount of Explosives Present

While it is difficult to make generalizations about how much explosives contamination is in a fingerprint, a typical fingerprint will contain many particles, with a total mass often on the order of 100 micrograms. When working with low and medium vapor pressure explosives at room temperature, more explosives material is contained in the fingerprint than would be present in a liter of air saturated with vapor (by a factor of 1,000 to 1,000,000.) Thus, for low and medium vapor pressure explosives, explosives detection is usually based on particulate detection.

Choosing Particulate or Vapor Detection Methods

High Vapor Pressure Explosives: Best Detected with Vapor Detection

High vapor pressure explosives are relatively easy to detect with vapor detection using ion mobility spectrometers (IMS.) Dynamites, which usually contain EGDN and/or NG as an explosive ingredient, can usually be detected from their vapor. Detecting these compounds by swiping surfaces for particles is also possible, but it may be less effective. The high vapor pressures of these explosives cause small particles to evaporate rapidly and thus detection can be difficult.

Medium Vapor Pressure Explosives: Most Appropriate Method Depends on the Material

Medium vapor pressure explosives can sometimes be detected from their vapor, but particulate detection based on surface swiping is usually preferred due to low vapor concentrations. For example, in a quick comparison of vapor vs. particulate for TNT, the amount of TNT vapor available for sampling is likely to be small as compared to the TNT particulate contained in a typical fingerprint, which might contain several micrograms.

Ammonium nitrate is a medium vapor pressure explosive material. It is a special case due to the large quantities (hundreds or even thousands of pounds) of this explosive that might be used in a large vehicle bomb, and not in small bombs found on a person or shipped through the mail. When ammonium nitrate is used, there is likely to be lots of contamination present to detect through swipe-based detection, but additionally, various bulk explosives detection techniques (i.e., X ray) could also be effective.

Low Vapor Pressure Explosives Best Detected With Swipe Collection

The ***low vapor pressure*** explosives do not produce enough vapor to be detected from their vapor in any but the most exceptional circumstances and efforts to detect these compounds using trace technology must focus on swipe collection of particles.

This characteristic makes swiping the preferred collection technique when dealing with plastic explosives such as C–4, Semtex, and Detasheet™, which contain RDX and/or PETN as the explosive ingredient.

Temperature Strongly Affects Vapor Pressure

Ambient temperature has a dramatic effect on the explosive material's vapor pressure. Therefore, on a cold day, there is less explosive vapor available to detect. Hot days increase the amount of available explosives vapor.

Taggants Can Help Identify Some Low-Vapor-Pressure Explosives

The pure explosive materials RDX and PETN have extremely low vapor pressures, and the vapor pressures of plastic explosives are even lower, due to the presence of oils and plasticizing agents that give the plastic explosive its form and consistency. When these explosives are manufactured, they are often spiked with a high vapor pressure, nitrogen-containing compound called a *taggant* to make them more easily detectable. These taggants have high vapor pressures (similar to NG or EGDN), and their presence in the plastic explosives makes vapor detection possible. However, relying on the presence of the taggant for vapor detection of plastic explosives is risky, because old, homemade, and some foreign-made plastic explosives do not contain a taggant. Nevertheless, detection of one of the taggants using vapor sampling with a trace detection system should be interpreted as possibly indicating the presence of a plastic explosive.

Swipe Collection Involving Physical Contact Could be Dangerous

Despite the advantages of better sample collection through swipe methods, direct contact with a package that might contain explosives could cause the bomb to detonate. Therefore, vapor collection is preferred in many circumstances.

Trace Detection Technologies

Introduction

The technologies and equipment presented in this section represent the state-of-the-art commercially available explosives trace detection equipment.

Always Seek Most Recent Info

The explosives detection and security sector is rapidly evolving and all information is subject to change. The potential buyer should always check with the manufacturing company to obtain the most up-to-date information.

Acronyms of Trace Technologies

The remaining sections of this chapter discuss specific trace explosives detection technologies. Table 1 lists common trace detection technologies and their associated acronyms.

Table 1. Common Trace Detection Technologies

Detector Type	Acronym
Ion **M**obility **S**pectrometer	IMS
Gas **C**hromatograph / **I**on **M**obility **S**pectrometer	GC/IMS
Gas **C**hromatograph / **C**hemi**L**uminescence	GC/CL
Gas **C**hromatograph / **M**ass **S**pectrometer	GC/MS

Ion Mobility Spectrometry (IMS)

IMS Most Common Trace Method

Ion mobility spectrometry (IMS) is the most common technique used for commercial applications of trace explosives detection. IMS instruments can operate in swipe (particulate) and/or vapor detection modes.

Principle of Operation of IMS

IMS detection is based one how fast ions move and reach the detector.

The operator collects a sample either by drawing in air near the object or by swiping a surface to collect particles. The system delivers the sample to the ionization region of the IMS detector (left side of Figure 5), where electrons interact with the incoming explosives molecules to form negative ions. The negative ions next move into the drift region of the IMS (right side of Figure 3–2.) The time required for the ions to travel the length of the drift region is called the ***drift time*** and is a complex function of the charge, mass, and size of the ion. The drift time is used to identify a material as a potential explosive. Typical drift times are on the order of a few milliseconds (1 millisecond = 0.001 second.)

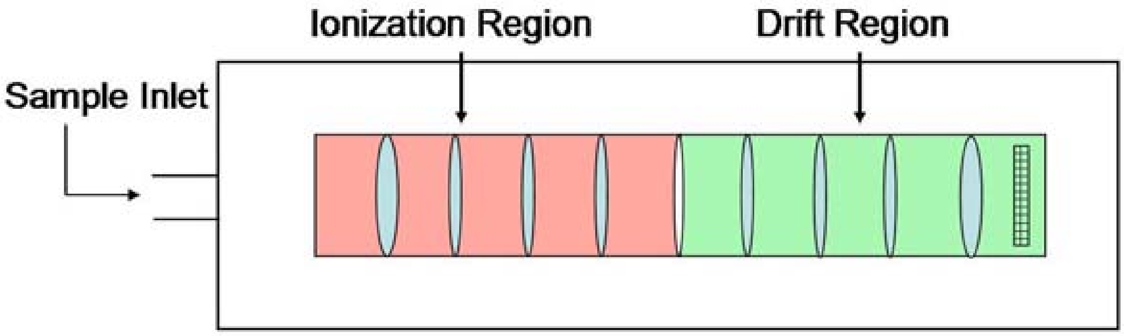


Figure 5. Illustration of the ionization and drift region in an ion mobility spectrometer (IMS) detector.

IMS System Features

- ***Portability***—IMS systems range from small, hand-held systems to large, dedicated-site portal systems. The hand-held IMS systems weigh approximately six to 20 pounds, can be carried by one person for field applications, and can be transported in the trunk of a passenger car. Benchtop systems weigh approximately 45 to 60 pounds and usually stay in one place; the operator brings a sample to the system. Walk-through personnel screening is done with a portal that weighs hundreds of pounds and is set up permanently for continued use at one entry point.
- ***Ease of Use***—Most units can be successfully operated by a person with only a few hours of training.
- ***Throughput Rate***—Approximately two to three samples per minute, but throughput can be higher depending on the system.
- ***Sample Collection***—Most units have vapor and particle collection abilities.
- ***Power Requirements***—Battery and AC-powered systems
- ***System Setup***—Warm-up time is approximately 10 minutes for the hand-held and benchtop systems. Warm-up times are longer for portals.
- ***Cost —Hand-held:*** $19,000 to $30,000
  Benchtop: $40,000 to $50,000
  Portals: $130,000 to $750,000

Advantages of IMS Systems

IMS is one of the most widely used techniques for trace detection of explosives and other contraband materials. IMS systems operate under ambient conditions and are priced moderately.

Disadvantages of IMS Systems

IMS instruments normally contain a small quantity of radioactive material as an ionizing source. This radioactive source does not pose any health risks if the system is operated properly, but simply having such a source may lead to extra paperwork and regulatory oversight.

The drift time associated with a given ion is dependent on atmospheric pressure, and can thus change during inclement weather or when the spectrometer is moved more than a few hundred feet in elevation. These conditions require little more than routine, periodic recalibration, but users need to be aware of this issue.

Differentiating Peaks May Be Difficult

Another drawback of IMS technology is peak resolution in mixtures or "real-world samples". Two different materials that form ions of similar size and mass may appear as a single broad peak rather than two distinct peaks in an IMS spectrum.

Using Gas Chromatography to Separate Ions Before They Reach the IMS

One method of resolving the overlapping peak problem is to separate the molecules before they enter the IMS. This separation is accomplished by first introducing the vapor sample to a gas chromatographic (GC) column prior to the IMS. The GC column is a narrow tube coated with a chemical substance called the stationary phase. This stationary phase interacts more strongly with some materials than with others, thereby affecting the material's speed as it travels through the column. The time required for a material to travel the length of the GC column is its ***retention time***. The GC column separates each material prior to its entrance into the IMS.

Therefore, even if two materials have identical IMS drift times, they will likely have different GC retention times, and can be identified because the materials will not enter the IMS at the same time. A combined GC/IMS system can handle a sample that is a mixture of different compounds.

IMS-Based Personnel Screening Portal

Explosives detection personnel portals are walk-through systems for rapidly screening personnel for trace amounts of explosives at sites such as airports. Personnel are required to walk slowly or pause briefly in the portal. The portal residence time is necessary to dislodge explosive particles off skin, clothing, or hair. The explosives material is collected and identified using an IMS detector. Walk-through personnel screening portals utilizing IMS based technology are commercially available from both GE Security and Smiths Detection (see Table 2.) For other personnel screening techniques, refer to the low-dose x-ray backscatter personnel screening section in chapter 4 for bulk detection methods for personnel screening.

Commercially Available IMS Systems

Stand-alone IMS systems, GC/IMS, and other ion mobility-based systems are commercially available for package, personnel, and vehicle screening applications. See Table 3–2 for various commercial trace explosives detection systems. Figures 6 and 7 show representative commercial IMS-based systems.

Photo furnished by: Smiths Detection

Figure 6. Examples of commercial IMS technology manufactured by Smiths Detection; top left, a Sabre 4000 hand-held instrument, right, the Sentinel, a personnel portal and bottom left, an Ionscan 400B benchtop instrument.

Photos top and right furnished by GE Security. Photo at bottom left furnished by Sandia National Laboratories

Figure 7. Commercially available ion trap mobility spectrometers (ITMS), which is an IMS-based technology from GE Security. Top left, the VaporTracer[2] hand-held instrument; right, the EntryScan[3], a personnel portal; and bottom left, the Itemiser[3], a benchtop instrument

Chemiluminescence (CL)

Principle of Operation of Chemiluminescence

Chemiluminescence is the production and emission of light that occurs as a product of a chemical reaction(s) as shown in Scheme 1.

A + B → products + light (Scheme 1)

Detect IR Light from Nitro or Nitrate Molecules

Most common explosives materials contain nitrogen (N) in the form of either nitro (NO_2) or nitrate (NO_3) groups. Additionally, most explosive material taggants used in plastic explosives also contain NO_2 groups. The most commonly used chemiluminescence reaction scheme for explosives detection involves infrared radiation (IR) light emission from excited-state nitrogen compounds.

The produced IR light is directly proportional to the amount of NO present, which is related to the amount of the original nitrogen-containing explosive material that was present.

CL System Features

- ***Portability***—Hand-held and portable systems are available. The hand-held system weighs less than 7 lb and the portable system weighs over 150 lb.
- ***Ease of Use***—Some units can be successfully operated by a person with only a few hours of training. Some systems have half-day training sessions available.
- ***Throughput Rate***—Approximately three samples per minute.
- ***Sample Collection***—Vapor and/or particle collection on most systems.
- ***Power Requirements*****—**Battery- and AC-powered systems.
- ***System Setup***—Varies between instruments. Hand-held instruments are ready in less than 1 minute.
- ***Cost—Hand-held***: $18,000 to $20,000
  Portable: $50,000 to $60,000

Advantages of CL Systems

CL detectors do not utilize a radioactive ionizing source and thus users can avoid some of the paperwork and possible regulatory oversight that may be associated with detectors that use radioactive sources.

Disadvantages of CL Systems

A significant drawback of CL systems is their inability to detect explosives that are **not** nitro-based.

Combine CL with a GC to Detect Nitro-Based Explosives

Used alone, CL techniques cannot identify what type of explosive molecule is present. All that can be said is that a nitrogen-containing molecule was present that decomposed to yield NO, and such molecules are found in explosives and taggants but also in fertilizers, some perfumes, and other common materials. For this reason, chemiluminescence detectors are typically not used alone but are fitted with a front-end gas chromatograph column (GC), as described previously in the section on ion mobility spectrometry. The combined GC/CL provides a unique GC retention time and separates materials prior to their CL detection.

Commercially Available CL Systems

See Table 2 for information on various commercially available chemiluminescence explosives detection systems from Scintrex Trace and Thermo Electron Corporation. Figures 8 and 9 show two commercial CL systems.

Photo furnished by: Scintrex Trace Corporation

Figure 8. Hand-held commercial chemiluminescence explosives detection system from Scintrex Trace Corporation, E3500

Photo furnished by: Thermo Electron Corporation

Figure 9. Portable commercial chemiluminescence explosives detection system from Thermo Electron Corporation, EGIS II

Thermo-Redox

Principle of Operation of Thermo-Redox

Thermo-redox technology is an electrochemical technique based on the thermal decomposition of explosive molecules and the subsequent reduction of NO_2 groups. A sample is drawn into the system and is passed through a concentrator tube, which selectively traps explosive-like materials. The sample is heated rapidly to release NO_2 molecules, and these molecules are detected using proprietary technology.

Thermo-Redox System Features

- ***Portability***—Hand-held systems that weigh under 7 lb.
- ***Ease of Use***—Most units can be successfully operated by a person with only a few hours of training.
- ***Throughput Rate***—Two to three samples per minute.
- ***Sample Collection***—All systems collect vapor and some can also collect particle samples.
- ***Power Requirements—***Battery powered systems.
- ***System Setup***—Ready within 1 minute of power-up.
- ***Cost—Hand-held:*** $8,000 to $20,000

Advantages of Thermo-Redox Systems

Thermo-redox detection techniques do not utilize a radioactive ionizing source, and thus users can avoid some of the paperwork and possible regulatory oversight that may be associated with radioactive sources.

Disadvantages of Thermo-Redox Systems

This technology detects only the presence of NO_2 groups and cannot distinguish explosives materials and potential interferents that contain NO_2 groups. Thus, the system identifies the presence of an "explosive-like" material, without identifying a specific explosive.

Commercially Available Thermo-Redox Systems

Thermo-redox systems for explosives detection are commercially available from Scintrex Trace (see Table 2.) Figure 10 shows a commercial thermo-redox system.

