Homeland Security

Summary

SAVER

The U.S. Department of Homeland Security, Preparedness Directorate, Office of Grants and Training (G&T) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders in performing their duties. The mission of the SAVER Program is to

- Provide impartial, practitioner relevant, and operationally oriented assessments and validations of emergency responder equipment.
- Provide information that enables decision-makers and responders to better select, procure, use, and maintain emergency responder equipment.
- Assess and validate the performance of products within a system, as well as systems within systems.
- Provide information and feedback to the user community through a well-maintained, Web-based database.

The SAVER Program established and is supported by a network of technical agents who perform the actual assessment and validation activities. Further, SAVER focuses primarily on two main questions for the emergency responder community, "What equipment is available?" and "How does it perform?"

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IMS-based Trace Explosives Detectors for First Responders

The National Institute of Standards and Technology has published a report that establishes minimum performance requirements and an associated test method for Ion Mobility Spectrometry (IMS) based trace explosives detectors for use by the emergency responder community. In the report, information concerning the theory and operation of IMS trace detectors is presented to enhance the understanding of the performance requirements, and to aid emergency responders in the selection of equipment that best suits their specific needs. A test method is provided in the report that addresses the basic performance criteria of desktop IMS trace detectors. The basic performance criteria are the minimum requirements that a detector must meet to qualify as an IMS trace explosives detector. The basic performance criteria may not be sufficient for all applications, and therefore a more complete set of criteria is also provided.

This summary is a brief excerpt of what is found in the IMS-based Trace Explosives Detectors for First Responders report. The report should be reviewed for the full discussion and recommendations. The complete report can be found on the SAVER Web site.

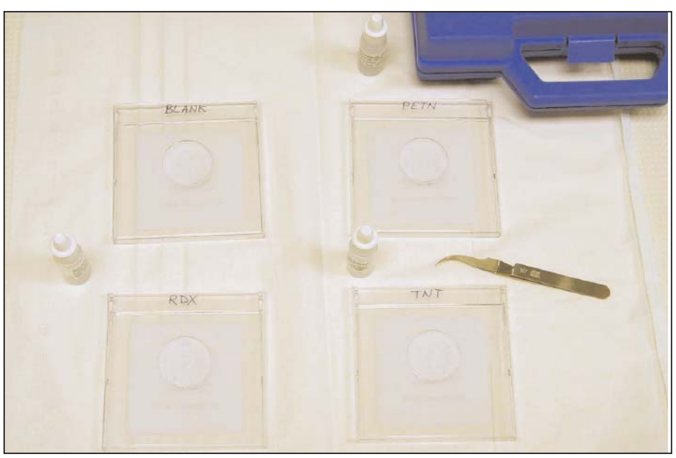
Test Method Kit.

IMS Trace Detection

The premise of IMS trace detection is that anyone handling explosives (or narcotics) will leave microscopic, invisible traces on anything they touch. These fingerprint residues will be present on personal items such as clothing and hair, and on objects such as luggage handles, laptop computers, door handles, steering wheels, etc. Such fingerprint residues commonly contain enough explosives (or narcotics) to be detected by IMS instruments as long as the material can be effectively sampled.

Examples of IMS Usage

One of the most extensive uses of IMS trace explosives detection is for screening passengers and items at U.S. airports, conducted under the auspices of the Transportation Security Administration (TSA). The TSA has deployed thousands of IMS desktop instruments at security checkpoints, and has a general list of performance requirements. In particular, the TSA requires a high throughput rate because of the need to screen large numbers of people/samples, and so has a fairly low tolerance for false positive alarms. The U.S. military uses IMS trace explosives detectors to screen people, mail, vehicles, and other items at points of entry; their performance requirements include high sensitivity to the common explosives, particularly under field conditions and for realistic test samples. IMS detectors are used at entry points to government facilities to test vehicles and people for trace explosives. The U.S. Coast Guard uses IMS trace detection to screen cargo on ships, primarily for narcotics detection but also for explosives detection. Corrections facilities use IMS trace detection, again primarily for narcotics detection. Some state police agencies use IMS detectors to detect narcotics, explosives, and chemical warfare agents.



Workspace preparation for use of IMS test method kit.

Generalized IMS Usages

Some general categories of usage of IMS trace detection can be defined based on the information above. One category is a general screening usage, such as that employed by the TSA, where the detector location is relatively fixed and people or objects are sampled as they pass by the screening station. Screening implies sampling a general population of people and/or objects for which the expectation of an actual occurrence of explosives is low. Screening applications are used for high-security events and at venues such as courthouses, sports arenas, public monuments, government facilities, etc. In general, the critical operational requirements include high throughput and continuous operation.

