POTENTIAL AND LIMITS OF ULTRA-TRACE DETECTION OF EXPLOSIVES

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Abstract

The Amplifying Fluorescent Polymer (AFP) method is currently the most advanced commercially available technology in the field of explosive detection. A large range of detectable explosives, along with detection speed and ultra-high sensitivity, make the technology a suitable means for fast identifying of immediate threat of explosive material detonation. However, like other explosive detection methods, this technology also has limits that need to be taken into account when using it efficiently.

Key words
Ultra-trace detection, explosives, IED, Amplifying Fluorescent Polymer, AFP.

1 INTRODUCTION

High-energy materials are a common element occurring in industry, old burdens, and possessions of all kinds' collectors or residual war deposits. Finally yet importantly, there is an ever more current threat of using high-energy materials in form of Improvised Explosive Device (IED) within terrorist attacks or criminal activities. Each of these sources may present a threat to protection of population, as well as to security and rescue bodies of the state.

In case of capturing such threats, it is critical to timely and effectively launch the security process and eliminate threats by specified bodies. In the Catalogue of Typical Activities of the IRS (Integrated Rescue System) is the "Threat of IED Use or Detection of IED, Suspected Object, Ammunition, Explosives and Explosive Objects" [1] elaborated which deals with such process. Ultra-trace explosive detection systems serve to detect such threats quickly and effectively. However, they can also be a preventive element - in case they assist in random checks and surveys aimed at detecting illegal preparation of high-energy materials.

2 PRINCIPLE OF TECHNOLOGY

The Amplifying Fluorescent Polymer works on principle of chemical sensors that are bonded to a polymer chain. In case of reaction of a target molecule of high-energy material with a chemical sensor, the fluorescence (fluorescence gain or attenuation) of the whole chain on which the sensor is bound is changed. This allows the system to achieve ultra-high sensitivity, since interactions of each target molecule cause a higher order response than non-cross-linked chemical sensors. [2]

This specific device introduced within units of the Integrated Rescue System of the Czech Republic is Fido X3 (FLIR Systems, Inc., Wilsonville, USA). It is a robust device for detection from swipes as well as direct gas detection. However, direct gas detection is relatively inefficient and depends on the volatility of the substance and the appropriate detection conditions (temperature, wind speed, humidity, and source of vapour). The chemical sensors are transmitted in the instrument by so-called sensor elements, glass capillaries with the possibility of replacement in case of sensors overheating or detrition.

Figure 1
Fido X3

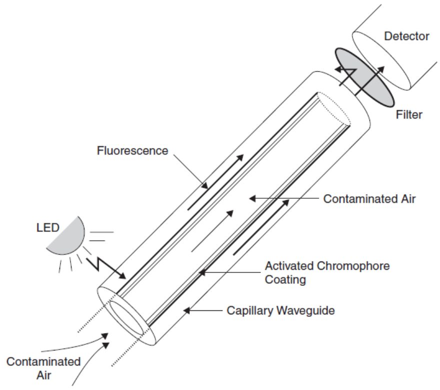

Figure 2
Sensor element schema

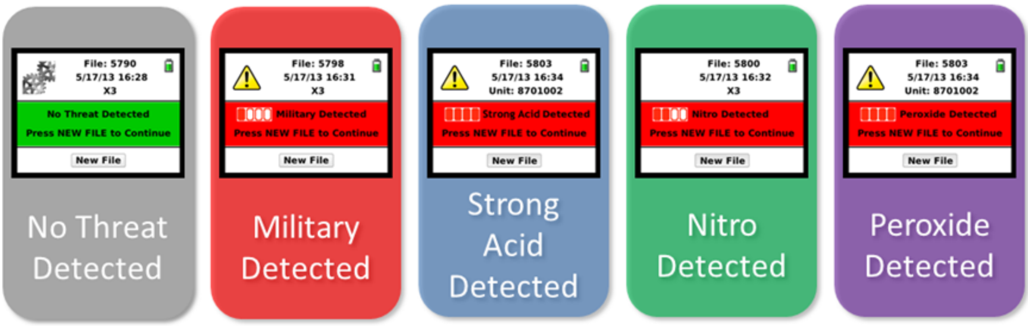

Figure 3
Detective Response

Table 1
Explosives detectable by Fido X3 [3]

TNT (Trinitrotoluene)	Tetryl
DNT (Dinitrotoluene)	Det cord
RDX (Hexogen)	Pyrodex
PETN (Pentaerythritol tetranitrate)	Nitromethane
NG (Nitroglycerine)	Nitrotoluene
EGDN (Ethylene glycol dinitrate)	Nitrobenzene
Composition-B (Comp B)	TATP (Acetone peroxides)
Composition-4 (C4)	HMTD (Hexamethylene triperoxide diamine)
Deta Sheet	High concentrations of peroxides
Semtex 1-A	Precursors of improvised explosives (based on ammonium nitrate, urea nitrate, nitric acid)
Some gunpowders	

3 POTENTIAL OF TECHNOLOGY

Primary potential of the instrument within IRS is in ability of rapid identification of threat of high-energy material. In event of existing suspicion of presence of an explosive, STČ 03 / IZS is activated and pyrotechnic service provides handling of explosive materials. However, the threat is not always detected automatically and device potential to identify such threat significantly reduces the risk of interfering units to case unintended initiation of high-energy material.

Figure 4
Direct gas detection

The second significant benefit of the system may to increase the effectiveness of controls for protection of objects and persons. The swiping and detection of exposed surfaces in passers-by may reveal the person's desire to make high-energy material. Likewise, the device can be used to explore space, buildings and vehicles in terms of IED storage capacity.