Photo furnished by: Scintrex Trace Corporation

Figure 10. Hand-held commercial thermo-redox explosives detection system from Scintrex Trace Corporation, EVD-3000

Surface Acoustic Wave (SAW)

Principle of Operation for SAW

Surface acoustic wave (SAW) detection of explosives materials is based on frequency changes that occur when materials are deposited on the SAW crystal surface (detector surface.)

Combining with Gas Chromatography

In a combined GC/SAW-based system, the SAW detector is fitted with a front-end GC as described previously in the section on ion mobility spectrometry. When vapors exit the GC, they are trapped selectively on the surface of the SAW detector, where the frequency shift can be correlated to the explosive material concentration. The frequency shift is dependent upon the properties (mass and the elastic constants) of the material being deposited, the temperature of the SAW crystal, and the chemical nature of the crystal surface. The GC/SAW allows different molecules that are detected by the SAW to be specifically identified with their unique GC retention times.

Additionally, the temperature of the SAW crystal adds sensor specificity based upon the vapor pressure of the explosives species being trapped. This feature is useful in distinguishing between volatile materials and sticky explosive materials.

GC/SAW System Features

- ***Portability***—Portable systems about the size of a large briefcase
- ***Ease of Use***—Vendor offers a training course
- ***Throughput Rate***—One or more samples per minute
- ***Sample Collection***—Vapor sampling only
- ***Power Requirements***—Battery-powered systems
- ***System Setup***—Operational within 10 minutes of setup
- ***Cost***—Portable Unit: $21,000 to $25,000

Advantages of GC/SAW

The main advantage of using a GC/SAW detector is the ability to detect other chemicals in addition to explosives. Another advantage of GC/SAW detectors is that they do not utilize a radioactive ionizing source, and thus users can avoid some of the paperwork and possible regulatory oversight that may be associated with radioactive sources.

Disadvantages of GC/SAW Systems

The main advantage of GC/SAW detectors is also their biggest disadvantage. The GC/SAW is nonspecific and the presence of other chemicals may make explosives detection more difficult. Additionally, a gas container is necessary for operating the instrument.

Commercially Available GC/SAW Systems

Electronic Sensor Technology manufactures commercial GC/SAW systems available for trace explosives detection (see Table 2.) Figure 11 shows a commercial GC/SAW system.

Photo furnished by: Electronic Sensor Technology

Figure 11. Portable commercial GC/SAW explosives detection system from Electronic Sensor Technology, 4200 zNose

Chemical Reagent-Based (Color Change)

Principle of Operation

Reagent-based (color change) explosives detection of residue is made by observing a **color** change after the addition of chemical reagents to an explosive sample. The operator deposits chemical reagents in a series, observes color changes with each reagent addition, and determines if explosives are present.

Detection Based on Color Changes

Color-based explosives detection kits are marketed by Mistral Security Inc.:

- Expray uses aerosol reagents to detect what the manufacturer refers to as Group A explosives (TNT, DNT, picric acid, etc.), Group B explosives (Semtex H, RDX, PETN, NG, smokeless powder, etc.), and compounds that contain nitrates.
- Drop-Ex and PDK kits use liquid reagents. Drop-Ex#4 and PDK detect improvised chlorate/bromate and peroxide-based explosives.

Scenario for Detecting Explosives

A suspect surface (e.g., a package or a person's clothing) is wiped with the special test paper. Using Expray, the operator sprays the test paper with a specialized spray, noting any color changes. If there is no reaction, the same paper is sprayed with another reagent. Based on the color changes, the operator can identify the type or group of explosives. The explosives testing order is critical, and all reagents should be used in their proper order to perform a complete test on the sample residue.

Chemical Reagent-based System Features

- ***Portability***—Kits weigh less than a few pounds
- ***Ease of Use***—Very simple, but the instructions must be followed precisely and the order of sample testing is critical
- ***Throughput Rate***—One (or more) per minute, depending on the reaction to the reagent
- ***Sample Collection***—Particle collection only
- ***Power Requirements***—None, but in some testing scenarios, a light source is necessary (a flashlight is sufficient)
- ***Cost***—$115 to $150 for a kit that performs 50 tests

Advantages of Reagent-based Systems

The biggest advantage of the reagent-based technique is the low cost of the kits, though if a large number of tests are performed over an extended period of time, greater costs could be incurred. The kit's low cost, coupled with its simplicity and ease of use, may make it attractive for the law enforcement community.

Disadvantages of Reagent-based Systems

The biggest disadvantage of color-based systems is the reliance on the operator's interpretation of color, as follows:

- Identifying the specific type of explosive present when a positive result occurs is not always possible.
- Only the specific colors in the instructions can be judged a positive detection. Other discoloration is possible, but should be judged negative.
- Operators may have some degree of color blindness.

Additionally, vapor sampling cannot be performed and detection is very dependent on sample concentration.

Chemical Reagent-based Systems

Figure 12 shows the Expray field test kit, which consists of three spray containers and special test papers. The chemistry associated with these color changes is proprietary. See Table 2 for specific information on Mistral Security Inc. products.

Photo furnished by: Mistral Security, Inc.

Figure 12. Hand-held commercial Expray field test kit for explosives detection from Mistral Security Inc.

Mass Spectrometry (MS)

Principle of Operation of MS

Mass spectrometry (MS) uses an explosive material's molecular weight and fragmentation patterns for identification. While there are different types of mass spectrometers, it is basically a mass filtering technique. Molecules are ionized and passed through a filter (e.g., magnetic, ion trap, time-of-flight), which allows ions to be identified based on their charge-to-mass ratio.

Hyphenated GC/MS Systems

Most MS systems used for explosives detection are fitted with a front-end GC as described previously in the section on ion mobility spectrometry. The combined GC/MS allows different molecules that are detected with the mass spectrometer to be identified specifically with the additional information of their unique GC retention times.

MS is a powerful laboratory technique and now fieldable GC/MS systems are available for field applications.

MS System Features

- ***Portability***—Most of the currently available GC/MS systems are laboratory systems, but portable systems are becoming available. The portable systems weigh approximately 75 pounds.
- ***Ease of Use***—Some technical ability or experience is necessary.
- ***Throughput Rate***—Approximately 3 samples per hour, but throughput will vary with the sample and its preparation.
- ***Power Requirements—***Operates on a generator or AC power.
- ***System Setup***—Portable units have a short set-up time (on the order of five minutes) and about a 45-minute "warm-up" time.
- ***Cost***—Portable units range in cost from $135,000 to $215,000.

Advantages of GC/MS

Mass spectrometry is a mature technology and is a very powerful laboratory technique for chemical analysis. MS has excellent specificity for compound identification.

Another advantage of GC/MS detectors is that they do not utilize a radioactive ionizing source, and thus users can avoid some of the paperwork and possible regulatory oversight that may be associated with radioactive sources.

Disadvantages of GC/MS Systems

Some MS systems require a gas supply or vacuum pump. The sample analysis time can be relatively long.

Commercially Available GC/MS Systems

See Table 2 for information on various commercially available mass spectrometry explosives detection systems. Figure 13 shows two commercial MS systems.

Photos furnished by: Constellation Technology Corporation (left) and Bruker Daltonics (right)

Figure 13. Portable commercial GC/MS explosives detection systems from Constellation Technology Corporation, CT-1128 (left) and Bruker Daltonics (right)

Ultraviolet (UV) Fluorescence

Principle of Operation of UV Fluorescence

Ultraviolet (UV) fluorescence is a technique where trace amounts of explosives materials fluoresce when UV light illuminates the explosives material.

UV Fluorescence System Features

- ***Portability***—A hand-held scanner has several feet of cable to the processing unit.
- ***Ease of Use***—Not available. Due to ongoing system testing, not all parameters have been determined.
- ***Sample Collection***—The detector must be within 1 inch of the object and the scanned area is small.
- ***Throughput Rate***—Not available. Due to ongoing system testing, not all parameters have been determined.
- ***Power requirements*—**Battery- or AC-powered.
- ***Cost***— Not available.

In the fourth quarter of 2004, CDEX Inc. is scheduled to release a portable trace explosives detection system based on UV fluorescence. The system will be called the Personnel Security Screening System (PS^3.) See Table 3 for vendor information on CDEX Inc.

Canine Detection of Explosives

Overview

Trained canines have been used more than perhaps any other technology or detection method for the detection of explosives under real-world conditions. A dog's nose is the best vapor sensor that evolution has to offer and it competes favorably with man-made detection technologies under many circumstances. Canines have two qualities that trace chemical sensors (such as ion mobility spectrometers) cannot match at present:

(1) high mobility, and
(2) the ability to follow a scent to its source.

Canines are usually the detection method of choice for applications that involve any significant search component.

Final Thoughts and Vendor Information

Future Outlook

The explosives detection techniques discussed in this chapter are expected to remain the principal techniques for use in law enforcement and other applications for at least the next several years. The expected trend for new equipment is toward more portable, miniaturized units, rather than improvements in sensitivity. The sensitivity of current instruments is already adequate for most applications. The miniaturization of equipment will likely reduce the cost of the equipment. Another possible future trend is to have systems that combine two or more detection technologies into a single system.

Applications

Table 2 contains information on systems that are commercially available for personnel, package, and vehicle inspections. Table 3contains contact information for trace detection equipment vendors.

Considerations for Choosing a System

Before choosing a system:

1. Define all requirements for the application. For example, if the application is for a personnel screening checkpoint with a high volume of pedestrian traffic, the equipment should have a high throughput rate and have the demonstrated capability to discern the presence of an explosive mass (i.e., a bomb) on a person.
2. Work with a knowledgeable company salesperson or applications engineer (review chapter 2 on equipment purchase considerations.)
3. Solicit advice or information from a third party such as an independent testing laboratory or government agency.
4. Solicit information from current customers of the product you want to buy.

Refer also to *Chapter 2, Explosives Detection System Purchase Considerations.*

Caveats

Vendors can also provide advice on the suitability of their products for specific applications, though such advice will clearly not be disinterested. All costs in Table 2 are approximate and will depend on the options and accessories purchased.

Seek the Most Recent Information

The explosives detection and security sector is evolving rapidly and all information is subject to change. The potential buyer should always check with the manufacturing company to obtain the most up-to-date information, including information on new systems.

Table 2: Commercial Trace Explosives Detection Systems

(*Cost Column: Low cost is less than $25,000; Medium cost is $25,000 to $50,000; High cost is more than $50,000)

Manufacturer	Trace Detector Model	Cost*	Detector Type[a]	Advertised Sensitivity[b]	Approx. Size /Weight	Use
Hand-held Instruments						
GE Security	VaporTracer[2]	Low – Med	ITMS (IMS based)	pg	8"x5"x16" 7 lb	Personnel, package, and vehicle search
Mistral Security Inc.	EXPRAY Kit Model M1553	Low	Color	ng	2 lb	Personnel, package, and vehicle search
Mistral Security Inc.	Drop-Ex Kit Model M1584	Low	Color	ng	1 lb	Personnel, package, and vehicle search
Mistral Security Inc.	PDK Kit Model M1582	Low	Color	ng	0.5 lb	Personnel, package, and vehicle search
Scintrex Trace Corp.	E 3500	Low	CL	ppb to ng	4"x5"x20" Under 7 lb	Personnel, package, and vehicle search
Scintrex Trace Corp.	EVD-2500	Low	TR	ppb	4"x5"x20" Under 7 lb	Personnel, package, and vehicle search
Scintrex Trace Corp.	EVD-3000	Low	TR	ppb	4"x5"x20" 6 lb	Personnel, package, and vehicle search
Sibel Ltd, represented by Bahia21 Corp.	MO-2M	Low	NLDM (IMS based)	ppb to pg	12"x3"x4" under 3 lb	Personnel, package, and vehicle search
Smiths Detection	SABRE 4000	Low	IMS	pg	13"x4"x4.5" under 6 lb	Personnel, package, and vehicle search
Portable Instruments						
Bruker Daltonics	MM2	High	GC/MS	Not available	15"x11"x15" 66 lb	Personnel, package, and vehicle search
Constellation Technology Corp.	CT-1128	High	GC/MS	fg[c]	15"x23"x15" 75 lb	Personnel, package, and vehicle search
Electronic Sensor Tech.	ZNose Model 4200	Low	GC/SAW	ppb	10"x12"x6" 27 lb	Personnel, package, and vehicle search
Electronic Sensor Tech.	Znose Model 7100	Low	GC/SAW	ppb	14"x7.5"x14" 30 lb	Personnel, package, and vehicle search
Benchtop Instruments						
GE Security	Itemiser[3]	Med	ITMS (IMS based)	pg	15"x19"x20" 26 lb	Personnel, package, and vehicle search
Smiths Detection	IONSCAN 400B	Med	IMS	pg	22"x13"x12" 47 lb	Personnel, package, and vehicle search
Thermo Electron Corp.	EGIS III	High	GC/CL	pg	51"x25"x26" 165 lb	Personnel, package, and vehicle search
Thermo Electron Corp.	EGIS II	Med – High	GC/CL	pg	29"x29"x18.5" 165 lb	Personnel, package, and vehicle search
Thermo Electron Corp.	EGIS Defender	Med	GC/DMS (IMS based)	pg	22"x22"x16" 25 lb	Personnel, package, and vehicle search

Table 2: Commercial Trace Explosives Detection Systems, continued

Manufacturer	Trace Detector Model	Cost*	Detector Type[a]	Advertised Sensitivity[b]	Approx. Size /Weight	Use
Dedicated Location Instruments						
GE Security	EntryScan[3] (personnel portal)	High	ITMS (IMS based)	ng	102"x48"x40" 630 lb	Personnel Portal (fixed checkpoint portal)
Scintrex Trace	LVBDS (vehicle portal)	High	GC-IMS/CL	ppb to ng	Max vehicle size 18'x7'x6'	Vehicle Portal (fixed checkpoint portal)
Smiths Detection	IONSCAN SENTINEL II (personnel portal)	High	IMS	pg	70"x90"x60" 1200 lb	Personnel Portal (fixed checkpoint portal)

[a] detector types

CL: chemiluminescence
DMS: differential ion mobility spectrometry
GC: gas chromatography
IMS: ion mobility spectrometry
ITMS: ion trap ion mobility spectrometry
MS: mass spectrometry
NDLM: non linear dependence of ion mobility
SAW: surface acoustic wave
TR: thermo-redox

[b] vendor advertised sensitivity (amount of explosives detected)

fg = femtogram = 1 x 10^{-15} grams
ng = nanogram = 1 x 10^{-9} grams
pg = picogram = 1 x 10^{-12} grams
ppb = one part per billion (1 ppb) = one molecule of explosive vapor for every billion molecules in the air

[c] when the mass spectrometer is in selective ion mode (SIM)

Table 3. Vendor List for Commercially Available Trace Explosives Detection Technologies

Company	Phone Number	Web Address	Address
Bahia21 Corporation	301–296–4333	www.bahia21.com	15200 Shady Grove Rd, Suite 202 Rockville, MD 20850
Bruker Daltonics	978–663–3660	www.bdal.com	40 Manning Rd Billerica MA 01821
CDEX Inc	301–881–0080	www.cdex-inc.com	1700 Rockville Pike, Suite 400 Rockville, MD 20852
Constellation Technology Corporation	727–547–0600	www.contech.com	7887 Bryan Dairy Road Largo, FL 33777
Electronic Sensor Technology	805–480–1994	www.estcal.com	1077 Business Center Circle Newbury Park, CA 91320
GE Security (formerly GE Ion Track)	978–658–3767	www.gesecurity.com	205 Lowell Street Wilmington, MA 01887
Mistral Security Inc	800–9MISTRAL 301–913–9368	www.mistralgroup.com	7910 Woodmont Ave, Suite 820 Bethesda, MD 20814
Scintrex Trace Corp. (subsidiary of Control Screening)	613–224–1061	www.scintrextrace.com	300 Parkdale Ave. Ottawa, Ontario, Canada K1Y 1G2
Smiths Detection Inc. (formerly Smiths Heimann, Barringer, ETG, Graseby)	703–351–5896	www.smithsdetection.com	1601 N Kent Street #1013 Arlington, VA 22209
Thermo Electron Corporation	203–605–2534	www.thermo.com/security	148 Old Gate Lane Milford CT 06460

Chapter 4. Bulk Explosives Detection Technologies

Introduction to Bulk Detection

Overview

This chapter provides an overview of the second major category of explosives detection called bulk explosives detection technologies (as shown in Figure 14.) Bulk detection systems use a radiation source to interrogate the material in question and detect the response from all materials present. This chapter discusses the following topics:

- ***Imaging technologies***, including single- and dual-energy x-ray, backscatter x-ray, fluoroscopy, and dielectrometry technologies.
- ***Nuclear-based technologies***, including thermal neutron analysis, pulsed fast neutron analysis, and nuclear quadrupole resonance (NQR.)

