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EVALUATION OF HAND-HELD ION-MOBILITY EXPLOSIVES VAPOR DETECTORS

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ABSTRACT

Two types of ion-mobility detectors were evaluated in both laboratory and field tests. Laboratory test results show that these detectors are highly sensitive to dynamite and pistol powder and have good false-alarm agent rejection. Field tests of these two detectors revealed that they would detect dynamite and Ball-C-Propellent in free air. However, neither of the ion-mobility detectors would detect these explosives if the explosives were concealed.

EVALUATION OF HAND-HELD ION-MOBILITY EXPLOSIVES VAPOR DETECTORS

Introduction

The electron capture detector represents the state-of-the-art in commercial explosives vapor detectors. Four manufacturers produce explosives detectors based on the electron capture principle.[1,2] These electron capture detectors, however, are not ideal detector systems since they require an inert carrier gas as well as a radioactive source for ionization of the explosives molecules. The ion-mobility explosives detectors developed by Ion Track Instruments (ITI) Inc. and Pye Dynamics, Ltd. offer an alternative to the electron capture detector.

A laboratory and field-test evaluation of the performance and practicality of the Ion Track Instruments Ultratek™ and Pye Dynamics PD3 detectors has been conducted. In this paper, the operation of these types of detectors is reviewed, the test procedure and results are presented and the test data are interpreted. Maintenance characteristics and cost considerations are also discussed.

Detector Description

Ion-Mobility Explosives Detector Principles

The principles behind ion-mobility detection have been known for many years. Until recently, however, these principles had not been applied to the detection of explosives. Their primary commercial use was in the field of leak detection.

There are five basic components which comprise the ion-mobility explosives vapor detector: an ionization zone, an ion-accelerating field, a drift tube, an ion collector, and a fan or impeller used to obtain a flow through the drift tube. These five components are shown in Figure 1.

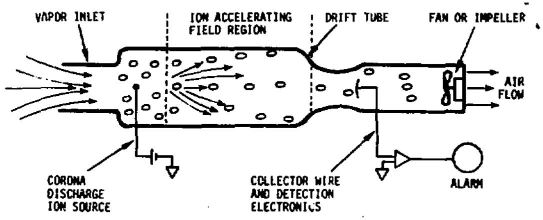

Figure 1. Schematic of an Ion-Mobility Detector

The ionization source used in these commercial explosives vapor detectors is a corona discharge which either fractures the molecule into ionic fragments or ionizes the molecule through an electron capture reaction. These ions are swept through the drift tube by the fan located behind the collector. The ion accelerating field causes the ions to be separated into explosives and nonexplosives ions. In a normal sampling case, this separation process would be applied to the mixture of explosives vapors and air swept into the detector inlet. Characteristically, after explosives vapors (usually nitrated-organic molecules) pass through the corona, they produce an ion heavier than the ions created by normal air. The field, which is used to accelerate the ions, is directed so that the ions which have a fan-induced velocity are spatially separated. This separation causes a percentage of the heavier ions to traverse the drift tube where they are detected by the collector. The change in current at the collector can be amplified to cause an alarm.

<u>Ion-Track Instruments Inc. Ultratek™ Explosives Detector</u>

The Ultratek™, shown in Figure 2, is a portable, hand-held, ion-mobility explosives vapor detector. The Ultratek™ is available with a carrying case which contains two spare 9-volt alkaline PP3 batteries, a clothing, packing materials, and other items which could block the air flow, are searched.

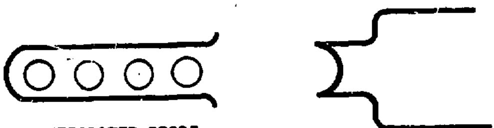

Figure 3. Ultratek™ Inlet Probes

The inlet flow rate on the Ultratek™ is 1.07 m/s. At a distance of 1.5 cm, the flow rate decreases to 0.13 m/s. The air flow through the detector should remain constant and not be restricted or increased at the inlet. A false alarm could occur if the airflow increases.