A second category of usage, like that employed by the U.S. Coast Guard, requires moving the detector to the area that must be sampled, such as onboard a ship. The requirements for a mobile usage of this type will probably include portability and ruggedness. IMS trace detection could be used for mobile applications in some of the ways that trained canines are used today. During routine traffic stops, a mobile IMS detector in the officer's vehicle could be used to detect explosives (or narcotics) on a driver's license or the suspect's car. Mobile IMS instruments could be used to check critical infrastructure such as bridges and tunnels by swiping likely surfaces during a sweep of the area. The domiciles or vehicles of suspected terrorists could be sampled to look for explosives and gain evidence for further action.

Advantages and Limitations of IMS

IMS instruments are widely used for trace explosives detection, and compared with other types of analytical instruments are fast, relatively inexpensive, and can be used in a wide variety of environments with relative ease by people with minimal training. IMS instruments are generally easy to install, can be relatively mobile, and can have very high duty cycles. IMS instruments are widely deployed by various federal agencies, and the Transportation Security Administration (TSA), in particular, is working with the manufacturers towards improving the accuracy and reliability of the instruments.

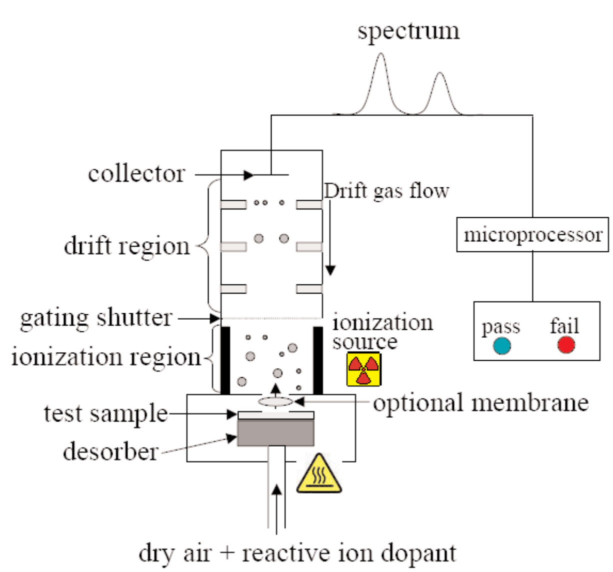
The primary limitation of IMS for trace detection of explosives is that vapor collection is generally ineffective due to the low volatility of many explosives, and although operating in a sniffer mode would be best in many situations, it is not realistic. IMS instruments for explosives detection are best used in particle sampling mode. In addition, IMS is not as definitive for identification of explosive compounds when compared with other types of analytical instruments, and there are innocuous materials that can be falsely identified as explosives. Although IMS instruments for trace detection are relatively inexpensive, there are consumable costs that may become considerable if the units are operated continuously and/or in humid environments. Rigorous adherence to the recommended maintenance procedures is necessary to maintain performance, and our experience shows this may involve considerable attention and time, although not more than is expected in general for analytical instruments.

IMS Instrument Categories

IMS detectors fall into three general categories based on physical configuration: 1) walk-through portals, 2) desktop units, and 3) handheld units. In addition to differences in size, these three different configurations have their own sample collection procedures. Walk-through portals are designed to dislodge particles of explosives from the body or clothing as people pass through. Desktop units require a cloth or paper of some type that is swiped over a surface to collect any particles of explosive. Handheld units are designed to collect vapors directly from the air, but may also accommodate a desktop-like swipe collection. At the current time, desktop units are the most prevalent category of IMS instruments used as trace explosives detectors. Portal units are still primarily in the evaluation stage, and handheld units that rely on direct vapor sampling are limited in the number of different explosives that can be detected.

IMS Identification of Explosives

All IMS instruments must have a library (spectral database) of peaks that serve to identify the explosives that the instrument is capable of analyzing. A chemical compound will generally produce multiple peaks, representing different molecular clusters with the reactant ions, and typically the IMS software uses the peak with the largest intensity for identification. Some IMS instruments

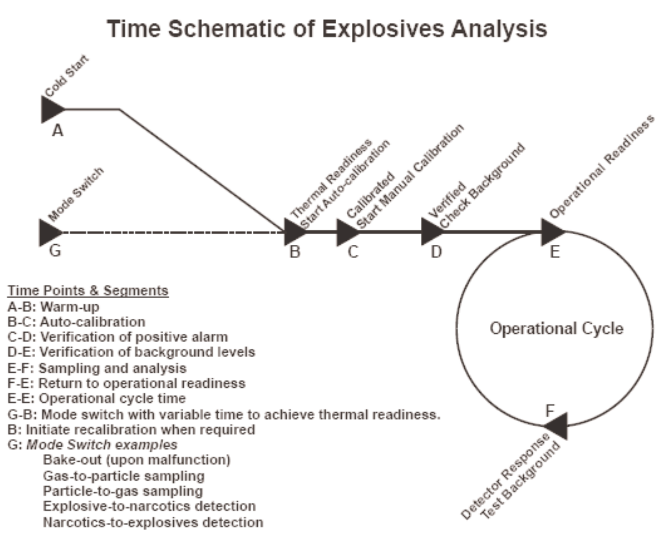


Schematic representation of an IMS instrument. Ionized gas molecules shown by grey circles.