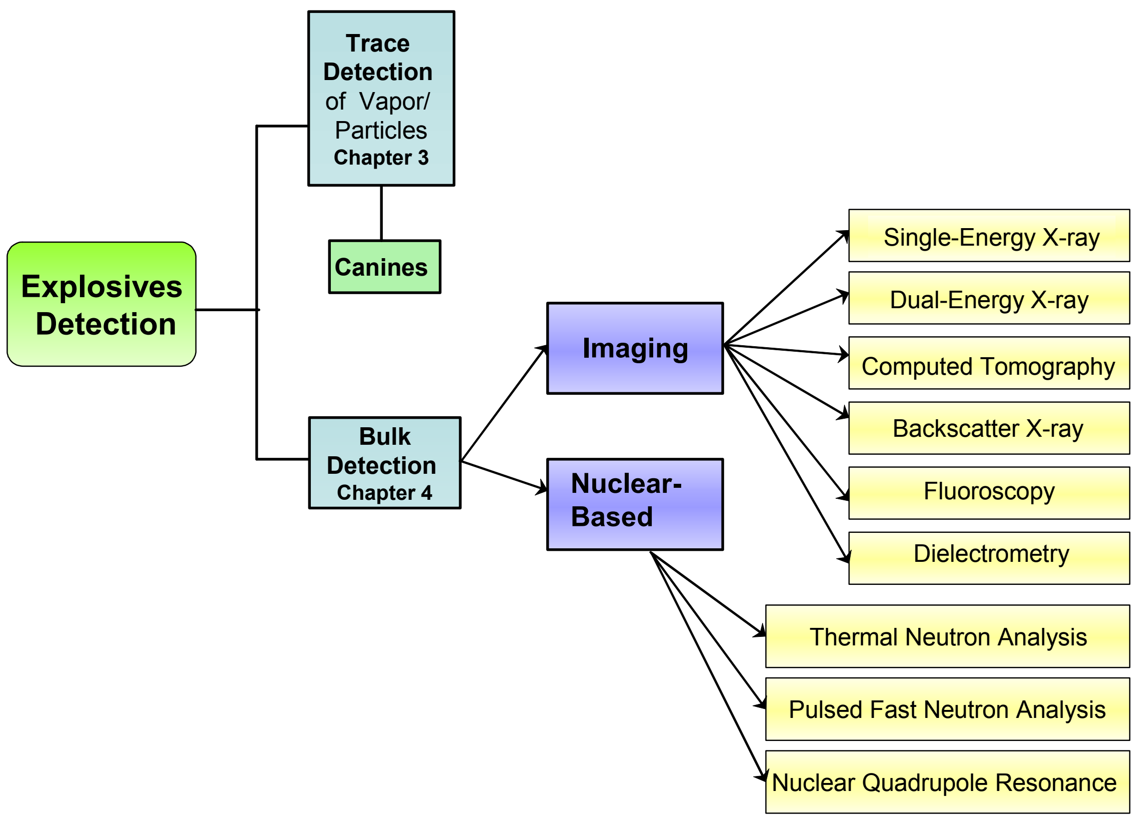


Figure 14. Major Explosives Detection Technologies with Bulk Technology Details

Principles of Bulk Detection

In bulk detection, a visible amount (macroscopic mass) of explosives material is detected, either by imaging techniques or via a technique that probes nuclear properties (e.g., atomic number [Z number]) of the material. The number of protons in an atom's nucleus is defined as the atomic number (Z) of that element. Bulk techniques include:

- Imaging technologies, normally x-ray-based but could also be gamma-ray-based
- Nuclear-based technologies

Bulk explosive techniques measure characteristics of the materials in question in an attempt to detect the possible presence of explosives. Analysis of these parameters can result in calculated mass, density, and Z number of the material in question. While none of these characteristics are unique to explosives, they can indicate a high probability of the presence of explosives. The false alarm rate for bulk detection devices can be low enough in general to allow for automatic detection of explosives-like materials (e.g., in luggage screening.) Alarm resolution is still an important issue when using bulk detection technologies.

Detecting Explosive-like Substances

To positively identify a material uniquely as an explosive, a chemical analysis technology such as mass spectrometry is required. All of the bulk detection technologies have strengths and weaknesses. If enough information is gathered on a suspect material, a determination of the presence of explosives may be made.

Alarm Resolution is Critical

Not all alarms indicate a threat. An explosives detection alarm can occur if the object under inspection contains explosives-like material. Users of bulk explosives detection equipment need to be trained in the proper interpretation of alarms and procedures to follow if alarms occur.

Imaging Technologies

X Rays and Gamma Rays Can Interact with a Material in 3 Ways

Gamma rays and X rays, like microwaves and visible light, are part of the electromagnetic spectrum. X rays are high-energy radiation and are slightly lower in energy than gamma rays. Both gamma rays and X rays pose safety hazards, but they differ in their origin. Gamma rays originate in an atom's nucleus, and are produced by radioactivity. X rays originate outside an atom's nucleus in the area where the electrons reside.

When X rays and gamma rays encounter matter, three outcomes are possible. They may

- pass through the material (transmission),
- be absorbed (absorption), or
- be deflected off of its original course (scattered or backscattered.)

All three of these outcomes occur in distinct proportions determined by the initial x-ray energy and the bulk characteristics (i.e., density, absorption coefficient, backscatter coefficient, and Z number) of the encountered material.

This section of the chapter discusses commercially available imaging technologies. X-ray systems are the predominant imaging technologies and will be discussed in depth. A few gamma ray systems are commercially available and are mentioned under the appropriate x-ray technique heading. Other techniques such as dielectrometry and fluoroscopy will also be discussed.

X-ray Technologies

X-ray Technologies Detect Explosive-like Materials (Low Z Materials)

X-ray-based technologies do not detect explosives; they detect materials that have explosives-like characteristics. High density and low Z number are characteristic for explosives-like materials as compared to other materials and thus can be distinguished.

Bulk x-ray technology detectors are usually enhanced package search scanners. These devices usually serve a dual purpose: the x-ray images are analyzed for guns and other weapons at the same time they are analyzed for the presence of materials that may be explosives.

Types of X-ray Technology

Currently available x-ray technologies include:

- Single energy
- Dual energy
- Computed tomography (CT)
- Backscatter (including a personnel screening technique)
- Fluoroscopy

Single-Energy X-ray Technique

Detects Bomb Parts, Not Explosives Materials

Single-energy x-ray systems are useful for bomb detection (looking for wiring, fusing, and metal parts) and not as useful for the detection of the explosives material itself.

In single-energy x-ray techniques, an x-ray beam of one energy is used and the image indicates the degree of absorption of the X rays. Typically, single-energy techniques do not provide enough information for explosives materials detection, but for certain other applications, this technique may be sufficient.

Cargo and vehicle screening is one important application of single-energy X rays. High-energy X rays and gamma rays are used to achieve penetration of metal parts of vehicles and shipping containers.

Aracor, L3 Communications Security and Detection Systems, Rapiscan Security Products, and Smiths Detection Inc. all manufacture high-energy x-ray systems for vehicle and cargo screening (see Table 4.) Rapiscan Security Products and SAIC manufacture gamma ray systems for vehicle and cargo screening (see Table 4.)

Dual-Energy X-ray Techniques

Principle of Operation of Dual-Energy X-Ray Systems

The two basic types of dual-energy systems utilize:

- a single broad x-ray beam and a dual detector arrangement, or
- low-energy X rays and high-energy X rays to image materials. X-ray data are obtained at both x-ray energies. The two independent images are computer-processed to compare low-energy to high-energy x-ray absorption.

The displayed results characterize and identify the various materials by their shape, and artificial colors are assigned to different Z-numbered materials. The system uses color to separate items in the image into organic (low Z number) and inorganic materials (high Z number.) The resulting image is displayed on a monitor for visual identification (see Figure 15.)

Photo furnished by: L3 Communications, Security and Detection Systems

Figure 15. The left image is of a commercially available dual-energy system and the right image is of a briefcase that has alarmed; the area of concern is marked with a red box.

Advantages of Dual-Energy Systems

The advantages of dual-energy x-ray systems are:

- material discrimination based on shape
- the ability to detect metals and other high Z number materials in addition to explosives
- low cost
  - baggage screening system costs start at $25,000 and automated baggage screening systems cost up to $300,000
  - cargo screening system costs vary greatly depending on x-ray strength and penetration, but systems cost from $60,000 to $900,000

Disadvantages of Dual-Energy X-Ray Systems

The disadvantages of dual-energy x-ray systems are:

- It can be difficult to separate objects from one another in an image, especially when the object does not strongly interact with X rays.
- The dual-energy technique does not determine a material's thickness; therefore, it cannot unambiguously determine the Z number of a material.

Multi-Axis Approach

An approach to help determine a material's thickness is to use multi-axis/dual-energy, which provides two or three images of the package at 90 degrees from each other. While the two or three views do not provide a complete cross-sectional reconstruction, they do provide additional information for the system to allow a better determination of the presence of explosives-like material.

Commercially Available Dual-Energy X-Ray Systems

Automated detection systems based on both dual-energy and dual-energy/multi-axis technology are currently available. Control Screening LLC, L3 Communications Security and Detection Systems, Rapiscan Security Products, and Smiths Detection Inc. currently manufacture instruments that utilize dual-energy x-ray techniques (see Table 4.) Figures 16 through 19 illustrate some of the commercially available equipment from the four manufacturers of dual-energy x-ray systems.

Photo furnished by: Control Screening LCC

Figure 16. Examples of commercially available dual-energy x-ray systems from Control Screening LCC.

Photo furnished by: L3 Communications Security and Detection Systems

Figure 17. Examples of commercially available dual-energy x-ray systems from L3 Communications Security and Detection Systems.

Photos furnished by Rapiscan Security Products

Figure 18. Examples of commercially available dual-energy x-ray systems from Rapiscan Security Products.

Photos furnished by Smiths Detection Inc.

Figure 19. Examples of commercially available dual-energy x-ray systems from Smiths Detection Inc.

Computed Tomography (CT) Technique

Principle of Operation of CT

Computed tomography (CT) is an x-ray technique that produces two-dimensional images of cross-sectional "slices" through an object at many angles and then combines these slices to obtain a three-dimensional image.

Some CT instruments operate by taking images in slices throughout an object. The source and detector both move and rotate around a scan circle in which the object in question is centered. The x-ray beam penetrates the object and is detected on the opposite side. A set of projection data is obtained at a particular angle. The source and detector are then rotated, and a new projection is obtained. Typically, 180 projections are taken at one-degree intervals around the object. Each x-ray measurement is converted into an electrical signal and computer processed. These images have a more coarse spatial resolution than conventional x-ray images. However, CT images do have improved density resolution compared to conventional x-ray images.

Another way CT instruments operate involves selective CT slices in a suspicious area of an object. A standard x-ray image is taken and a density profile of the object in question is generated. CT slices are taken of any suspect areas based on density. Figure 20 (top), a standard x-ray image with density profile, is shown and a suspect density area is boxed. The CT slices are taken in the suspect area about 1 mm apart and shown in Figure 20 (bottom.) Explosives-like materials in CT images are displayed in red. Metallic materials near the explosives-like materials are displayed in green.

Advantages of CT Systems

The advantages of the CT technique include:

- CT produces a true cross-sectional slice and objects that are hidden and obscured are identified.
- X-ray measurements and material absorption coefficients can be obtained directly from the material of interest, even if the surrounding material obscures the object.
- Detects explosives-like materials and discriminates them from most other innocuous, low Z number materials. This ability is possible because CT can accurately determine the material density.