Pye Dynamics PD3 Explosives Detector

The PD3, shown in Figure 4, is another portable, hand-held, ion-mobility explosives vapor detector. The PD3 comes equipped with a carrying case containing a battery charger, spare battery pack, earphone, interchangeable sampling probes, test sample, spare parts kit, cleaning tools, and an instruction booklet. When the short probe is in place, the detector is 32 cm (12.5 inches) long and 5 cm (1.97 inches) wide and weighs 0.75 kg (1.65 pounds). The operating controls on the detector consist of a three-position ON/OFF and ON-WHEN-PRESSED switch, an audio alarm volume control and a set zero control. The detector's alarm outputs consist of an audible alarm that varies in frequency from zero to 1 kHz and an LED that lights when the audio frequency exceeds a preset value. An earphone is provided which, when plugged in, mutes the audio tone.

The detector is powered by a 12-volt dc nickel-cadmium rechargeable battery with a continuous operating time of approximately 4 hours. An audio alarm of 8 kHz sounds when the battery pack needs recharging.

clothing, packing materials, and other items which could block the air flow, are searched.

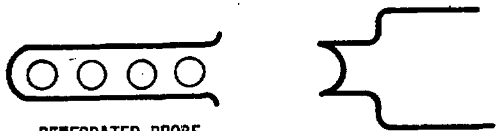

Figure 3. Ultratek™ Inlet Probes

The inlet flow rate on the Ultratek™ is 1.07 m/s. At a distance of 1.5 cm, the flow rate decreases to 0.13 m/s. The air flow through the detector should remain constant and not be restricted or increased at the inlet. A false alarm could occur if the airflow increases.

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The detector is powered by a 12-volt dc nickel-cadmium rechargeable battery with a continuous operating time of approximately 4 hours. An audio alarm of 8 kHz sounds when the battery pack needs recharging.

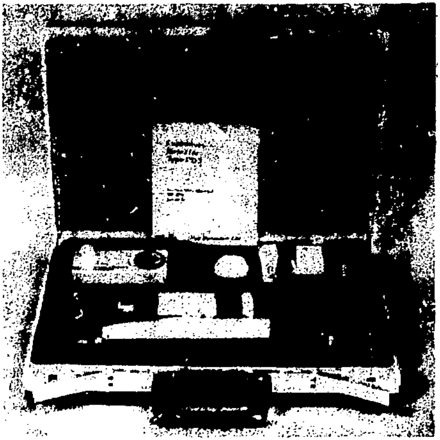

Figure 4. PD3 Explosives Detector

The PD3 comes with two types of inlet probes (see Figure 5). The short probe is suggested for use when packages, vehicles, luggage, etc., are searched. The perforated probe has eight holes on two sides with a solid front face. This probe is suggested for use in searching clothing, packing materials, and other items which could block the air flow.

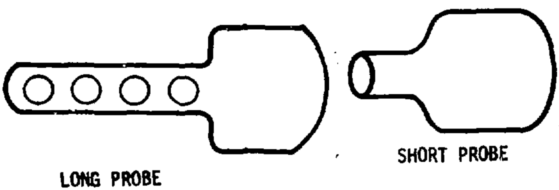

Figure 5. PD3 Inlet Probes

The inlet air flow is a critical factor in the detector's functional ability. For this reason, the inlet flow should not be restricted or increased. The inlet flow rate is 1.78 m/s; at a distance of 1.3 cm, the flow rate decreases to 0.2 m/s.

Evaluation of Detectors

Test Procedures

The qualitative tests performed on the PD3 and the Ultratek™ were conducted in two series. The purpose of the first series of tests was to determine the qualitative behavior of the detectors in the laboratory, i.e., which explosives and nonexplosive substances would cause alarms when test samples contained in a vial were presented directly to the inlet nozzle. The second series of tests involved simulated field operation which used samples composed of larger quantities of explosives, such as a stick of dynamite in a lunch box. The purpose of the second series of tests was to determine how practical the PD3 and Ultratek™ detectors are under simulated field operating conditions.

The first series of tests, conducted in the laboratory, used test samples consisting of approximately 1 gram of explosives contained in 33-ml, capped vials. The quantities of the nonexplosives varied as the nature of the substance used, such as, cotton balls soaked in gasoline. All sample explosives vials were capped when not in use and placed into a sealed ziplock bag.