use multiple peaks for compound identification. The instrument manufacturer establishes a window that brackets an explosives peak, and when a sample is analyzed, the intensities in that window in the unknown spectrum are interrogated to determine whether a peak is present. IMS instruments will generate a positive alarm for peaks that are intense enough to exceed some specified threshold level.

IMS calibration

The drift time of an ion, and hence its peak position, is affected by environmental factors, including the temperature, pressure, and humidity of the air in the drift region. Drift region temperatures are controlled by heaters that are normally set to a fixed temperature by the instrument manufacturers. Atmospheric pressure, on the other hand, cannot be controlled and will vary with elevation and with changes in weather. For this reason, a calibration procedure is needed to compensate for changes in peak position by correcting drift times with an internal calibrant. All IMS instruments must have some method of restricting water vapor from entering the ionization region of the detector. This is usually accomplished by using a desiccant, which must be monitored and replaced periodically. Some IMS detectors are designed with a membrane that is impermeable to water at the sampling inlet; these detectors still require a desiccant, although replacement is less frequent. Membranes tend to remove materials that might interfere with the analysis and therefore improve selectivity, but at the expense of sensitivity. Most IMS detectors can be operated in the normal ranges of relative humidity, but may require frequent changes of desiccant under high relative humidity conditions.



Schematic for the time sequence of explosives analysis by IMS.

The quantity of explosive that will generate a positive alarm will depend on a number of factors, and will vary for the different explosives. Each instrument will have a recommended threshold for each explosive, defined in terms of peak intensity, above which a positive alarm will be produced. Well below the threshold level, the lowest amount of each explosive that can be reliably detected is known as the detection limit. The detection limit is typically determined under ideal laboratory conditions and is consequently much lower than the minimum amount that can be detected on a person or a surface.

IMS detectors can be operated in either the negative ion or the positive ion mode, as both types of ion are formed in the ionization process. Explosives are typically analyzed in the negative ion mode, and narcotics are typically analyzed in the positive ion mode. Those IMS instruments that provide for a mode switch from explosives to narcotics detection must allow for this switch in detector polarity and provide appropriate calibrants for both classes of materials. A higher desorber temperature is typically used for narcotics, as compared with explosives, and some time may be required for heating or cooling following a mode switch.

Sampling Issues

Sample collection is perhaps the biggest challenge in detecting explosives in real-life situations, and knowledge of the physical behaviors of explosive compounds and likely areas for sampling are paramount for effective screening. The manufacturers of IMS instruments have developed several approaches for sampling either particles or vapors that cater to different needs and applications. The sample swipes for desktop IMS instruments can vary in both material and shape, with wands or other devices for holding the swipes. The vapor collectors and portals also employ a variety of approaches for sample collection.

When sampling for particle residues using swipes, it is recommended to rub hard on the surface and to attempt to get any residue onto the center of the swipe, or that portion of the swipe that will be in the center of the desorbed area. The manufacturer should indicate where the target area is on the swipe for maximum detection. The TSA is working to develop wands for holding the swipe that will inform the user when sufficient pressure has been applied. In addition, there is active research in determining those articles or areas that represent the best choice for sampling, either because they tend to retain residues best or because they are more likely to have come in contact with explosives.