Disadvantages of CT Systems

The disadvantages of CT systems are:

- system complexity
- high cost—automated baggage screening system costs start at more than $500,000
- higher radiation dose per object (current models are not camera-film-safe)
- throughput is lower (slower when detection method is obtaining slices completely through the object in question)

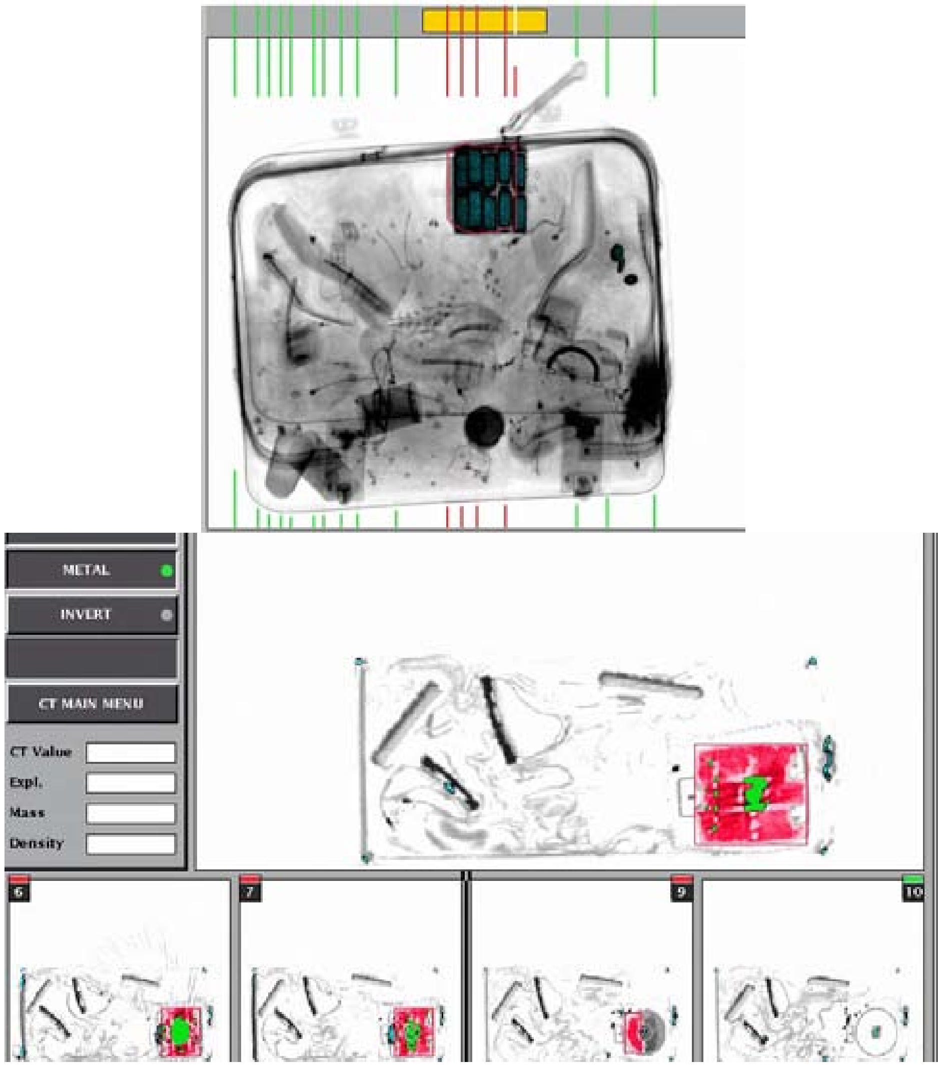


Photo furnished by: InVision Technologies

Figure 20. Standard x-ray image of luggage is on the top displaying a threat object. The CT slices are taken through the suspect area (images are below.) Explosive-like materials are displayed in red and metallic materials near the explosive-like material are displayed in green

Commercially Available CT Systems

CT systems are currently manufactured by InVision Technologies and L3 Communications Security and Detection Systems (Figures 21 and 22.) See Table 4 for commercially available CT systems for bulk explosives detection.

Photo furnished by: InVision Technologies

Figure 21. Commercially available CT system from InVision Technologies.

Photo furnished by: L3 Communications Security and Detection Systems

Figure 22. Commercially available CT system from L3 Communications Security and Detection Systems.

Backscatter X-ray Techniques

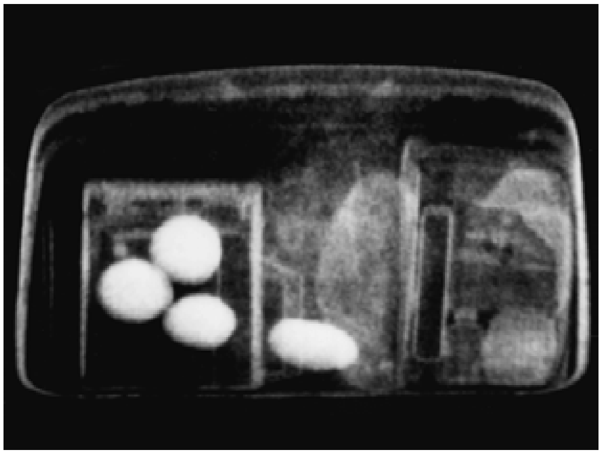
Principle of Operation of Backscatter X-ray Systems

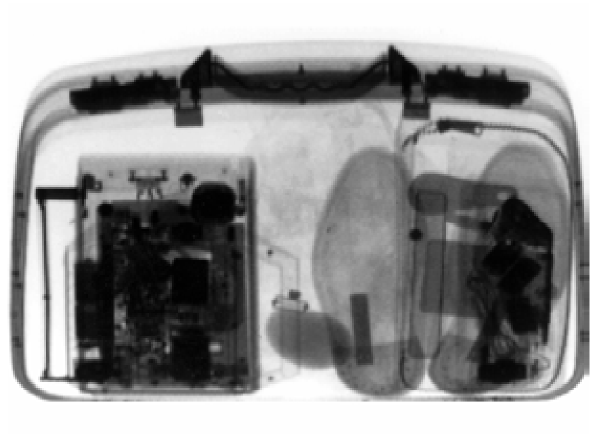
Backscatter X rays occur when the input x-ray radiation interacts with the material in question and results in the scattering of the input radiation. The amount of x-ray scattering exhibited by a material is a characteristic of the material. Low Z number materials are distinguishable from the higher Z number materials by their radiation-scattering characteristics.

Materials with Low Z Numbers Appear Bright in Backscatter X-ray Image

The backscatter x-ray systems provide both a standard transmission x-ray image and a backscatter x-ray image (acquired separately) of the material in question. The standard x-ray image provides the identification of high density materials, which are typically metal objects. The backscatter x-ray image highlights organic materials such as plastic explosives. Comparing the two images provides information about a material's composition.

In Figure 23, the right image is the standard single-energy transmission x-ray image while the left image is the backscatter x-ray image of the same package. A radio that had been identified in the normal x-ray image (right) contains three organic suspect items in the backscatter x-ray image (left.)





Photos furnished by: AS&E

Figure 23. Comparison of images of the same suitcase containing four threat objects from a backscatter system, left, and a conventional single-energy x-ray transmission, right.

Advantages of Backscatter X-ray Systems

The advantages of backscatter x-ray systems are:

- additional information obtained from the standard x-ray image and the backscatter image
- moderate cost; baggage systems cost $55,000 and up

Disadvantages of Backscatter X-ray Systems

The disadvantage of backscatter x-ray technology is that excessively dense materials can hide other objects. Low Z-number objects could remain hidden behind dense materials, and it would be necessary to re-image the package from the other side to complete the search.

Double-Beam Backscatter Imager

A double-beam backscatter model avoids the dense material problem but at a higher cost. These models examine a package from both sides simultaneously, making it less likely that a dense object will obscure a low Z-number item.

Commercially Available Backscatter X-ray Systems

Backscatter x-ray detection systems are commercially available from American Science and Engineering Inc. (AS&E) for bulk explosives detection (Table 4.) Figure 24 shows some commercially available backscatter x-ray systems from AS& E with applications ranging from a search of hand-carried items to a search of large cargo. AS&E also has a cargo screening system that combines backscatter x-ray technology with high-energy x-ray technology.

Some commercially available hand-held gamma backscatter systems detect anomalies. The anomaly detector alarms when differences in density are found within a material such as a vehicle tire. Figure 25 shows a commercially available anomaly detector.

Photos furnished by: AS&E

Figure 24. Commercially available backscatter x-ray systems from American Science and Engineering Inc. (AS&E.)

Photo furnished by: SAS R&D Services

Figure 25. Commercially available gamma backscatter system from SAS R&D Services, Buster K910B.

Low-Dose X-Ray Backscatter Personnel Screening

Principles of Low-Dose X-ray Backscatter Personnel Screening

This technique screens personnel using low-dose x-ray backscatter. Low-energy X rays are used to screen people and find materials hidden on their bodies. The system can image explosives and other contraband hidden under the clothing of persons being scanned (Figure 26.)

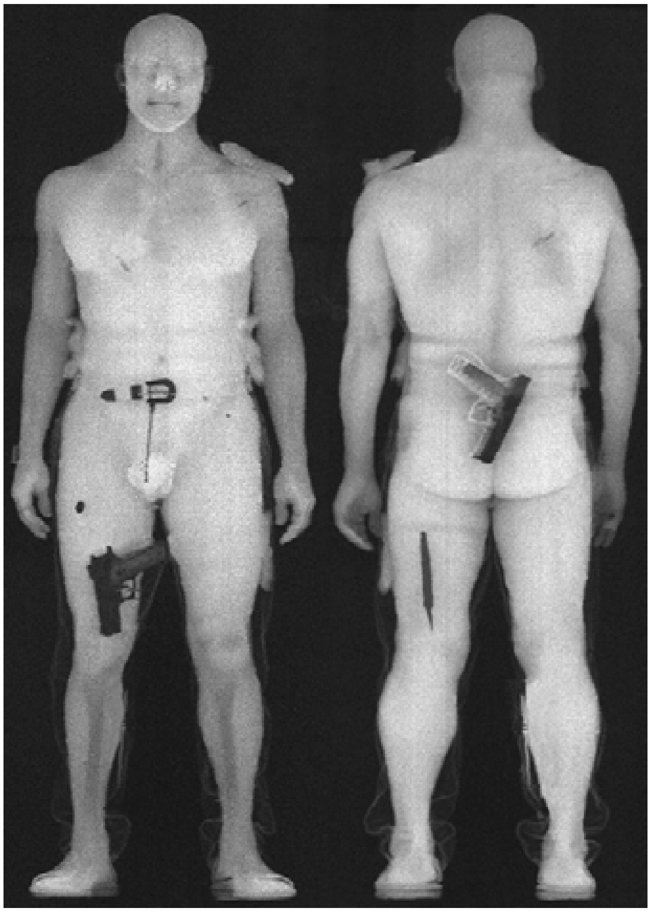


Photo furnished by: AS&E

Figure 26. Low-dose backscatter x-ray image of a fully clothed man displays hidden organic and inorganic materials

Safety and Exposure to X Rays

In any personnel screening system, safety is of prime importance. The radiation dose received while being scanned needs to be so low that it is virtually indistinguishable from exposure from naturally occurring radiation (such as on an airplane flight.) The backscatter x-ray personnel system exposes the subject to a radiation dose that is very low and considered safe, but many people still find any x-ray exposure objectionable. Present scanners can scan only one side at a time. A person would have to be scanned two times, front and back, to ensure that no explosives were located on the person.

Advantages of Low-Dose X-ray Backscatter Personnel Screening

Advantages of low-dose x-ray backscatter personnel screening include:

- Hands-free screening of people, replaces pat-down and strip searches
- The resulting image displays size, shape, and location of the object

Disadvantages of Low-Dose X-ray Backscatter Personnel Screening

Disadvantages of the low-dose x-ray backscatter personnel screening are:

- Invasion of privacy of the screened individual. This factor is important because the human body is imaged and the operator visually inspects the image.
- Radiation safety and the public's dread of any radiation.

Commercially Available Systems Low-Dose X-ray Backscatter Personnel Screening

Detection systems based on x-ray backscatter technology for personnel screening are currently manufactured by AS&E and Rapiscan Security Products (Figure 27 and 28.) See Table 4 for commercially available low-dose backscatter x-ray personnel screening systems for bulk explosives detection. Refer to the IMS section in chapter 3 for personnel screening using trace detection methods.

Photo furnished by: AS&E

Figure 27. Low-dose backscatter x-ray personnel system from American Science and Engineering Inc. (AS&E.)

Photo furnished by Rapiscan Security Products

Figure 28. Low-dose backscatter x-ray personnel system from Rapiscan Security Products.

Fluoroscopy

Principles of Operation of Fluoroscopy Systems

Fluoroscopy is an x-ray imaging technique where transmitted radiation through an object is detected. A monitor can view a dynamic image or still images of the object.

Fluoroscopic equipment is used typically as portable scanners for screening mail and small packages for explosive devices.

Advantages of Fluoroscopy Systems

The advantages of fluoroscopy are:

- Many systems are field-portable units and some are handheld
- Many of these systems can be transported and set up by one person
- Some of the devices can be used real-time (dynamically)
- This technique uses low-energy X rays

Disadvantages of Fluoroscopy Systems

Some disadvantages of fluoroscopy are:

- The device contains an x-ray radiation source.
- The device has a small viewing area.
- The device uses a low-energy x-ray source; therefore, X rays do not penetrate into the object very far.

Commercially Available Fluoroscopy Systems

See Table 4 for commercially available fluoroscopy equipment.

Dielectrometry

Principle of Operation of Dielectrometry Systems

Dielectrometry, another imaging technique, uses a low-energy microwave field to irradiate objects. The dielectric and loss properties of the object are measured in the microwave field. The phase and magnitude of these field lines change depending on the dielectric properties of the object in the field. Dielectric property changes are due to various physical, chemical, or structural properties of the material.

The human body has a unique dielectric response (signature) and is different from any explosives signature. The system compares the dielectric of the object in the microwave field to known values (e.g., human body values) and can distinguish anomalous areas where the dielectric properties are different. The dielectric sensor is an anomaly detector that can detect anything of sufficient volume that is different from the human body or other material in question.

Advantages of Dielectrometry Systems

Some advantages of dielectrometry are:

- ***Views all sides***. This measurement technology requires access to all sides. The portal scans all sides at once by sweeping around the body.
- ***Radiation safety***. Dielectrometry uses low-level microwave energy, a non-ionizing radiation.
- ***Protects the privacy of the screened individual***. The display shows a generic wire-frame human model to display locations of any identified anomalies.

Disadvantages of Dielectrometry Systems

Some disadvantages of dielectrometry are:

- ***Non-specific detector***. It detects anomalies, not explosives.
- ***Moving equipment***. Concerns about the imaging array equipment moving around a person, especially a child.

Commercially Available Dielectrometry Systems

See Table 4 for a commercially available, hand-held dielectrometry system from Emit Technologies LLC.

In autumn 2004, Emit Technologies is scheduled to release a personnel screening portal based on this technology. The system is called the People Portal II. See Table 5 for vendor information on Emit Technologies LLC.

Nuclear-Based Technologies

Nuclear-Based Technologies Can Provide Greater Specificity than Imaging

Nuclear-based technologies interrogate the nucleus of the material under inspection. Some nuclear-based techniques utilize high-energy neutrons as the probing radiation to interact with the material's nuclei which in turn emit characteristic radiation. The emitted radiation can be used to predict the presence of an explosive or explosive-like material with high probability. Another nuclear-based technique probes the nuclei of the material in question with radio frequency pulses and detects quadrupole nuclei (see the Glossary.)

Nuclear-based technologies are much more material-specific for explosives than are imaging technologies and are less subject to operator interpretation of data.

Types of Nuclear-Based Technologies

The following nuclear-based technologies will be discussed in this section: nuclear quadrupole resonance (NQR) and different neutron activation techniques utilizing thermal and fast neutrons. Any technique that is not commercially available will not be discussed.

Nuclear Quadrupole Resonance (NQR)

Principle of Operation of NQR

Nuclear quadrupole resonance (NQR) is an explosives detection method based on nitrogen quadrupole detection. A weak radio frequency (RF) signal is detected from the quadrupole nuclei present in the explosive material. NQR is sometimes referred to simply as quadrupole resonance (QR.)