The explosives chosen for this study were

1. Composition C-4,
2. Detasheet™, C type,
3. Detasheet™, D type,
4. PETN,
5. PBX-9404,
6. TNT, chemically pure,
7. TNT, military grade,
8. RDX, type A,

9. RDX, type B,
10. Dynamite (nitroglycerine-based) Petrogel™,
11. Black powder,
12. 2,4-DNT,
13. Pistol powder, Bullseye™ brand, and
14. Rifle powder, type 4831.

The nonexplosives used were

1. Aftershave lotion, Aramis™,
2. Antiperspirant, Aramis™ (aerosol),
3. Preshave lotion, Williams Lectric Shave™,
4. Cigarette smoke,
5. Automotive antifreeze,
6. Unleaded gasoline,
7. Diesel fuel,
8. Kerosene,
9. Chemical fertilizer, Desert Green™,
10. Shoe polish, Kiwi™ (black),
11. Typing correction fluid solvent, Correctette™,
12. Freon 12™, Effa-Duster™ (aerosol),
13. Acetone, Spectra-Grade, and
14. Engine exhaust.

For the nonexplosive aerosol samples, cotton balls were saturated with the liquids and placed into 33-ml vials. The aerosol Freon 12™ was sprayed onto a paper substrate immediately before each test.

At the time of the tests, the detectors were turned on and manually zeroed. The earphone on the PD3 and the short probe were used on both instruments. In the tests, the detectors were used to check the opened vials and their response was recorded.

The second series of tests consisted of simulated field tests which were conducted in an area where the handling of larger quantities of high explosives was possible.

The explosives used and the quantity of each are given in the following list:

1. Tetryl, TNT base; 225 grams,
2. Comp B-3, TNT/RDX mixture; 225 grams,
3. HMX, Grade II Class A; 100 grams,
4. RDX, Type B Class A; 175 grams,
5. PETN; 225 grams,
6. IMR 4350 (military rifle powder); 345 grams,
7. Dynamite, Giant Gel 40™ (40 percent nitroglycerine); 150 grams each, 2 sticks,
8. TNT; military grade, 92 grams,
9. PBX-9404, 148 grams,
10. Pistol Powder, Hi-Tech™, 100 grams,
11. C-4, 100 grams,
12. Detasheet, type D, 76 grams,
13. Ball-C-Propellent, 100 grams,
14. Black Powder, 225 grams.

Each of the explosives was stored in plastic bags with the exception of the dynamite and the IMR 4350. The tests were conducted by two people: one individual, equipped with disposable plastic gloves, handled the explosives and the other operated the detectors. Only one type of explosive was permitted in the test area at any given time. Except for the dynamite (contained in paper-wrapped sticks) and IMR 4350 (contained in its own commercial can), each explosive was first tested in a plastic bag. Next, each bag was opened and the explosive allowed to "breathe" in free air before it was tested. The dynamite was tested as received and the IMR 4350 was allowed to "breathe" after the cap had been removed from the can. If a material caused an alarm in the first series of tests, it was placed in a lunch box, a tool box, and a briefcase, in turn, and retested. Before the retests, however, sufficient time (approximately 10 minutes) was allowed to elapse so that the vapor pressure in the test container could equilibrate. The test procedure was then repeated for each of these items.

In order to decrease the possibility of cross-contamination, the plastic gloves used by the explosives handler were changed before each new explosive was brought into the test area. Each test container (lunch box, briefcase, and tool box) was cleaned and checked after each use.

Test Results

The results from the laboratory tests are listed in Table 1.

Interpretation of the Laboratory Test Results

The audio response or tick rate for both detectors was used as the basis of detection in laboratory tests. The following definitions are used in Table 1 to describe detector response:

1. None--No increase over zero setting.
2. Very slight--A slight increase in the tick rate.
3. Slight--The tick rate approximately doubles over zero setting.
4. Moderate--The tick rate almost becomes a constant tone.
5. Large--A constant tone occurs (PD3 LED lit occasionally).
6. Very large--A very high pitched tone occurs (PD3 LED remained lit)

The zero setting is determined by the operator; for these experiments, the zero settings for both detectors were set at approximately 3 to 4 ticks per second.