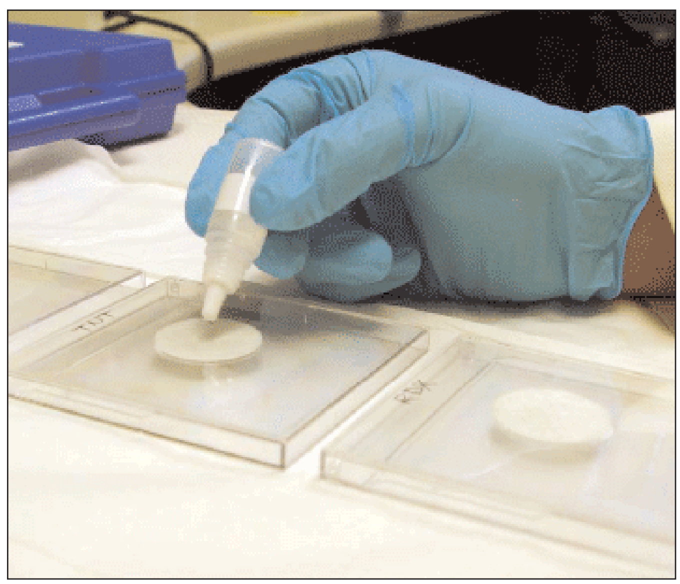
Practical Issues

All IMS instruments should be operable by trained, non-technical personnel, but note that the user interface, operating controls, and data recording procedures vary in complexity for the different instruments. Some manufacturers provide more access to default settings, such as threshold levels, desorber temperatures, etc. While it is useful for the knowledgeable operator to have access to these settings, particularly during calibration procedures, or to investigate errors such as false positive alarms, it is also necessary to be able to block access to these settings to maintain a consistent operating procedure during routine use.

There are a number of consumable items that are required for all IMS instruments, including sample swipes, desiccant, internal calibrants, dopants, gloves, membranes, batteries, etc., and these consumable costs will vary among the detector systems. Some IMS instruments can analyze explosives and narcotics simultaneously, whereas others require switching detection modes and repeating the sample collection; switching detection modes may require a considerable time for restabilization. IMS instruments operate from a standard AC power supply, and many also operate from batteries. The operating time on battery power will vary.

Potential Problems

Chemical compounds that have the same drift time as one of the known explosives can trigger false positive alarms. Such interfering compounds are known to exist and can be present in relatively common products such as some perfumes and hand creams. In addition, the wide range of possible sample swipes, most of which have not been thoroughly characterized, present a possible source of false positives. False negatives can result from the presence of compounds that are preferentially ionized and may, therefore, prevent ionization of the explosives; these compounds are called masking agents. One way to diagnose such a problem is to observe the ion mobility spectrum to determine whether a peak for the reactant ion is present. The absence of a reactant ion peak in the spectrum can signal the presence of a masking agent.



Test sample preparation. Application of single drop holding the bottle at approximately a 45° angle.

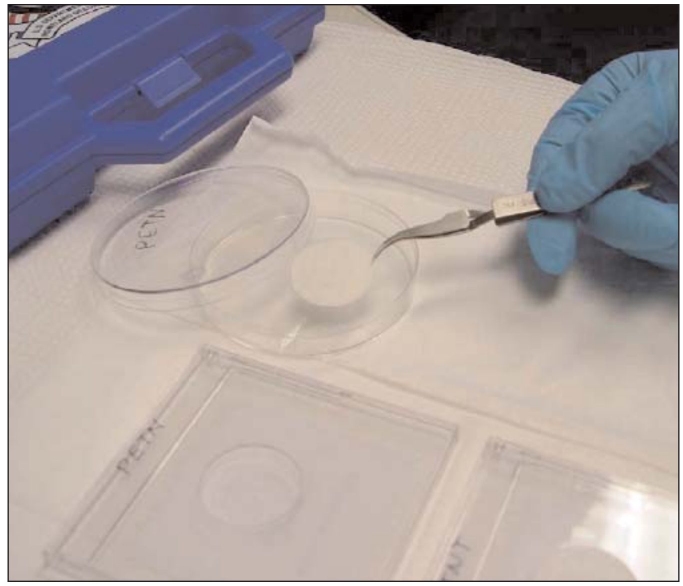
Dirt, oils, and other environmental contaminants may be sampled with the explosives, complicating the analysis and leading to false positives or negatives. In particular, oils are known to interfere with the analysis of narcotics by IMS. False positives and false negatives can occur from a change in the drift time of a compound, which can result from clustering (grouping) of the analyte gas molecules with water and other molecules, or from the presence of additional molecules in the drift region. In addition, simply changing the preset threshold levels, which are set somewhat arbitrarily with respect to detection limits, can alter the frequencies of false positives and false negatives.

Nuisance alarms arise from the presence of materials that produce a true positive alarm, but where the presence of those materials does not represent a threat. Both ammonium nitrate and nitroglycerin are used in bomb making and will alarm on most IMS instruments, but they have innocuous, legitimate uses as fertilizer and heart medicine, respectively. Nuisance alarms do not necessarily indicate a fault with the instrument, as the determination of the intended use of the material is beyond the scope of any analytical instrument designed strictly for compound identification. Nuisance alarms can also arise from contamination due to inadequate housekeeping or other sample handling issues.

Conclusion

Other than the information concerning the theory and operation of IMS trace detectors, the report also includes an overview of generalized operational procedures, an outline of instrument selection issues, a list of basic performance criteria, and a test method.

More information on the IMS-based Trace Explosives Detectors for First Responders report can be found on the SAVER Web site.



Storage of dried test sample.

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For more information on the cutting torch assessment project, please see the SAVER Web site or contact the SAVER Program Support Office.

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