NQR Operation

When quadrupole nuclei are exposed to a pulsed RF field, they move to a higher energy state. Upon removal of the RF field, the nuclei return to their original lower energy state and the excess energy is released. The released energy is of a characteristic energy, which is dependent upon atom type and crystal structure.

Advantages of NQR Systems

The advantages of NQR include the following:

- No ionizing radiation source is used.
- Highly specific for the identification of explosive compounds. There is little interference from other nitrogen-containing materials that may also be present.
- Very low false alarm rate.
- The probability of detection for a given explosive mass is shape independent for NQR.

Disadvantages of NQR Systems

Disadvantages of NQR include the following:

- Susceptibility to shielding (notably metal shielding.) Metal shielding can make an explosive invisible to NQR; therefore, it is highly recommended that this technique be used in combination with another complementary technique.
- Not all types of explosives can be detected.
- Requires proximity of the object to the RF field source. Thus, the primary application of this technology has been the screening of relatively small items such as mail, small packages, and baggage.

Commercially Available NQR Systems

NQR systems for bulk explosives detection are commercially available from Quantum Magnetics (See Table 4.) Figure 29 shows a commercially available NQR system.

Photo furnished by Quantum Magnetics

Figure 29. Commercially available NQR system from Quantum Magnetics, QR500.

Neutron-Based Techniques

Thermal Neutron Activation

Principle of Operation of Thermal Neutron Activation

Thermal neutron activation (sometimes also called thermal neutron analysis) is an explosives detection method based on the characteristic emission of gamma rays in the object of concern.

Thermal Neutron Activation Operation

Thermal neutron activation is a bulk detection technique in which an item or area to be screened for explosives is exposed to a low-energy stream of neutrons. The thermal neutron interacts with the nucleus of matter under inspection and the neutron is absorbed and results in the emission of a high-energy gamma ray. Nitrogen nuclei have a strong interaction with thermal neutrons unlike carbon and oxygen, which have weaker interactions. The nitrogen nuclei emit gamma rays of a characteristic energy of 10.8 MeV. Detection of any emitted 10.8 MeV gamma rays indicates that the material contains nitrogen. Many explosives are nitrogen-containing compounds; therefore, this technique can be used to identify materials that contain nitrogen, which also have a high probability of being explosives.

Available Neutron Sources

The neutrons used in a thermal neutron activation system are provided by either a radioactive isotope or by an electronic neutron generator. An electronic neutron generator adds cost and experimental complexity to the system, but it has a safety advantage over a radioactive source in that the stream of neutrons can be turned on and off, thus reducing radiation exposure concerns.

Advantages of Thermal Neutron Activation Systems

The advantages of thermal neutron activation are:

- ***Wide variety of applications***. The penetrating nature of both the neutrons and the emitted gamma rays, which readily pass through most common materials (including metal), can be used in a wide variety of explosives detection applications including:
    - vehicle screening,
    - small cargo screening,
    - baggage inspection, and
    - detection of unexploded ordnance.
- ***High accuracy*** and ***low false alarm rate***.

Disadvantages of Thermal Neutron Activation Systems

Some of the disadvantages of thermal neutron activation are:

- Not suitable for personnel screening. Exposure to neutrons can have unacceptable health consequences.
- Not suitable for inspection of large cargo containers due to the technique's use of low-energy neutrons.
- General radiation exposure concerns.

- Thermal neutron analysis does not detect all kinds of explosive materials.
- High cost
  - baggage screening cost is approximately $150,000
  - cargo screening cost is approximately $1,300,000
- Nitrogen-containing, non-explosive materials may set off alarms. For example, a truck containing large amounts of nitrogen-rich fertilizer could produce the same signal as a truck containing an equivalent mass of explosives. However, in practice, very few vehicles contain large amounts of nitrogen-rich materials.

Commercially Available Thermal Neutron Activation Systems

Thermal neutron activation (TNA®) detection systems are commercially available from Ancore Corporation (see Table 4) for bulk explosives detection. Ancore Corporation also manufactures a system that combines thermal neutron activation with fast neutron activation (FNA.) Figure 30 shows some of the commercially available systems from Ancore Corporation.

Vehicle at right in photo below carries a mobile unit; monitor at left is inside the cab for operator viewing.

Photos furnished by Ancore Corporation

Figure 30. Some of the commercially available TNA® systems from Ancore Corporation.

Fast Neutron Activation (FNA)

Principle of Operation of Fast Neutron Activation Systems

Fast neutron activation techniques use fast neutrons (rather than thermal neutrons, which are highly penetrating) to interact with nuclei of interest. The neutrons interact with the nuclei of the various chemical elements in the object, emitting characteristic gamma rays, which acts like an elemental fingerprint.

Fast Neutron Activation Yields Information on Several Elements

Fast neutron activation is a bulk detection technique in which an item or area to be screened for explosives is exposed to a high-energy stream of neutrons. The fast neutron interacts with the nucleus of matter under inspection and the neutron is absorbed and results in the emission of a high-energy gamma ray. Gamma ray emission occurs for carbon, nitrogen and oxygen. The technique is able to determine the type of substance under analysis.

Available Neutron Sources

The neutron source used in a fast neutron activation system is provided by an electronic neutron generator. The electronic neutron generator adds cost and experimental complexity to the system, but it has a safety advantage in that the stream of neutrons can be turned on and off, thus reducing radiation exposure concerns.

Commercially Available Fast Neutron Activation System

Ancore Corporation manufactures a system that combines thermal neutron activation (TNA®) with fast neutron activation. Figure 31 is a monitor display showing an alarm on suspect material in a truck from the combined thermal neutron activation (TNA®) and fast neutron activation system.

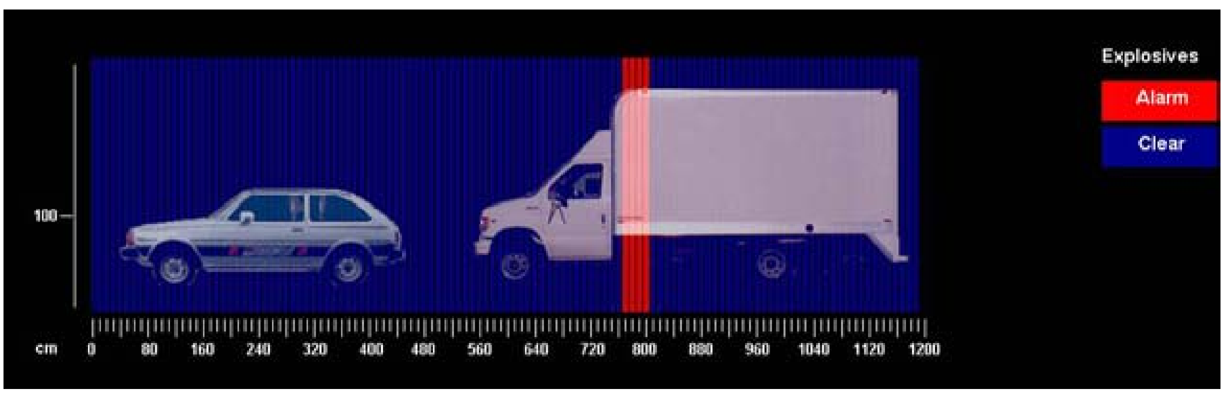


Photo furnished by: Ancore Corporation

Figure 31. A monitor display showing an alarmed vehicle from a VEDS system from Ancore Corporation.

Pulsed Fast Neutron Activation

Principles of Operation of Pulsed Fast Neutron Activation

Pulsed fast neutron activation (also called pulsed fast neutron analysis) is a technique where fast neutrons are pulsed at the nuclei of interest. The characteristic gamma ray emission is collected. Pulsed fast neutron activation yields information on several elements including carbon, hydrogen, nitrogen, and oxygen. Using very short fast neutron pulses (on the order of nanoseconds), the location of the detected material can be determined. Pulsed fast neutron activation is a highly specific technology for the identification of various substances.

Neutron Source

The high-energy neutron source used in a fast pulsed neutron activation system is provided by an electronic neutron generator. An electronic neutron generator adds cost and experimental complexity to the system, but it has a safety advantage over a radioactive source in that the stream of neutrons can be turned on and off, thus reducing radiation exposure concerns.

Advantages of a Pulsed Fast Neutron Activation System

Advantages of pulsed fast neutron activation are:

- Information is gathered on elements besides nitrogen, such as carbon and oxygen, which helps in explosives-like material determination.
- This technique has good neutron penetration and can be used on large cargo containers.
- Three-dimensional location information can be determined in the object of concern.

Disadvantages of a Pulsed Fast Neutron Activation System

Disadvantages of pulsed fast neutron activation systems are:

- System complexity
- High cost
  - A fixed location vehicle system costs over $5,000,000
- Radiation and shielding concerns

Commercially Available Pulsed Fast Neutron Activation System

A pulsed fast neutron activation (PFNA®) system for bulk explosives detection is commercially available from Ancore Corporation (see Table 4.) Figures 32 to 34 illustrate how a PFNA® system locates suspect items. Figure 32 depicts a mock improvised explosives device hidden inside a computer monitor, which is packaged as part of an air cargo container shipment (the photo on the right side.) Figure 33 shows the pulsed fast neutron activation system (PFNA®) scanning the air cargo container. Figure 34 shows the output of the scan, with three suspect areas shown in a three-dimensional image of the air cargo container.

Photos furnished by: Ancore Corporation

Figure 32. At left, a mock explosive device is concealed in a computer monitor. At right, the box containing the mock explosive is placed inside an air cargo container.

Photo furnished by: Ancore Corporation

Figure 33. A PFNA® system scans the air cargo container that contains the mock explosive

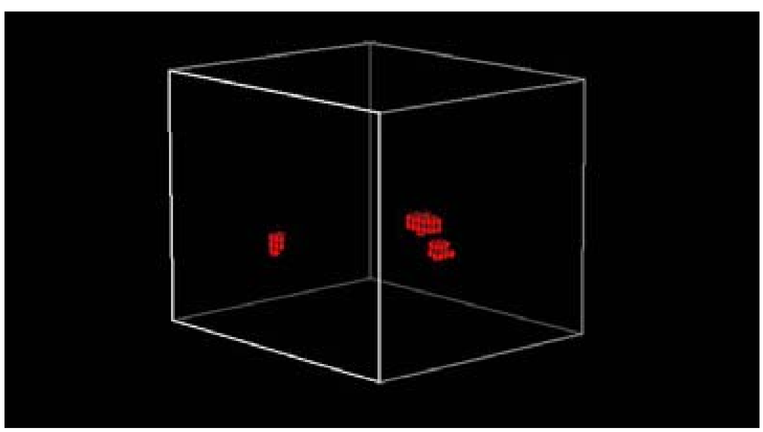


Photo furnished by: Ancore Corporation

Figure 34. The resulting image from the PFNA® scan displays threats in three dimensions.

Pulsed Fast/Thermal Neutron Activation

Principles of Operation

This pulsed neutron-based technique uses both fast neutron and thermal neutrons. Neutrons are pulsed at the nuclei of interest and characteristic gamma ray emission is collected. Pulsed fast/thermal neutron activation yields information on several elements including carbon, hydrogen, nitrogen, and oxygen.

Neutron Source

The neutron source used in a fast/thermal neutron activation system is provided by a pulsed neutron generator. A pulsed neutron generator adds cost and experimental complexity to the system, but it has a safety advantage over a radioactive source in that the stream of neutrons can be turned on and off, thus reducing radiation exposure concerns.

Advantages of Pulsed Fast/Thermal Neutron Activation

Advantages of pulsed fast/thermal neutron activation are:

- Information is gathered on elements besides nitrogen, such as carbon and oxygen, aiding in the determination of explosives-like material.
- Moderate cost—Portable system costs $145,000 and up

Disadvantages Of Pulsed Fast/Thermal Neutron Activation

Disadvantages of pulsed fast/thermal neutron activation systems are:

- system complexity
- radiation and shielding concerns
- no location information is obtained

Commercially Available Pulsed Fast/Thermal Neutron Activation Systems

A portable neutron analysis system for explosives detection is manufactured by SAIC called PELAN that performs pulsed fast/thermal neutron activation (see Table 4.) Figure 35 shows the PELAN inspecting a vehicle.

Figure 35. Commercially available neutron analysis system, the PELAN, from Science Application International Corporation (SAIC.)

Final Thoughts and Vendor Information

Outlook for Next Few Years

The explosives detection techniques discussed in this chapter are expected to remain the principal important techniques for use in law enforcement and other applications for at least the next several years. While new technologies will undoubtedly appear on the scene, there is usually a several-year gap between the development of a new technology and its commercialization for widespread use. New technologies are likely to supplement rather than replace existing technologies. Another likely future trend is to have systems that combine two or more detection technologies into a single system and several are under development.

Applications

Table 4 contains information on systems that are commercially available to inspect mail, small and large parcels, luggage, unknown devices, cargo, personnel, and vehicles of all sizes. Table 5 contains contact information for bulk equipment vendors.

Considerations for Choosing a System

Before choosing a system:

- ***define all requirements for the application***. For example, if personnel screening is the most important requirement, bulk explosives detection systems may be inappropriate because of radiation concerns. The only bulk explosives detection technology that is appropriate for personnel screening is a low-dose x-ray backscatter system. The agency using the system must be able to demonstrate an x-ray radiation dose of sufficiently low magnitude that personnel will receive a dose less than the recommended yearly x-ray dose. A negative public perception of radiation-emitting devices may also be a deciding factor.
- ***work with a knowledgeable company salesperson or applications engineer*** (review chapter 2 on equipment purchase considerations.)
- ***solicit advice or information from a third party*** such as an independent testing laboratory or government agency. TSA has extensively tested several of the x-ray systems and has approved some equipment for special uses (e.g., luggage screening at airports.)

Seek the Most Recent Information

The explosives detection and security sector is evolving rapidly and all information is subject to change. The potential buyer should always check with the manufacturing company to obtain the most up-to-date information, including information on new systems.

