L-3 Communications CyTerra Corporation

Development of a Universal Explosives Detection System

Presented by:
Edward E. A. Bromberg, PhD
L-3 Communications CyTerra Corporation

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Outline

- Review challenge to develop EMD
- Review of the strengths and limitations of the ETD currently being used or used in the past.
- Review of some previous work to develop a universal explosives detection system using micro-calorimetery.
- Overview of L-3 Communications CyTerra's EMD (energetic material detector) technology as applied to ETD units.

L-3 Communications CyTerra EMD Unit

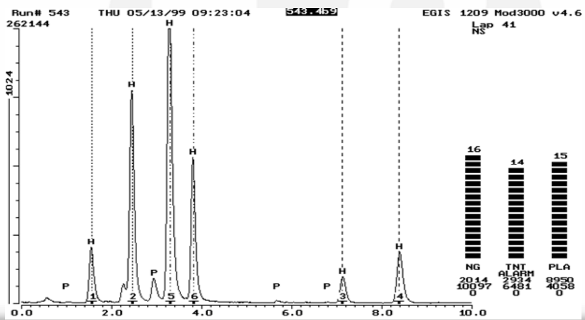
- Challenge - develop a trace detection technology that addresses limitations of current technologies.
- Ideal characteristics of new technology.
  - *Should not require a library to update to identify an explosive material*
  - *Should have a large dynamic range.*
  - *Should have fast recovery from large alarm levels*
  - *Should have a high probability of detection with a low false alarm rate*
  - *Should not require driers, carrier gases or radioactive sources.*
  - *Should have a high reliability with a low life cycle cost*
  - *Should be fully automatic with no interpretation required by user*
- In the rest of this talk I will review some of the limitations of current technology, some prior work on development of a universal detection system, and how the CyTerra EMD (Energetic Materials Detection) approach addresses these challenges.

Current ETD units

- Strengths
  - Typically they have high sensitivity and selectivity
  - Acceptable reliability
  - General acceptance
  - Have been around for a while and are well understood
  - Have been integrated into the general screening processes.
- Limitations
  - Rely on a library, can only alarm on materials in library
  - Technology may not be amenable to all explosive materials
  - FAR increases as more substances are activated
  - Can be overloaded, and take time to recover from alarms
- Will use GC-CL as the example, but but most of what is said is applicable to the other technologies as well.

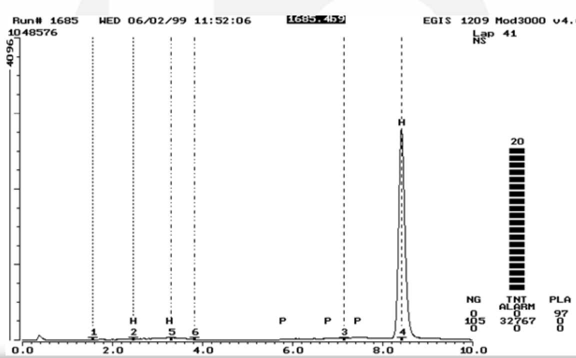
Example using GC-CL – Calibration Curve

- Below you can see a typical calibration curve for the Thermo Electron EGIS 3000 gas chromatography chemiluminescence unit.
- Note six peaks for DNT, EGDN, NG, PETN, RDX, TNT.
- Note also each peak has an acceptance window.



Example of an alarm using an EGIS 3000

- This is an example of a TNT alarm.
- Note the two "H"s and three "P"s. The "H"s are peaks found within an explosives window, but below the alarm trigger level.



Limitations of EGIS

- Can only alarm on preprogrammed peak positions.
- Detector is tuned to NO containing explosives.
- Because of the low vapor pressure of RDX, it can hang up in the piping of the system and be difficult to clear out.
- Additional explosives can be added to the library after fact, but this increases the regions where a peak will give an alarm, thus increasing the probability of a spurious, or non-explosive material giving an alarm increasing the FAR.

Micro-Thermal Detection as a Universal Detector

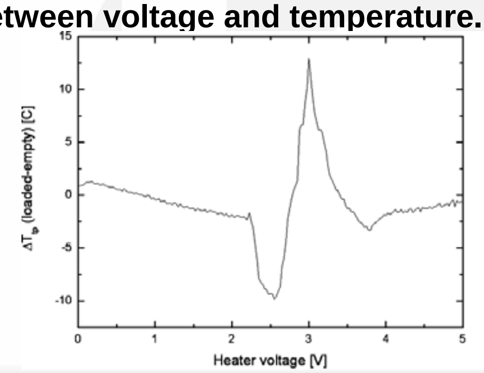
- Micro-Thermal Detection of explosives work has been performed by a group at the University of Lowell, led by Prof. Bannister, and in Israel, led by Asaf Zuck and elsewhere.
- The work of these teams showed that they could measure the exothermic decomposition of energetic material and use that unique feature to distinguish the energetic material from non-energetic material.
- From Zuck et al "use a property that is common to all types of explosives and distinguishes them from non-explosive materials."

