GE
Security

Effective Detection of Taggants in Explosives Using Trace Technology

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Introduction

Taggants, or volatile chemical markers added to commercially-made explosives, were introduced in 1991 to aid in detecting plastic explosives. Since then, sensitive instruments have been developed to accurately identify explosives directly by detecting trace amounts of either their vapors or particulate emissions, without the use of taggants. However, an international trend to include taggant detection in explosives screening has led to the misconception that all trace detection instruments, whether vapor or particulate detectors, should also test for taggants.

This paper describes the chemical makeup of detection taggants, and explains how taggants were designed specifically to enhance vapor detection. The information will illustrate that taggant detection is intended for and is best suited to vapor detection rather than particulate detection.

Detection Taggants

In an effort to deter terrorism, The Montreal Convention of 1991[1] mandated that complying nations ensure that all plastic explosives manufactured within their borders include chemical markers, or "taggants." A reaction to the bombing of Pan Am Flight 103 over Lockerbie Scotland in 1988, and administered by ICAO (International Civil Aviation Organization), the Montreal Convention specified the use of "detection taggants" to help improve explosives detection prior to detonation. Detection taggants are not to be confused with "identification taggants," which give information about the explosives manufacturers. Identification taggants are not mandated by the Montreal Convention and are not included in this discussion.

Targeted for Vapor Detection

The Montreal Convention's Technical Annex specifies explosives that must be marked as those "formulated with one or more high explosives which in their pure form have a vapor pressure less than 10^{-4} Pa at a temperature of 25° C." A substance with low vapor pressure is one that has low volatility, or likelihood to exist in vapor form. The document goes on to identify these low vapor pressure "high explosives" as including but "not restricted to cyclotetramethylenetetranitramine (HMX), pentaerythritol tetranitrate (PETN) and cyclotrimethylen-etrinitramine (RDX)." The vapor pressure of these identified "high explosives" as well as TNT is shown in Table 1.

Table 2 lists the detection taggants specified in the Montreal Convention. These have a considerably higher vapor pressure than the explosives in Table 1. The higher volatility of the taggants means that their vapor trace emissions are, relatively speaking, easier to detect than those of the less volatile explosives. The Convention makes it clear that these taggants "are intended to be used to enhance the detectability of explosives by vapour detection means."[1]

Table 1: Common explosives with low vapor pressure (less than 10^{-4} Pa @ 25° C)[2]

Explosives	Chemical Name	Chemical Composition	Molecular Weight	Density (g/cm^3)	Vapor Pressure (pbb) 25° C
TNT	2,4,6- trinitrotoluene	$C_7H_5N_3O_6$	227.13	1.65	9
RDX	Hexahydro- 1,3,5-trinitro- 1,3,5- triazine	$C_3H_6N_6O_6$	222.26	1.82	0.006
HMX	Octahydro- 1,3,5,7-tetrani-tro- 1,3,5,7-tetraazocine	$C_4H_8N_8O_8$	296.15	1.96	0.0001
PETN	Pentaerythritol tetranitrate	$C_5H_8N_4O_{12}$	316.14	1.76	0.0005

Table 2: Detection Taggants identified by Montreal Convention[2]

Explosive Marker	Chemical Name	Molecular Formula	Molecular Weight	Min. conentration (by Mass)	Vapor Pressure (pbb)
EGDN	Ethylene glycol dinitrate	$C_2H_4(NO_3)_2$	152	0.2%	60,000
DMNB	2,3-Dimethyl 2,3-Dinitrobutane	$C_6H_{12}(NO_2)_2$	176	0.1%	27,000
p-MNT	para-Mononitrololuene	$C_7H_7NO_2$	137	0.5%	>50,000
~~o-MNT~~[3,4]	~~ortho-Mononitrolotuene~~	~~$C_7H_7NO_2$~~	~~137~~	~~0.5%~~	~~>200,000~~

According to the Montreal Convention, the "high explosives" that require the addition of taggants to aid in their detection are explosives with low vapor pressure (less than 10^{-4} Pa at 25° C). The addition of taggants (which have a higher vapor pressure as seen in Tables 1 and 2) allows for the more reliable detection of these explosives "by vapor detection means." o-MNT is shown crossed out because it has been deleted from the approved detection taggant list.