Figure 5
Hands swiping when checking a person

Finally yet importantly, ultra-trace sensitivity of the device allows detection of so-called secondary contamination. That is, contamination of surfaces that have encountered the explosive in recent past. This can be beneficial in investigating and detecting ongoing preparations for a terrorist attack or criminal offense with the IED using. When checked persons are suspected, it can be proven whether they have been exposed to an explosive within last hours.

4 COMPARISON WITH THE USE OF DOGS

The most effective way to detect explosive materials is to use specially trained dogs. Despite the indisputable advantages, a number of limits are bound to their use, primarily based on their biological and very difficult quantified body. Despite the enormous advances made by ultra-trace detection, there is currently no technology at the level where the use of dogs can be replaced. However, with the right approach, methods can be complementary and streamlined.

Table 2
Comparison of use of dogs and ultra-trace detector [4, 5, 6, 7, 8,]

Dog	**Ultra-trace detection**
Training costs: 5 000 - 25 000 $	Costs: Fido X2 – 10 000 $ Fido X3 – 40 000 $
Costs for handler, housing, Treatment, feed, etc.	Cost of spare sensor elements, service, battery recharging, service etc.
Proven, very sensitive	Wide and firmly defined span of explosives
Adaptable	Resistant, repairable
Dog itself looks for the resource	Not subject to stress, fatigue, forgetfulness, discomfort, operator expectation
Wide range of explosives	The capture efficiency is completely dependent on proper sampling
Short time of attention	Direct gas detection is not completely effective
Forgetting in repeated negative results	
Influenced on stress or discomfort	
Influenced by expectations of the handler	

5 SAMPLING

Correct method of sampling is crucial for the effective use of the ultra-trace detection system. It spreads over a wide range of factors and extends beyond simple sampling. In case of person control, it is necessary to work with suspicious contexts and behavioural signs of nervousness when selecting people for testing. Control of non-living objects is then subject to selection of statistically likely competent surfaces of contamination. [9, 10, 11]

Sampling is always primarily aimed at secondary contamination detecting. Direct targeting to expose an explosive itself increases the risk of its initiation. For an IED which is hidden in a luggage, it is possible to reveal the explosive by swiping traces of the explosive material from latching mechanism of the luggage without necessity to open the it. Similarly, the explosive hidden in a checking person can often be identified on hands or on outer parts of clothing and personal belongings (wallet, papers, electronics, keys, etc.).

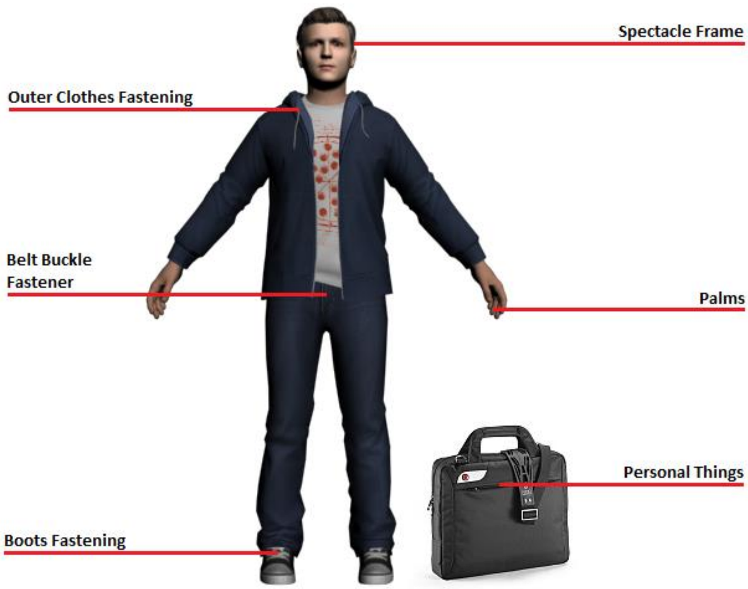

Figure 6
Priorities for person sampling

6 FALSE POSITIVITY AND FALSE NEGATIVITY

False positive and false negative signals occur within all detection methods of explosives. For AFP, this occurrence is less common than other methods [12], but this option has to be taken into account. A higher risk is occurrence of false negativity, when an explosive may not be detected during detection. The ultra-trace sensitivity of the device guarantees a great chance of capturing detectable explosives even in very small quantities. False negativity occurs with explosives that the device is unable to detect, or with incorrect sampling by the operator.

False positivity occurs when a chemical sensor is activated by harmless substances with a similar chemical reactivity to detected explosives (aromatic nitro compounds in perfumes, sulphur and peroxides in products, naphthalene, repellents, etc.) or, for example in medical use of substances detected as explosives (nitro-glycerine).

Table 3
Substances causing false positivity

Interferent	Note
Substances containing trigger groups	Nitro groups
	Peroxides
	Sulphur
	Nitrates
DEHP (Bis (2-ethylhexyl) phthalate)	The 2-ethyl-1-hexanol hydrolysis product is a volatile C4 component
Exhausts of diesel engines	
Some drugs	NG is excreted by sweat
Other substances	Naphthalene
	DEET (repellents)
	Chlorothalonil (fungicide)

7 CONCLUSION

Ultra-trace detection of explosives has a wide potential of use and can mean a significant improvement in population protection. However, it is necessary to use the technology with respect to its limitations and only by trained personnel.

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