Table 4. Commercial Bulk Detection Systems

***Cost Column Key: "Low" is less than $70,000, "Medium" is $70,000 to $300,000, and "High" is more than $300,000**

System	Technology	Use	Company	Cost*
Handheld units (Could apply to all categories, except personnel screening)				
M600	Dielectrometry	Handheld Anomaly Detector	Emit Technologies LLC 206–378–5518	Low
CDS–2002i	Gamma Backscatter	Handheld Anomaly Detector	SAIC 800–962–1632 858–826–9831	Low
Buster K910B	Gamma Backscatter	Handheld Anomaly Detector	SAS R&D Services Inc. 954–432–2345	Low
Mail and Small-Package Searches				
Model 66Zplus	Transmission and Z Backscatter X-ray	Mail, Small Package	American Science and Engineering, Inc. (AS&E) 978–262–8700	Low
SP-EDS	TNA®	Small Packages	Ancore Corporation 408–727–0607	Medium
MAILGUARD	Fluoroscopy	Mail, Small Package	Control Screening LLC 973–276–6161	Low
DynaVision 300,	Dual-Energy X-ray	Mail, Small Package	Control Screening LLC 973–276–6161	Low
AutoClear 4025, 5333	Dual-Energy X-ray	Small and Hand-carried Packages	Control Screening LLC 973–276–6161	Low
LINESCAN Models 110-II, 215, and 222	Dual-Energy X-ray	Hand-carried Packages	L-3 Communications Security & Detection Systems 781–939–3800	Low
PX-M	Dual-Energy X-ray	Small and Hand-carried Packages	L-3 Communications Security & Detection Systems 781–939–3800	Low
QR160	NQR	Hand-carried Packages	Quantum Magnetics 858–605–5500	Medium
Rapiscan 519	Single-Energy X-ray	Packages	Rapiscan Security Products 310–978–1457	Low
Scanmax15 Scanmax20 Scanmax25	Fluoroscopy	Mail, Small Package	Scanna MSC Inc. 941–925–9730	Low
Hi-Scan PS 3010, 5030-S, 6030di, 6040d	Dual-Energy X-ray	Hand-carried Packages	Smiths Detection Inc. 703–351–5896	Low

Table 4. Commercial Bulk Detection Systems, continued

System	Technology	Use	Company	Cost*
Baggage and Medium-Sized Package Searches				
Model 101Z, 101GT	Transmission and Z Backscatter X ray	Large Packages, Baggage	American Science and Engineering, Inc. (AS&E) 978–262–8700	Medium
Model 101ZZ	Transmission and Double-sided Z Backscatter X ray	Large Packages, Baggage	American Science and Engineering, Inc. (AS&E) 978–262–8700	Medium
Model 101ZVAN	Transmission and Double-sided Z Back-scatter X ray	Large Packages, Baggage (mobile)	American Science and Engineering, Inc. (AS&E) 978–262–8700	Medium
DynaVision400A AutoClear 400+, 6040,	Dual-Energy X ray	Hand-carried Packages	Control Screening LLC 973–276–6161	Low
AutoClear 7555, 10080T, 100100T	Dual-Energy X ray	Large Packages, Baggage	Control Screening LLC 973–276–6161	Low
CTX 9000 DSi, 5500 DS, 2500	X ray, Computed Tomography	Packages, Baggage	InVision Technologies, Inc. 510–739–2400	High
VividMVT	Dual-Energy X ray, Multi-axis	Automated Large Packages, Baggage	L-3 Communications Security & Detection Systems 781–939–3800	Medium/ High
VividVDS108 VividVIS108	Dual-Energy X ray	Automated Packages, Baggage	L-3 Communications Security & Detection Systems 781–939–3800	Medium
LINESCAN 107, 112, 208, 231, 237 and 239	Dual-Energy X ray	Large Packages, Baggage	L-3 Communications Security & Detection Systems 781–939–3800	Low
eXaminer 3DX 6000	X ray, Computed Tomography	Packages, Baggage	L-3 Communications Security & Detection Systems 781–939–3800	High
VCT30	Dual-Energy X ray, Computed Tomography	Packages, Baggage	L-3 Communications Security & Detection Systems 781–939–3800	High
QR500	NQR	Baggage	Quantum Magnetics 858–605–5500	Medium
Rapiscan 500 Series 515, 520B, 522B, 524, 526, 527, 528, 532H	Dual-Energy X ray	Packages, Baggage	Rapiscan Security Products 310–978–1457	Low
Rapiscan Mobile 536	Dual-Energy X ray	Packages, Baggage (mobile)	Rapiscan Security Products 310–978–1457	Medium
Rapiscan XRD1000	Dual-Energy, Dual-View and X ray Diffraction	Automated Baggage	Rapiscan Security Products 310–978–1457	Medium

Table 4. Commercial Bulk Detection Systems, continued

System	Technology	Use	Company	Cost*
Rapiscan 3D20	Dual-Energy X ray	Packages, Baggage	Rapiscan Security Products 310–978–1457	Medium
Hi-Scan 6040i, 7555i, 9075	Dual-Energy X ray	Packages, Baggage	Smiths Detection Inc. 703–351–5896	Low
Hi-Scan 100100V, 100100T, 12080	Dual-Energy X ray	Large Box, Packages	Smiths Detection Inc. 703–351–5896	Low
Hi-Scan 8380-3D	Multi-axis Dual-Energy X ray	Packages, Baggage	Smiths Detection Inc. 703–351–5896	Medium
Fixed and Mobile Cargo Searches				
Model 101XL PalletSearch	Transmission and Z Backscatter X ray	Large Packages, Cargo, Palletized Cargo	American Science and Engineering, Inc. (AS&E) 978–262–8700	Medium/ High
Ancore Cargo Inspector (ACI)	PFNA®	Cargo	Ancore Corporation 408–727–0607	High
DynaVision 935, 945	Dual-Energy X ray	Cargo, Palletized Cargo	Control Screening LLC 973–276–6161	Medium
AutoClear Inspection Trailer	Dual-Energy X ray	Cargo, Packages, Baggage (mobile)	Control Screening LLC 973–276–6161	Medium
CX450 series	X ray	Packages, Cargo, Palletized Cargo (mobile)	L-3 Communications Security & Detection Systems 781–939–3800	High
CX-160P	X ray	Palletized Cargo	L-3 Communications Security & Detection Systems 781–939–3800	Medium
Linescan 207 towcart Linescan 231 towcart CX-160V	X ray	Packages, Baggage (mobile)	L-3 Communications Security & Detection Systems 781–939–3800	Medium
MXRT MXRVS	High-energy X ray	Cargo (mobile)	Rapiscan Security Products 310–978–1457	High
Rapiscan 546	Dual-energy X ray, optional dual view	Palletized Cargo	Rapiscan Security Products 310–978–1457	Medium
Rapiscan 2000 series (Fixed and Relocatable)	High-energy X ray	Cargo Containers and Vehicle (mobile)	Rapiscan Security Products 310–978–1457	High
Pallet VACIS	Gamma Ray	Palletized Cargo	SAIC 800–962–1632 or 858–826–9831	Medium
SilhouetteScan Mobile CAB2000	X ray	Screening systems (mobile)	Smiths Detection Inc. 703–351–5896	High
Hi-Scan 145180, 150150, 180180	Dual-Energy X ray	Cargo, Palletized Cargo	Smiths Detection Inc. 703–351–5896	Medium
ScanTrailer ScanVan ScanMobile	Dual-Energy X ray	Cargo (mobile)	Smiths Detection Inc. 703–351–5896	Medium

Table 4. Commercial Bulk Detection Systems, continued

System	Technology	Use	Company	Cost*
Fixed and Mobile Vehicle Searches				
MobileSearch	Transmission and Z Backscatter X ray	Vehicle, Cargo (mobile)	American Science and Engineering, Inc. (AS&E) 978–262–8700	High
Z BackscatterVAN	Z Backscatter X ray	Vehicle, Cargo (mobile)	American Science and Engineering, Inc. (AS&E) 978–262–8700	High
Shaped Energy	High-energy X ray and Z Backscatter X ray	Vehicle, Cargo (mobile)	American Science and Engineering, Inc. (AS&E) 978–262–8700	High
Mobile V-EDS	TNA® and FNA	Vehicle (mobile)	Ancore Corporation 408–727–0607	High
Portal V-EDS	TNA® and FNA	Vehicle	Ancore Corporation 408–727–0607	High
Eagle	High-energy X ray	Vehicle, Cargo (mobile)	Aracor 408–733–7780	High
Cx-2500M	High-energy X ray	Vehicle, Cargo (mobile)	L-3 Communications Security & Detection Systems 781–939–3800	High
Rapiscan 4200 (GaRDS) (Fixed and Relocatable)	Gamma Ray	Vehicle, Cargo (mobile)	Rapiscan Security Products 310–978–1457	High
Rapiscan 4100 series	Gamma Ray	Vehicle	Rapiscan Security Products 310–978–1457	High
Portal VACIS Relocatable VACIS Railroad VACIS	Gamma Ray	Vehicle, Cargo	SAIC 800–962–1632 858–826–9831	High
Mobile VACIS	Gamma Ray	Vehicle (mobile)	SAIC 800–962–1632 858–826–9831	High
HCV-Mobile	High-energy X ray	Vehicle, Cargo (mobile)	Smiths Detection Inc. 703–351–5896	High
HCV-Stationary, AirCargo, Gantry	High-energy X ray	Vehicle, Cargo	Smiths Detection Inc. 703–351–5896	High
Personnel Searches				
BodySearch	Z Backscatter X ray	Personnel	American Science and Engineering, Inc. (AS&E) 978–262–8700	Medium
Secure 1000	Backscatter X ray	Personnel	Rapiscan Security Products 310–978–1457	Medium

Table 4. Commercial Bulk Detection Systems, continued

System	Technology	Use	Company	Cost*
Portable Units (Could apply to all technology categories except personnel searches)				
foXrayII foXray Treker	Portable X ray	Portable Viewing of Suspicious Packages	Delta X-ray 703–820–5204	Low
XR150 XR200	Portable X ray	Portable Viewing of Suspicious Packages	Golden Engineering 765–855–3493	Low
Lixi Imaging scope Lixi Penetrator	Fluoroscopy	Portable Viewing of Suspicious Packages	LIXI Inc. 847–961–6666	Low
Logos Digital Imaging	Portable X ray	Portable Viewing of Suspicious Packages	Logos Imaging LLC 765–939–4044	Low
RTR-4	Portable X ray	Portable Viewing of Suspicious Packages	SAIC 800–962–1632 858–826–9831	Low

Table 5. Vendor List for Commercially Available Bulk Explosives Detection Technologies

Bulk Explosives Detection System Vendors			
Company	**Phone Number**	**Web Address**	**Address**
Ancore Corporation (Rapiscan)	408–727–0607	www.ancore.com	2950 Patrick Henry Drive Santa Clara, CA 95054
Aracor (Rapiscan)	408–733–7780	www.aracor.com	425 Lakeside Dr. Sunnyvale, CA 94085
American Science and Engineering, Inc. (AS&E)	978–262–8700	www.as-e.com	829 Middlesex Turnpike Billerica, MA 01821
Control Screening LLC	973–276–6161	www.controlscreening.com	2 Gardner Rd Fairfield, NJ 07004
Delta Xray	703–820–5204	www.delta-xray.com	2111 Wilson Blvd, Suite 700 Arlington, VA 22201
Emit Technologies LLC	206–378–5518	www.emittech.com	511 Boren Ave. N, 3rd floor Seattle, WA 98109
Golden Engineering Inc.	765–855–3493	www.goldenengineering.com	PO Box 185 Centerville, IN 47330
InVision Technologies	510–739–2400	www.invision-tech.com	7151 Gateway Blvd Newark, CA 94560
L3 Communications Security & Detection Systems	781–939–3800	www.dsxray.com	10 Commerce Way Woburn, MA 01801
LIXI Inc.	847–961–6666	www.lixi.com	11980 Oak Creek Parkway Huntley, IL 60142
Logos Imaging LLC	765–939–4044	www.logosimaging.com	P.O. Box 765 Richmond, IN 47375
Quantum Magnetics (Subsidiary of InVision Technologies)	858–605–5500	www.qm.com	15175 Innovation Dr. San Diego, CA 92128
Rapiscan Security Products	310–978–1457	www.rapiscan.com	3232 W Segundo Blvd Hawthorne, CA 90250
Science Application International Corporation (SAIC)	800–962–1632	www.saic.com/products/security	16701 West Bernardo Drive San Diego, CA 92127
SAS R&D Services	954–432–2345	www.sasrad.com	2714 SW 183rd Ave. Miramar, FL 33029
Scanna MSC Ltd	941–925–9730	www.scanna-msc.com	4370 South Tamiami Trail Suite 160 Sarasota, FL 34231
Smiths Detection Inc. (formerly Smiths Heimann, Barringer, ETG, Graseby)	703–351–5896	www.smithsdetection.com	1601 N Kent Street #1013 Arlington, VA 22209

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Glossary of Explosives-Related Terms

This glossary provides definitions for acronyms and commonly used terms related to explosives and explosives detection technologies and equipment.

alarm: a signal given by an explosives detection system (EDS) that indicates to the operator that a detection of explosive material has been made. For equipment, the alarm might be either audio (e.g., a buzzer sounds) or visual (e.g., a message on a computer screen.)

alarm resolution: the process by which an operator determines if a threat item is present after receiving an alarm.

alarm threshold setting: the signal level above which an EDS is set to alarm. An EDS may make a detection of an amount of explosive below the alarm threshold setting, but it will then be assumed that the signal obtained is either (1) a nuisance alarm or (2) noise.

ammonia dynamites: a class of dynamites in which, during manufacture, a portion of the nitroglycerin is replaced by ammonium nitrate and nitroglycol. These dynamites cost less and are less sensitive to shock and friction than straight dynamites.

ammonia-gelatin dynamites: gelatin dynamites for which, during manufacture, a portion of the nitroglycerin/nitrocellulose gel is replaced by less costly ammonium nitrate.

ammonium nitrate: the explosive compound NH_4NO_3, the main ingredient of ANFO and some water-gel explosives.

analyte: in analytical chemistry, the compound that one is attempting to study, analyze, or identify.

ANFO: a mixture of ammonium nitrate and fuel oil, often used in vehicle bombs.

anomaly: any condition that departs from the expected; abnormality

Astrolite®: a commercially available two-part explosive. One component is a liquid and the other is a solid.

atom: the smallest particle of an element.

atomic number: the total number of protons in the nucleus of an atom, equal to the nuclear charge; represented by the symbol Z.

attenuation coefficient: a measure of how much an incident probe (e.g., electromagnetic radiation) is attenuated as it passes through a given substance.

backscatter x-ray system: any x-ray system that detects objects (including explosives) based on the images produced from reflected X rays.

binary explosive: an explosive material containing two different explosive compounds.

black powder: a low explosive frequently used in mail bombs and pipe bombs; created by mixing potassium nitrate (KNO_3), charcoal, and sulfur.

blasting agent: a chemical composition or mixture, mainly consisting of ammonium nitrate, which will detonate when initiated by high explosive primers or boosters. Blasting agents contain no nitroglycerin and are relatively insensitive to shock and friction.

blasting cap: a device containing a small amount of primary high explosive, used for detonating a main charge of secondary high explosive.

blasting slurries: a blasting agent consisting of nitro-carbo-nitrates (NCN) mixtures with a gel-like consistency.

blast pressure wave: the wave of hot, very high-pressure gases traveling outward from an explosive detonation. The effect of this wave decreases as distance from the point of explosion increases.

bomb: any device containing explosive or incendiary material that is designed to explode or ignite upon receiving the proper external stimulus.

bomb detection: the discovery and identification of bombs. Bomb detection differs from explosives detection in that the detection may or may not be based on the detection of the explosive material in the bomb. The detection may be based on the detection of some other bomb component, such as metal parts that are identified using metal detection.

bombing: an illegal detonation or ignition of an explosive or incendiary device.

bonding agent: a material that is added to a chemical mixture in order to help bind the components together.

boosters: secondary explosives placed between the primary high explosive (blasting cap) and the main explosive charge, with the purpose of amplifying the detonation wave from the primary high explosive.

brisance: the destructive fragmentation effect of a charge on its immediate vicinity.

bulk explosives detection system: any EDS that directly detects a mass of explosive material. This detection is often (but not always) accomplished using x-ray technology, with the explosive material being observed as an object in the x-ray image. A bulk explosives detection system will never detect explosives if only residue is present, in contrast to trace explosives detection, where the explosive material is detected from vapor or particulate.

