Detecting explosive vapours in large volume freight: 2016 improvements

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OVERVIEW
SEDET's vapor explosive detector ACES 2.1 (Figures 1-2) based on a triple quadrupole mass spectrometer preceded by a differential mobility analyzer (DMA) has demonstrated the capability to separate gas phase species present in the atmosphere at concentrations below 0.01 ppq (10^-9 atmospheres) from explosive vapours present in large volume freight. This lower detection limit (LDL) is partially determined by the finite sensitivity of the analyzer, and partially by competition from other interfering vapours (with the same mobility, precursor and product ion masses as the target explosives) also present in ambient air at ~0.01 ppq.

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The present poster describes in general terms the explosive screener present in the atmosphere at concentrations below 0.01 ppq (10^-9 quadrupole mass spectrometer preceded by a differential mobility analyzer (DMA) has been fitted with two prelaminarizers and one laminarizer, which resolves the ions into the ion mobility filter (SEADM's PS DMA). At the Front End exit, a triple quadrupole mass spectrometer (Sciex Triple Quad API 5500) completes the analysis.

The following relevant results have been obtained during 2016 in the ACES explosives vapour detector:

(i) The DMA resolution has increased significantly.
(ii) The sensitivity gain has increased markedly, in particular in the TNT and EGDN channels.
(iii) The PoD for RDX is close to 100% for 20 fg captured on the filter. The detection probability for signals between 10 and 20 fg is 30%, and reaches nearly 100% for signals above 20 fg. In order to detect 0.01 ppq of RDX with a PoD above 90%, 20 fg are needed in the filter, equivalent to a sampling volume of 1,075 liters.

CONCLUSIONS
We are grateful to the EU H2020 SME Phase 2 Program "ACES", grant number 672001.

Table 1: ACES 2.1 sensitivity has increased significantly in 2016, with improvement factors above 4 for TNT. Sensitivity is defined as the number of ion counts measured by the mass spectrometer when 1 femtogram is deposited on the filter. Present sensitivity has reached 324 counts per femtogram for TNT, delivering unprecedented detection capability in large volume freight.

The sensitivity gain has been achieved through chemical means: a solution of acids in minute quantities (pg/s) is continuously injected in the desorber. The best results have been obtained with nitric acid, while other compounds also show relevant effects. The reasons for the sensitivity gain are still unclear. Our main hypothesis is that the acids eliminate pollution traces present in the desorber, which when present, react with explosives and retain them before they could reach the ionizer. The amount of acids injected is very small when compared to the HCl injected in the SESI, and does not interfere with ionization.

In Table 2, the results for 314 loaded tests for RDX. The Probability of Detection (PoD) is shown as a function of the femtograms (fg) captured on the filter. The detection probability for signals between 10 and 20 fg is 30%, and reaches nearly 100% for signals above 20 fg. In order to detect 0.01 ppq of RDX with a PoD above 90%, 20 fg are needed in the filter, equivalent to a sampling volume of 1,075 liters.

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Figure 1: SEADM's cargo screening concept

Figure 2: Schematic of the analyzer

Figure 3: Mobility plots of the tetraheptylammonion ion standard. X-Axis presents electrical mobility (Volts), Y-Axis presents signal intensity, also in Volts. The red plot presents a mobility peak with the previous DMA; the mobility peak in blue presents the mobility plot when the DMA has been fitted with one prelaminarizer, and the orange plot presents the mobility peak when the DMA has been fitted with two prelaminarizers.

Experiments carried out in SEADM's DMA workbench have demonstrated that SEADM's DMA can reach resolving powers above 100 for m/z 410 Da. Design improvements have been the following:

- Prelaminarization stage: Eliminates turbulences from the DMA recirculation circuit.
- Laminarizer stage: New laminarizers with improved aerodynamic characteristics.
- Two DMA blower modules enable higher Reynolds numbers in the DMA separation channel. In the future we expect to obtain the same Reynolds number improvement through a more efficient diffuser.

Figure 4: Increase in resolving power with DMA voltage. The resolving power now increases continuously with DMA voltage, while before it reached a plateau around 73.