Micro-Thermal Detection (continued)

- Zuck et al go on to say “An important conclusion from their work (U of Lowell) is that all explosives, of any character or composition, can readily be detected by thermal analysis. Moreover, since thermal analysis had an inherent capability for detection of any and all explosives, no modification of the analyzer will be required for new explosives.”
- This implies that once the thermal analysis output has been characterized for a group of explosives materials, it is generic for explosives materials and distinguishable from non-explosives, and this fingerprint can be expected to be present for explosives that were not part of the original group used for the characterization.

Example: Microcalorimeter thermogram of RDX

- Microcalorimeter thermogram of RDX in air (~ 300° C/s) (From Zunk et al, J. of Energetic Materials 26: 163-180, 2008)
- Note endotherm due to melting (2.5V) followed by exotherm due to decomposition (3.0V). There is a relationship (not shown) between voltage and temperature.



Limitation of Micro-Thermal Detection

- From Zuck et al "While the characterization of explosive particles by micro-thermal analysis looks possible, a great challenge is by bringing the particle from the external world to the sensor."
- Having an array of a large number of micro calorimeters in a small area could address this limitation.
- The challenge we faced at CyTerra during the early work was how we could develop a system using current available technologies to give a large number of micro calorimeters in a small area.

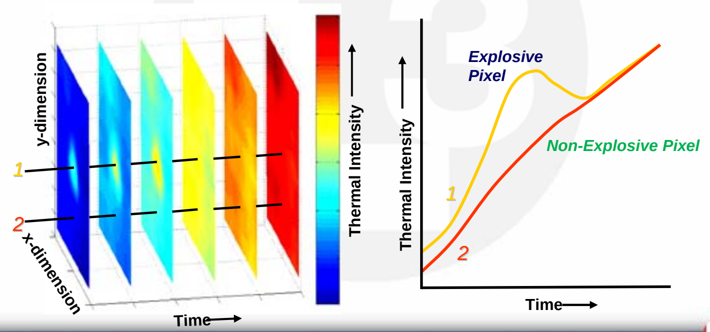
General Description of EMD

- Address issue of bringing sample to the detector by using non-conctact detection with an IR camera having a minimum of 320 x 240 pixels viewing typical sample area of wipe, i.e. 2 x 3 cm.
- Thus replacing a single micro temperature measurement with 76,800 temperature measurement elements (pixels).
- Therefore each pixel is viewing area less than 100µM on each side.
- Response time of detector is such to be able to monitor heating in excess of 500°C/sec.
- Thus using slightly modified commercial off the shelf IR cameras we are able to address the limitation quoted by Zuck.

Schematic of EMD Technology

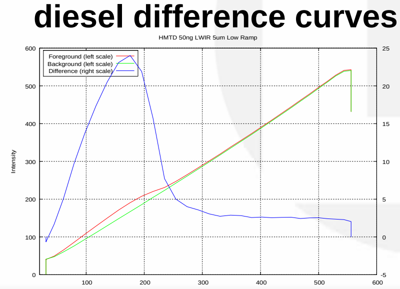
- Samples are rapidly heated for < 0.5 sec
- Approximately 76,800 data points are collected every 16.7 ms (60 Hz)
- Proprietary algorithm quickly searches data for explosive signature (~ 1 sec)
- Initial heating for analysis burns off all explosive residue resulting in a "Pass" for a refire

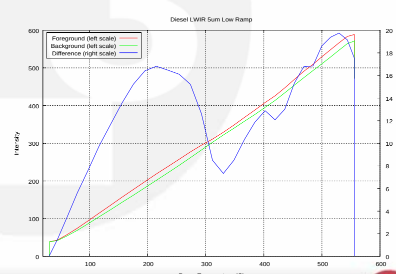
Select Slices of Experimental Data



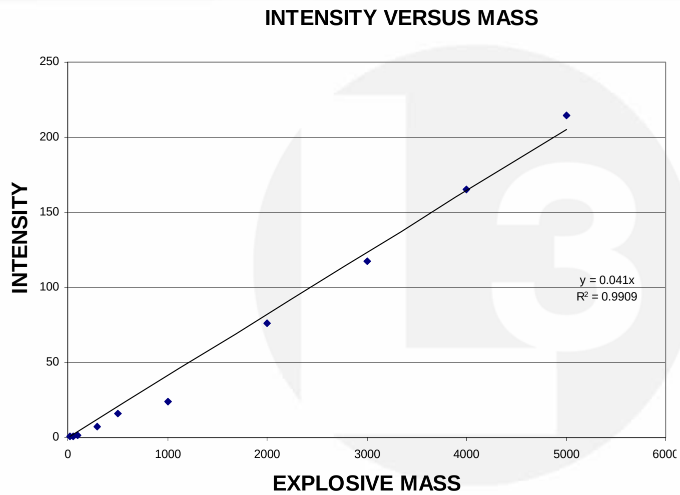
Example of Explosive and Flammable

- Left curve is an explosive material (HMTD). The green curve is the background wipe temperature, red curve temperature where suspected explosives are, and blue the difference between the two.
- Right curve is a flammable material (diesel fuel).
- Note difference in character between HMTD and diesel difference curves.