Field Test Results

The results from the field tests are listed in Table 2

Table 1

Laboratory Test Results

Material Tested	Ultratek™ Response	Pye Dynamics PD3 Response
Explosives:		
Composition C-4	None	None
Detasheet™, C type	None	None
Detasheet™, D type	None	None
PETN	None	None
PBX-9404	None	None
TNT, chemically pure	None	None
TNT, military grade	Very slight	Very slight
RDX, type A	None	None
RDX, type B	None	None
Dynamite	Large	Large
Black powder	None	None
DNT	None	None
Pistol Powder	Very large	Very large
Rifle powder	None	None
Nonexplosives:		
Aramis™ aftershave	None	None
Aramis™ preshave	None	None
Cigarette smoke	Very large	Very large
Automotive antifreeze	None	None
Antiperspirant, Aramis™	None	None
Unleaded gasoline	None	None
Diesel fuel	None	None
Kerosene	None	None
Fertilizer	None	None
Shoe polish	None	None
Typist's correction fluid solvent	None	None
Freon 12™	Very large	Very large
Acetone	Large	Large
Engine exhaust	Very large	Very large

Table 2

Field Test Results

Detector Used	Explosives Detected	Test 1	Test 2	Test 3	Test 4	Test 5
Ultratek	Ball-C-Propellant	None	Very large response	None	None	None
	Dynamite	None	Large response	None	None	None
PD3	Ball-C-Propellant	None	Very large response	None	None	None
	Dynamite	None	Large response*	None	None	None

*The LED on the PD3 did not light.

Interpretation of Field Test Results

In Field Test 1, the detectors checked for explosives contained in sealed plastic bags. In Field Test 2, the detectors checked the explosives when the plastic bags were open and held in free air when possible or in their open commercial containers. If a response was recorded on Test 2, Tests 3, 4, and 5 which used a lunch box, a briefcase, and a tool box, respectively, were conducted. The definitions used to describe the detector's response in the laboratory tests were also used for the field test results.

Ion-Mobility Explosives Detectors Maintenance Characteristics

The ion-mobility detectors require routine cleaning and changing of their battery packs, beyond this, they are maintenance free. The manufacturers recommend that all electronic repairs and adjustments be done by them. The frequency with which the ion-mobility detectors must be cleaned depends on the amount of usage they receive and the cleanliness of the use area. The detector tube and tube filter should be cleaned when dust and dirt have accumulated on the tube filter, or if the audio output becomes unstable or the detector becomes insensitive. The probe and probe filter should be cleaned when dust and dirt have accumulated.

Detector Costs

The Ultratek™ unit tested was purchased from

Ion Track Instruments, Inc.
Three A Street
Burlington, Massachusetts 01803

The cost of the unit was $2500.

The PD3 unit tested was purchased from

Phillips Electronics Instruments
85 McKee Drive
Mahwah, New Jersey 97430

The cost of the unit was $5950.

Summary

Table 3 summarizes the results of the evaluations performed on the Ultratek™ and PD3 detectors.

Table 3

Summary of Evaluation Results

Detector	Explosives Detected in the Laboratory	Explosives Detected in the Field	False Alarm Rejection	Maintenance	Costs (dollars)
Ultratek	Dynamite, pistol powder, and military grade TNT	In free air: dynamite and Ball-C-Propellant; none if concealed	High	Low	2500
PD3	Dynamite, pistol powder, and military grade TNT	In free air: dynamite and Ball-C-Propellant; none if concealed	High	Low	5950

Conclusion

The ion-mobility explosives vapor detectors are lightweight, easy to handle, have fast response and clear times, and can detect a few explosives under laboratory conditions. However, if representatively large quantities of explosives are concealed in nearly any form of packaging, the Ultratek™ and PD3 detectors which were evaluated performed poorly. An Ion Track Instruments Model 70 electron capture detector was used during the field testing of the ion-mobility detectors to establish the relative sensitivity of the two types of common explosives detectors. The Model 70 detected dynamite but did not detect Ball-C-Propellant during the container tests.

References

1. W. David Williams, Lester L. Sandlin, and Frank P. Conrad, Laboratory Evaluation of Five Commercial Electron Capture-Type Explosives Vapor Detectors, SAND78-0245, Sandia Laboratories, Albuquerque, New Mexico, June 1978.

2. Entry-Control Systems Handbook, SAND77-1033, Sandia Laboratories, Albuquerque, New Mexico, October 1978.