C-3: a military plastic explosive composed of approximately 80 percent RDX and 20 percent plasticizer. Also known as Composition C-3, it was the predecessor to C-4.

C-4: a military plastic explosive composed primarily (approximately 90 percent) of RDX. Also known as Composition C-4.

canine detection: the detection of explosives, narcotics, or other types of chemical compounds through the use of a dog that is trained to sniff out these substances.

carrier gas (also called a *dopant*): In IMS technology, a gas that is added to the inlet air flow containing the sample. The purpose of the carrier gas is to enhance the ionization process and, in some cases, to make the sample molecules easier to detect via the formation of a chemical adduct (i.e., a species consisting of the sample molecule attached to a carrier gas molecule or fragment.)

cavity charge: *see* shaped charge.

certification: a process through which an EDS is tested and, if it performs successfully, is judged to be suitable for certain applications.

Cf: Californium, a radioactive element that emits neutrons and can be used as a neutron source.

chemical explosion: an explosion caused by the extremely rapid conversion of a solid or liquid explosive into gases having a much greater volume than the original material.

chemiluminescence: a trace detection technique in which explosives are detected via light that is emitted from NO molecules in a chemically excited state. The excited-state NO molecules are formed through deliberately induced decomposition of the nitro (NO_2) groups in the original explosive compound.

combustible: a material capable of igniting or burning.

commercial explosives detection system: any EDS that can be purchased on the open market.

Composition B: a plastic explosive that contains approximately equal amounts of TNT and RDX.

computed tomography: an x-ray technique in which transmission images (“slices”) taken at many different angles throughout an object are combined to produce a three-dimensional image of the object.

conical shaped charge: a cone-shaped explosive charge employed to cut or punch a hole through a target.

contraband: any item or material that is smuggled into an area or facility where it is prohibited. For example, in a prison, contraband might include weapons, explosives, and narcotics.

Cordeau Detonant: a brand name for detonating cord (*see* detonating cord.)

CT: computed tomography.

deflagration: Rapid combustion. A subsonic process by which explosives release their energy through a rapid burning or autocombustion process, which is sustained by the energy release from the material. Low explosives explode via deflagration, and under some circumstances high explosives do also. The terms explosion and deflagration are sometimes used synonymously, with both being in contrast to detonation.

density: the mass of a substance per unit volume, usually expressed in units of grams per cubic centimeter (gr/cm^3.)

Detacord®: a brand name for detonating cord.

Detasheet®: a plastic explosive with a sheet-like structure that contains PETN.

detonating cord: a cord-like synthetic explosive product that contains PETN.

detonating fuse: a detonation initiator.

detonation: Instantaneous combustion. The supersonic process by which a high explosive decomposes and liberates its energy from shock wave compression.

detonation velocity: the speed at which the shock wave travels through an explosive material.

detonator: a device, such as a fuse or blasting cap, used to set off explosives.

dielectric sensor: uses a low-energy microwave field to irradiate objects. The results of the object in the microwave field are compared to known values, looking for anomalies.

dielectrometry: an anomaly detection technique that uses a low-energy microwave field to irradiate objects and measure their dielectric properties. An object's measured dielectric properties are compared to a standard dielectric value for the object in question.

dielectric constant: the ratio of electric flux density produced by an electric field in a given material, compared to the density produced by the same field in a vacuum (also called permittivity.) Also, the term used to describe a material's ability to store charge when used as a capacitor dielectric.

ditching dynamite: a form of straight dynamite widely used in commercial blasting operations, characterized by a high detonation velocity of over 17,000 fps.

DMNB: 2,3 dimethyl 2,3 dinitrobutane, used as a tagging agent or taggant in plastic explosives to make them more easily detectable. Molecular formula = $C_6H_{12}N_2O_4$; molecular weight = 176.02.

DNT: 2,4-dinitrotoluene, a high explosive compound with a high vapor pressure (near one part per million.) Molecular formula = $C_7H_6N_2O_4$; molecular weight = 182.

dopant: *see* carrier gas.

double-beam backscatter x-ray system: a backscatter x-ray system that uses two x-ray sources and two detectors so that both sides of an investigated article can be examined simultaneously.

dual-axis x-ray system: an x-ray system in which the object under investigation is examined with two x-ray beams using two different angles.

dual-energy x-ray system: an x-ray system in which the object under investigation is simultaneously irradiated with x-ray beams of two different energies. This configuration allows a wider range of target materials to be detected than if only one beam of one energy were used.

dynamite: a solid synthetic explosive material, widely used in blasting operations. Dynamite usually contains nitroglycerin as a major explosive component.

ECD: *see* electron capture detector.

eddy current: a current that is induced around a closed conducting loop by the application of an external magnetic field. Eddy currents are the technology employed in many portal metal detectors.

EDS: *see* explosives detection system.

effective atomic number: for a substance made up of more than one element, the apparent atomic number that results if one treats the substance as if it were composed only of a single element. It is closely related to the weighted average of the atomic numbers of the constituent elements.

EGDN: ethylene glycol dinitrate, a high vapor pressure high explosive that is one of the main explosive ingredients in certain types of dynamite. Molecular formula = $C_2H_4N_2O_6$; molecular weight = 152.

electric blasting cap: a blasting cap that is initiated by passing electric current through a bridge wire, thus igniting the primary explosive present in the cap.

electroluminescent image panel: a panel that is capable of converting electric energy into light.

electromagnetic radiation: Radiation that has both electric and magnetic properties. Examples: microwaves, light, infra-red, ultraviolet, X rays, gamma, radio, and television.

electron affinity: the energy involved when an electron is added to a neutral atom to form a negatively charged ion.

electron capture detector: a type of trace explosives detector wherein gas phase explosives molecules capture electrons from an electron-emitting source to form negative ions. The presence of an explosive is then deduced by observing a decrease in the electron current delivered from the emitting source to a detector. Compounds with high electron affinities (such as explosives) are detected.

electronegativity: the tendency of a molecule to attach an electron.

element: a substance composed of atoms having the same number of protons.

explosive: A compound or mixture of compounds that, when subjected to the appropriate stimulus (heat, shock, friction, etc.), undergo extremely rapid chemical changes that create large volumes of highly heated gases and exert pressure upon the surrounding medium. Explosives can release their energy in microseconds.

explosive bombing: the illegal explosion of a device containing high or low explosive material.

explosive mixture: a low explosive material composed of a mixture of a combustible and an oxidizer.

explosives detection system: any device, person, or animal that serves the purpose of detecting explosives. Examples include an ion mobility spectrometer, an x-ray scanner for screening luggage, a trained canine with a handler, and a security guard conducting manual inspections of backpacks and briefcases.

explosive train: a series of explosions arranged specifically to produce a desired outcome.

Expray: a commercially available, aerosol-based field test kit able to detect most explosives. Detection is based on operator interpretation of color changes of a special paper when it is treated with one of three types of aerosol spray.

false alarm: occurs when an EDS registers an alarm even though no explosive material or explosive residue is present. Such alarms may be caused by chemically similar innocuous compounds or by system malfunction. See also nuisance alarm.

false negative: an indication from an EDS that a person or item being screened for explosives is free of explosive material, when in fact the person or item does have/contain explosives.

false positive: an indication from an EDS that a person or item being screened for explosives has/contains explosive material, when in fact the person or item does not have/contain explosive material.

Flex-X: a military name for Detasheet®.

fluorophore: material capable of fluorescence.

fluoroscopic imaging: use of a fluorescent screen to view the contents of an opaque object, with the contents appearing as shadows formed by transmission of X rays through the object.

fps: feet per second, the standard unit for detonation velocities.

fragmentation bomb: a bomb (such as a pipe bomb) where explosive material is placed inside a metal or other solid casing, which breaks into fragments that are hurled at a high velocity when the bomb explodes.

free-running explosives: a group of blasting agents consisting of nitro-carbo-nitrates (NCN) in small pellet or granular form.

fuel oil: a combustible hydrocarbon material.

gamma rays: high-energy electromagnetic radiation emitted by certain atoms when they are properly stimulated. They originate in an atom's nucleus and are a radioactive emission.

gas chromatograph: an instrument that performs gas chromatography.

gas chromatographic column: a narrow, hollow tube (column) found on a gas chromatograph. The column is coated with a chemical substance called the stationary phase. The column's stationary phase interacts more strongly with some materials than with others, thereby affecting the material's speed as it travels through the column. The interaction of the column with the chemical species allows for their separation.

gas chromatography: an analytical technique utilizing a gas chromatograph for the separation of several chemical species.

GC: gas chromatography

gelatin dynamites: a class of dynamites with an explosive base of water-resistant gel, formed by combining nitrocellulose and nitroglycerin.

granulation: the grain size of an explosive powder, such as black powder.

guncotton: *see* nitrocellulose.

handler: the individual who works in a team with a dog that is trained to sniff out explosives or narcotics.

HE: high explosives.

high explosives: explosives that are capable of detonation, such as TNT, RDX, PETN, NG, and EGDN.

high-explosive train: an explosive train involving high explosives.

high-order detonation: complete detonation of an explosive at its highest possible detonation velocity.

HMTD: hexamethylenetriperoxidediamine, a peroxide-based homemade explosive material. Molecular formula $C_6H_{12}O_6N_2$ and the molecular weight =208.0.

HMX: a high explosive, chemically related to RDX. HMX (Her Majesty's Explosive), an eight-membered ring of alternating carbon and nitrogen atoms, with nitro (NO_2) groups attached to the nitrogen. HMX has an extremely low vapor pressure and hence is very difficult to detect using any vapor sniffing technique. The molecular formula = $C_4H_8N_8O_8$ (octahydrotetranitrotetrazine), also called octogen; molecular weight = 296.

hydrazine: the liquid component of the two-part explosive Astrolite. Hydrazine is also used in rocket fuel.

hygroscopic: readily absorbing moisture, as from the atmosphere.

immunochemical: relating to antibody-based techniques applied to trace chemical detection.

improvised explosive device: a homemade device filled with explosive or incendiary material and containing the components necessary to initiate the device.

IMS: *see* ion mobility spectrometer

incendiary device: a device constructed with flammable materials designed to produce a burning effect.

incendiary material: a flammable substance

incendiary thermal effect: the burning effect of an explosion, relatively insignificant compared to the blast pressure effect.

infrared radiation: electromagnetic radiation that is less energetic than visible light and more energetic than microwaves.

inorganic: any compound that is not organic.

instantaneous combustion: a colloquial term for detonation. Detonation is not truly instantaneous, but occurs in a matter of microseconds.

interference, interferent: any chemical compound that masks the presence of an explosive from a given explosives detection system.

ion mobility spectrometer (IMS): a trace chemical detector that detects explosives and other chemical compounds using ion mobility spectrometry.

ion mobility spectrometry: a technique for the trace detection of explosives and other chemical compounds. Compounds are ionized and identified based on the time required for the ions to travel through a region with an applied electric field.

jet: the extremely hot, swiftly moving bundle of gases and concentrated power resulting from a directionally directed explosion.

Jet-Axe: a commercially available linear shaped charge used to cut through doors, roofs, and walls to obtain access into a building.

Kine-Pak®: a commercially available two-part explosive that has excellent shock resistance even after mixture of the two components.

kV: kilovolts, a unit of energy.

kVp: kilovolts potential; x-ray source voltage descriptor.

lead azide: a primary high explosive compound, $Pb(N_3)_2$.

lead styphnate: a primary high explosive, often used in blasting caps; molecular formula = $C_6H_3N_3O_9Pb$.

linear shaped charge: a type of shaped charge used to cut or slice a target.

lower limit of detection (LLOD): the smallest amount of explosive of a particular type that a given EDS can detect. LLOD is usually expressed in mass units, such as 10 grams, 5 micrograms, etc.

low explosives: explosives that do not detonate, but rather explode via the process of deflagration.

low-explosive train: an explosive train employing only low explosives.

low-order detonation: incomplete detonation of an explosive, or detonation at less than maximum detonation velocity.

magnetic moment: a property of the nucleus of atoms that have a non-zero nuclear spin. These atoms are affected by the application of an external magnetic field and can give rise to a nuclear magnetic resonance (NMR) spectrum.

mail bomb: any bomb that is sent through the postal service in a letter or package. A mail bomb is usually designed to detonate when the letter or package is opened.

mass spectrometer: an instrument that performs mass spectrometry.

mass spectrometry: a chemical analysis technique in which the molecules to be studied are ionized, separated, and then identified based on their charge-to-mass ratio. Mass spectrometry is performed under conditions of high vacuum, in contrast to IMS, which is performed at atmospheric pressure.

mechanical explosion: an explosion caused by the buildup of excessive pressure inside a solid container, the pressure buildup resulting from the application of heat and hence vaporization of a material inside the container.

mercury fulminate: a primary high explosive compound, $Hg(OCN)_2$.

metal detection: the detection of metals and other conducting materials, usually based on the detection of eddy currents in an applied magnetic field.

microgram: one millionth of one gram, usually written as μg.

microrem: a unit of radiation dosage, equal to one millionth of a rem.

microsecond: one millionth of one second, usually written as μsec.

microwaves: electromagnetic radiation that is less energetic than infrared radiation but more energetic than radio waves.

military dynamite: an explosive (not a true dynamite) used in military construction and demolition work, composed of 75 percent RDX, 15 percent TNT, 5 percent motor oil, and 5 percent cornstarch.

military explosives: explosives manufactured primarily for military applications. Examples include TNT, tetrytol, and C-4.

milking: a dangerous process for extracting nitroglycerin from dynamite.

milligram: one thousandth of one gram, usually written as mg.

millimeter waves: electromagnetic radiation (microwaves) having a wavelength on the order of a few millimeters.

mine detection: the detection of land or sea mines that are buried or submerged. The detection may be made using metal detection, explosives detection, or some other detection technique.

nanogram: one billionth of one gram, usually written as ng.