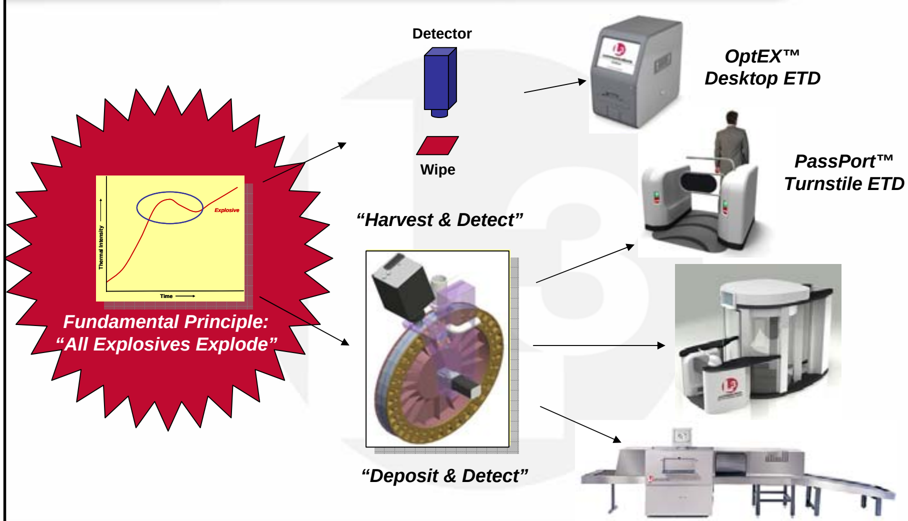


EMD Dynamic range



- Note large dynamic range which is due to a combination of a large number of distributed detectors and to large dynamic range of individual detectors.
- Upper range on diagram is limited to concentration available when experiments were performed. Actual range is much larger.

EMD Schematic and Technology Applications



Summary of experimental results

- Demonstrated universal detection.
  - The algorithm has been developed based upon a database using a number of explosives and potential interferences.
  - When challenged by explosives that were not part of the database, the EMD technology demonstrated its ability to alarm on these "unknown" explosives. Demonstrating that the EMD is not based upon the internal library.
  - We are obtaining a high PD with a low FAR
  - At current level of algorithm development we do not uniquely identify the different explosives. This is the main limitation.
- Due to the fact that the detection system has a large number of distributed detectors (pixels) the EMD has a dynamic range approaching five orders of magnitude.
- The EMD has a very fast clean up mode, typically one cycle.

EMD implementation into detection systems

- Step 1 - Collect sample
  - In OptEX™ we use a processed mesh mounted on a sampling wand has the appropriate harvesting characteristics to collect the sample in a manner similar to ETD units in the field. Sampling times are typically under ten seconds.
  - In PassPort™ the sample is collected for up to five seconds by a computer controlled vacuum using a mesh similar to the OptEX™. The sample particles are deposited onto the mesh. For hands and torso, the PassPort™ vacuums the subject directly, for shoes, an air-knife is used to dislodge particles from the shoe. Close coupled sampling is used to minimize dilution.
- Step 2 – Transport sample to analysis stage
  - In OptEX™, sample mesh is manually placed in sample drawer.
  - In PassPort™, sample mesh is automatically moved from sample position to analysis position under computer control in under one second.

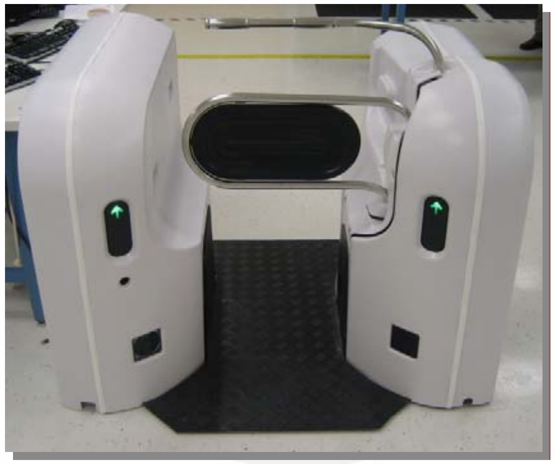
EMD implementation into detection systems (cont)

- **Step 3 – Collect data**
  - **In both OptEX™ and PassPort™, the sample mesh is heated resistively while being viewed by the IR camera, with data being stored for analysis. This process takes less than one second.**
- **Step 4 – Analysis**
  - **In both cases sophisticated algorithms analyze the data and report the results to the users in under two seconds.**

OptEX™

Figure 1. OptEX™

PassPort™



Questions?