Particulate Trace Detection

Particulate trace detection systems are largely immune from the vapor pressure characteristics of the substances they detect. They are optimized to test for trace amounts of substances collected on surfaces and in airborne particulates. For this reason, GE Security's particle trace detection systems are likely to be considerably better at detecting explosives than at detecting the taggants that mark them. The volatile nature of the taggants in fact serves to decrease their likelihood of detection in particulate mode.

Most importantly, due to the fact that taggants are used in quantities far smaller than the explosives themselves, particulate detectors detect explosives more accurately and reliably than taggant-based detection systems. Consider p-MNT, which is the best candidate for particulate detection because it has the highest required concentration (0.5% by mass) of the taggant agents listed in Table 2. Based on lab results, a direct sample from a surface that has a residue of a marked explosive will have at most only 1 particle of p-MNT for every 200 particles of explosive. This shows that testing particulate will detect the explosive well before it detects the taggant.

Highly sensitive trace particulate detection instruments such as GE Security's EntryScan, Itemiser, MobileTrace and VaporTracer systems, are widely used in airports, security checkpoints, and in the field because they have proven to be successful at detecting a wide array of explosives. By accurately detecting explosives themselves, these systems can uncover explosives that do not contain taggants, including improvised explosives devices (IEDs) and explosives manufactured by non-compliant countries or terrorist groups.

Conclusion

Because taggants were designed for vapor detection based on their volatility, a vapor detection device is much more practical than a particulate detection instrument for detecting taggants. With vapor detection, since the vapor pressure of the taggants is considerably higher than that of some explosives, the probability of detecting the taggant exceeds the probability of detecting explosive materials with low vapor pressures. This is not the case, however, with particle detection since the volatility of the taggants tends to lower the likelihood of their detection.

Summary

The Montreal Convention of 1991 states that detection taggants "are intended to be used to enhance the detectability of explosives by vapour detection means."[5] The addition of these volatile compounds to explosives by manufacturers is meant to increase the ability to detect explosives with low vapor pressure. Testing for both the taggants and the actual explosive through vapor detection raises the probability of detecting the taggant or the explosive. Therefore, taggant detection can aid in the detection of explosive materials in vapor detection equipment.

Taggant detection in a particle detection machine, however, provides little or no increase in explosives detection capabilities as taggants are relatively less easily detected than explosive substances due to much lower concentrations as well as the volatile nature of taggants which is largely incompatible with particulate detection, and in any case is not the intent of the Montreal Convention of 1991.

Vapor detection equipment is likely to be most suitable by design and function for taggant detection. GE Security's MobileTrace detects substances in either particulate or vapor modes and could also be well-suited for taggant detection in vapor mode.

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References

[1] The Convention on the Marking of Plastic Explosives for the Purpose of Detection, signed in Montreal in 1991, available from the International Civil Aviation Organization (ICAO), Committee on Marking, Rendering Inert, and Licensing of Explosives et al., 1998

[2] Handbook of Chemistry and Physics, 2004. Committee on Marking, Rendering Inert, and Licensing of Explosives et al., 1998

[3] o-MNT was removed by recommendation of the International Explosives Technical Commission effective 27 March 2002.

[4] International Civil Aviation Organization (ICAO), Council –166th Session, "Progress Report on the Implementation of Resolution A33-2: Consolidated Statement of Continuing ICAO Policies Related to the Safeguarding of International Civil Aviation Against Acts of Unlawful Interference." 22 April 2002. Section 3.2.

[5] The Convention on the Marking of Plastic Explosives for the Purpose of Detection, signed in Montreal in 1991, available from the International Civil Aviation Organization (ICAO), Committee on Marking, Rendering Inert, and Licensing of Explosives et al., 1998

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