NCN: nitro-carbo-nitrates.

negative pressure phase: the time period following an explosion and after the passing of the outward-going blast pressure wave, during which the pressure at a given point is below atmospheric pressure and air is sucked back into the area. Also called the suction phase, it is less powerful than the positive pressure phase, but of longer duration.

nerve agents: chemical agents that attack the nervous system.

neutron: an elementary particle; along with protons and electrons, one of the three particles that make up atoms. In thermal neutron activation, neutrons are used as a probe to look for explosives. Neutrons have no electrostatic charge.

NG: nitroglycerin.

nitro-carbo-nitrates: a type of blasting agent composed primarily of ammonium nitrate and oil.

nitrocellulose: a cotton-like polymer treated with sulfuric and nitric acids; used in the manufacture of certain explosives.

nitroglycerin, nitroglycerine: a high vapor pressure (vapor pressure approximately one part per million), high explosive compound that is the explosive ingredient in certain types of dynamite. Molecular formula = $C_3H_5N_3O_9$; molecular weight = 227.

NMR: nuclear magnetic resonance.

nonelectric blasting cap: a blasting cap in which the primary explosive material is set off using a flame.

nuclear-based detection system: any bulk explosives detection system based on the properties of the nuclei of the individual atoms within the explosives material, including thermal neutron activation, pulsed fast neutron activation (PFNA), nuclear magnetic resonance (NMR), and quadrupole resonance (QR) systems.

nuclear magnetic resonance: a bulk explosives detection technique based on the magnetic properties of the hydrogen atoms within the explosive being detected.

nuclear quadrupole resonance: induces nuclei of specific atoms to store RF energy for a short time and then rebroadcast the RF energy to a detector.

nucleus (nuclei, plural form): the positively charged center of an atom.

neutron: a subatomic particle that has no charge

nuisance alarm: Nuisance alarms result when the explosives detection system (either bulk or trace) issue an alarm for an item, although the item may not actually be a bomb or incendiary device. In bulk explosives detection, the size, density, shape, or other characteristics of an innocuous item may be so similar to the characteristics of explosives material that the system issues an alarm. In trace detection, a nuisance alarm may be caused by the detection of nitroglycerin (NG) carried by a heart patient. Nuisance alarms require alarm resolution.

organic compound: any compound that contains carbon.

oxidizer: any substance that chemically reacts with another substance to increase its oxygen content.

particulate: contamination in the form of residual particles attached to clothing, furniture, luggage, skin, or some other surface.

particulate detection: The acquisition and analysis of microscopic solid explosives material (such as the dust from TNT.) The sample is collected by contacting the surface of the suspect item with a swab, swipe, or wand to pick up the particles.

parts per (billion, million, or trillion): a quantitative measure. When used in reference to explosives vapor pressures, one part per billion means that under equilibrium conditions, the air above the explosive material will contain one molecule of explosive vapor for every billion molecules of air. *parts per million* is a thousand times more concentrated than parts per billion. Thus one part per million of explosives vapor in air means one molecule of explosive vapor is present for every million molecules of the air. *parts per trillion*: a measure of explosives vapor concentration analogous to parts per billion, but a factor of one thousand less concentrated. Thus, one part per trillion of explosives vapor in air means one molecule of explosive vapor is present for every trillion molecules of air.

Pentolite: a commonly employed booster explosive composed of 50 percent TNT and 50 percent PETN.

percussion primer: a primer that converts mechanical energy into a flame, such as the primer that is set off by the firing pin in a gun.

PETN: pentaerythritol tetranitrate, a common high explosive that is used in plastic explosives such as Detasheet® and Semtex, and has a low vapor pressure (a few parts per trillion at room temperature and atmospheric pressure.) Molecular formula = $C_5H_8N_4O_{12}$; molecular weight = 316.

PFNA: pulsed fast neutron analysis.

phosphor: any substance that can be stimulated to emit light by incident radiation.

photon: a discrete quantity of radiation.

picogram: one trillionth of one gram, usually written as pg.

PINS: portable isotopic neutron spectroscopy.

pipe bomb: a homemade bomb in which explosive material is packed into a section of pipe, usually metal. The pipe is designed to shatter upon detonation, thereby propelling fragments to inflict injury to people and damage to property.

pixel: the smallest resolvable spot on a computer or television screen.

plastic explosives: high-explosive materials that have the general consistency of plastic. They are usually composed of RDX and/or PETN, along with a small amount of oil or plasticizing agent. Examples include C-4, Detasheet®, and Semtex.

portable isotopic neutron spectroscopy: a portable explosives detection system based on the emission of gamma rays when a material is bombarded with neutrons from a Cf source.

portal: a walk-through, drive-up, or booth-like structure that screens personnel or vehicles for contraband. Examples include the metal detection portals currently deployed in airports and various explosives detection portals for personnel or vehicles.

positive pressure phase: the brief time after a detonation in which the local pressure is much greater than atmospheric pressure due to the outward moving blast pressure wave.

post-blast analysis: analysis of the site of an explosion to attempt to identify the type of explosive and methodology that were used.

potassium chlorate: an explosive compound, $KClO_3$.

potassium nitrate: a crystalline compound, KNO_3, used in the manufacture of explosives, pyrotechnics, and propellants.

preconcentrator: a mechanical device designed to collect a dilute trace chemical sample and concentrate it prior to delivery to a detector.

prill: the loose powder form of an explosive (as opposed to gel form) or a pellet of the compressed powder. The ready-made ANFO explosive is also marketed under the name "Prills".

Primacord®: a brand name for detonating cord.

primary explosives: high explosive compounds or mixtures that, when present in small quantities, can convert the process of deflagration into detonation. Primary explosives are used to induce detonation of a secondary explosive.

primer: a cap or tube containing a small amount of primary explosive and used to detonate a secondary main charge.

Primex®: a brand name for detonating cord.

probability of detection, or P_d: The probability that a given EDS can detect a certain amount of a given type of explosive under a particular set of conditions. If a positive detection is always made under these conditions, the probability of detection would be 100 percent. If a detection is made only half the time, the probability of detection would be 50 percent. In general, a large number of experimental trials need to be conducted to accurately determine this probability.

propellants: explosive compounds or mixtures used for propelling projectiles or rockets.

pulsed fast neutron analysis: a nuclear-based screening technique that measures the elemental composition of the object being scanned through neutron interaction with elemental constituents of the object, resulting in characteristic gamma rays.

Pyrodex®: a low explosive material used as a filler in some improvised devices. Developed by Hodgdon Powder Company, this propellant is available in powder or pellet form. Pyrodex® has 30 percent more power than common black powder.

pyrotechnics: mixtures of fuel and oxidizer powders; used to produce light (e.g., fireworks), sound, heat, or smoke.

Q: quality factor, electronics-related term defining the selectivity of a resonant circuit.

QR: *see* quadrupole resonance.

quadrupole nuclei: nuclei that have a non-spherical charge distribution and have a nuclear spin (I) greater than or equal to 1. Nitrogen quadrupole nuclei are the most frequently exploited for explosives detection.

quadrupole resonance: a bulk explosives detection technique in which the material under investigation is probed using RF radiation. This action results in excitation of the nuclei of nitrogen atoms, which emit photons of a characteristic frequency when they relax. The resulting signal is specific for a certain type of nitrogen-containing compound.

radioactivity: a property of some elements where spontaneous emission of electromagnetic radiation occurs by the disintegration of the nuclei of atoms.

radiation: energy emitted in the form of waves (light) or particles (photons.)

random screening: performing explosives detection screening on randomly chosen people or items entering a facility or area. Random screening is used to speed throughput while still providing some checks against the illicit transport of explosives into a given area. For example, a security checkpoint might screen every fourth person entering a secure facility. Random screening is less time-consuming than uniform screening.

RDX: a high explosive, cyclotrimethylenetrinitramine, also known as cyclonite. The abbreviation RDX stands for “research and development explosive”. RDX is the main ingredient of C-4 and is also used in Semtex. It has a low vapor pressure (low parts per trillion at room temperature and atmospheric pressure.) It consists of a six-membered ring of alternating carbon and nitrogen atoms, with nitro (NO_2) groups attached to the nitrogen atoms. Molecular formula = $C_3H_6N_6O_6$ (also known as hexogen); molecular weight = 222.

RF: radio frequency.

safety fuse: a flame-producing source used in some non-electric blasting caps.

saltpeter: *see* potassium nitrate.

SAW: surface acoustic wave

secondary explosives: high explosive compounds or mixtures that are generally initiated to detonation by intense shock. Secondary explosives are generally less sensitive than primary explosives but pack more explosive power.

secondary high explosive boosters: explosives that provide the detonation link in an explosive train between the very sensitive primary high explosives and the comparatively insensitive main charge high explosives.

secure area, secure facility: any area or facility where access is restricted by appropriate entry controls. Entry normally involves some form of identity verification and may also include contraband screening.

security checkpoint: any checkpoint at an entrance to a secure area that administers some sort of entry control and may also involve screening for contraband, including explosives.

Semtex: a type of plastic explosive, normally containing both RDX and PETN.

shaped charge: specially shaped explosive charges that are used to cut or punch holes in solid materials such as steel and concrete.

shielding: container used to hide the presence of explosives or special nuclear material.

shock wave: a sharp discontinuous pressure disturbance traveling faster than the speed of sound. A shock wave is created when a high explosive detonates.

shrapnel: precut or preformed objects (e.g., metal fragments, nails) placed in or attached to a bomb. When the bomb explodes, these objects are hurled at high velocity, with much potential damage to people and property.

single-energy transmission x-ray scanner: an x-ray scanner using only a single x-ray beam, in which the portion of the beam that penetrates the object under investigation is detected and used to produce the x-ray image.

smokeless powder: an explosive material (double-base propellant) in powder form, often containing nitroglycerin (typically 40 percent by weight) as the explosive ingredient.

sodium chlorate: an explosive compound, $NaClO_3$.

sodium nitrate: a chemical compound, $NaNO_3$, that is sometimes added to dynamite to increase the oxygen content and hence improve combustion.

specificity: the ability of a chemical analysis technique to distinguish similar chemicals from one another. The greater the specificity, the more certain the identification of a particular compound can be.

straight dynamites: a class of dynamites containing nitroglycerin as the explosive base.

surface acoustic wave: a detection method for explosives materials based on frequency changes that occur when materials are deposited on the SAW crystal surface (detector surface.) The SAW frequency shift can be correlated to the explosive material concentration. The frequency shift is dependent upon the properties (mass and the elastic constants) of the material being deposited, the temperature of the SAW crystal, and the chemical nature of the crystal surface.

tandem mass spectrometry: a technique of chemical analysis, also referred to as mass spec/mass spec, or simply MS/MS. Essentially, it involves sending analyte molecules through two mass spectrometers consecutively, in order to increase the specificity of the system.

TATP: triacetonetriperoxide, a peroxide-based, homemade explosive material that has a high vapor pressure and is very sensitive to impact. Molecular formula = $C_9H_{18}O_6$; molecular weight = 222.23.

tetramino nitrate: a highly sensitive primary high explosive, which can be formed from the reaction of ammonium nitrate with brass or bronze tools.

tetryl: a high explosive compound, similar in structure to TNT. Molecular formula = $C_7H_5N_5O_8$; molecular weight = 287.

tetrytol: a military explosive composed of approximately 75 percent tetryl and 25 percent TNT.

thermal neutron: a neutron having an energy that is typical of neutrons at room temperature.

thermal neutron activation: a bulk explosives detection technique, in which explosives are detected by the emission of characteristic radiation (gamma rays) that occurs when the explosive material is irradiated with thermal energy neutrons.

thermo-redox: an electrochemical detection technique based on the thermal decomposition of explosive molecules and the subsequent reduction of NO_2 groups.

threat: the event or occurrence that a protective measure is intended to guard against.

threat consequence: the results of a particular threat event occurring, including death or injury to personnel, and damage to property.

threat item: the item that an EDS is designed to detect, i.e., a bomb or contraband explosives material.

threat probability: the likelihood of a particular threat event actually occurring, on a scale of 0 percent (no probability of occurring) to 100 percent (complete certainty that the event will occur.)

throughput rate: the rate at which an EDS can process the people or objects being screened, generally expressed in units such as people per hour for a personnel portal, or bags per hour for an x-ray baggage scanner.

TNA®: Ancore has trademarked the acronym for thermal neutron activation, a technology used in several of its bulk explosives detection products.

TNT: 2,4,6–trinitrotoluene, a common high explosive with a moderate vapor pressure (near one part per billion at room temperature and atmospheric pressure.) Molecular formula = $C_7H_5N_3O_6$; molecular weight = 227.

Tovex: a trade name for certain water-gel-based explosives

trace explosives detection system: any EDS that detects microscopic quantities of explosive materials by collecting and identifying trace (vapor or particulate) residue from the material. In contrast to a bulk detection system, a trace detection system can detect residue in the form of vapor or particulate, and can indicate the presence of a bomb as well.

two-part explosives: explosives that consist of two separate components, which are sold as a unit in separate containers and need to be mixed together prior to detonation.

ultraviolet (UV) fluorescence: a technique where trace amounts of explosives materials fluoresce when UV light illuminates the material.

ultraviolet light: electromagnetic radiation that is less energetic than X rays but more energetic than visible light.

uniform screening: applying the same explosives detection process to ***all*** persons or items passing through a given security checkpoint. *See also* random screening.

vapor: Gas-phase molecules that are emitted from a solid or liquid explosive. The concentration of explosives in the air is related to the vapor pressure of the explosives material and to other factors such as the amount of time the explosives material is present in a location, the temperature, its packaging, air circulation in the location, etc.

vapor detection: The acquisition and analysis of air-borne, gas-phase explosives material. The sample is collected without contacting the surface of the sampled item.

vapor generator: any device designed to produce calibrated amounts of vapor of a particular compound.

vapor pressure: the quantity of vapor (usually expressed in terms of a concentration) of an explosive compound that exists above the compound in air at equilibrium under a specified set of conditions.

voxel: small volume element

water-gel explosives: explosive mixtures (slurries) consisting of saturated aqueous solutions of ammonium nitrates and other nitrates.

wavelength: a property of electromagnetic radiation that is inversely proportional to its energy.

working lifetime: the time period during which a given EDS is useful. For an IMS, a typical working lifetime might be on the order of 10 years.

x-ray absorption coefficient: the fraction of incident X rays that is absorbed by a given material.

x-ray backscatter coefficient: the fraction of incident X rays that is backscattered (i.e., reflected) by a given material.

X rays: high-energy electromagnetic radiation with wavelengths in the approximate range of 0.05 to 100 angstroms (one angstrom = 100 billionths of one centimeter.) X rays originate outside of an atom's nucleus in the area where the electrons reside and are less energetic than gamma rays.

x-ray transmission coefficient: the fraction of incident X rays that pass through a given material.

Z: symbol for atomic number (*see* atomic number.)

References

All information directly related to vendors and their products were obtained from the vendors and verified by the vendors for accuracy. For web site references, refer to the tables at the end of chapters 3 and 5.

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