Document Title:	**Potential Use of HAZMAT Gas Detectors for Detection of Accelerants Carried by Individuals**
Author(s):	**Chad Huffman, Ph.D., Lars Ericson, Ph.D.**
Document No.:	**246707**
Date Received:	**May 2014**
Award Number:	**2010-IJ-CX-K024**

Potential Use of HAZMAT Gas Detectors for Detection of Accelerants Carried by Individuals

DOJ Office of Justice Programs
National Institute of Justice
Sensor, Surveillance, and Biometric Technologies (SSBT) Center of Excellence (CoE)

NLECTC
Sensor, Surveillance, and Biometric Technologies Center of Excellence

April 5, 2012

Prepared by

ManTech International Corporation®

ManTech Advanced Systems International
1000 Technology Drive, Suite 3310
Fairmont, West Virginia 26554
Telephone: (304) 368-4120
Fax: (304) 366-8096

Dr. Chad Huffman, Senior Scientist

Dr. Lars Ericson, Director

UNCLASSIFIED

This project was supported by Award No. 2010-IJ-CX-K024, awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. The opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect those of the Department of Justice.

TABLE OF CONTENTS

1.0 INTRODUCTION

The National Institute of Justice (NIJ) Sensors, Surveillance and Biometric Technologies (SSBT) Center of Excellence (CoE) has prepared a draft addendum to the recently delivered report, "Assessment of Portable HAZMAT Sensors for First Responders," to address an information requested. Specifically, Metropolitan Police Service (London, England) reached out to fellow law enforcement and counterterrorism organizations to gather information on technologies that can be used to detect the presence of flammable accelerants on a person or vehicle.[1] The overarching objective is to prevent or stop the use of fire as a potential terrorism weapon.

The NIJ SSBT CoE has expanded upon work done for the Portable Hazmat Sensor assessment, providing preliminary guidance on how those devices might be used in the desired role and their projected effectiveness. This addendum is to be used for informational purposes only. NIJ and the SSBT CoE do not endorse any of the mentioned products.

NOTE: The SSBT CoE has not conducted any laboratory or field testing to verify the performance or features of specific devices or detection technologies. Assessments are based on subject matter expertise, available literature, and vendor materials.

2.0 ACCELERANTS

Arsonists often use accelerants to aid in the ignition and spread of fire. It is desirable to identify accelerants carried by individuals so that further investigation into the potential threat can be efficiently conducted. Several gas sensing technologies utilized by Hazardous Material (HAZMAT) responders have the ability to identify potential accelerants.[2] Some of the more commonly used accelerants are listed below:[3]

Table 1: 20 Common Ignitable Liquids used as Fire Accelerants

Acetone	Lacquer*
Carbon Disulfide	Lacquer thinner*
Coleman Fuel *	Methyl alcohol
Ethyl Alcohol	Methyl ethyl keytone
Ethyl Alcohol	Mineral Spirits (very similar to paint thinner)*
Ethyl Ether	Naphtha*
Fuel Oil no. 1*	Paint Thinner*
Fuel oil no. 2*Gasoline	Toluene
Isopropyl alcohol	Turpentine*
Kerosene (very similar to Fuel Oil no. 1)*	Xylenes (mixture of o, m, and p xylenes)*

* = Mixture of compounds, often without specific formulation

Most of the accelerants listed are organic in nature, however one potential difficulty is that many of the accelerants (the ones marketed with an *) are not a pure compound but a mixture of organic compounds. The mixture often does not have a well defined formulation. For instance, the formulation of gasoline can be dependent on the originating refinery, the crude oil that the refinery used to produce the gasoline, and even the time of year (a refinery may produce different formulations for cold and hot weather to better control their products volatility).

Because of the wide range of potential compounds and because of the potential of formulation differences, it would be necessary to be able to detect a wide range of volatile organic compounds (VOCs).

3.0 HAZMAT GAS SENSORS

Several sensor technologies that are used in gas detectors were discussed in the ManTech SSBT CoE Portable Hazmat Sensors Report and are listed below. These sensors and their potential use for accelerant detection are overviewed in the following paragraphs.

- Combustion Sensors
- Colorimetric Sensors
- Electrochemical Sensors
- Thermal Conductivity Sensors
- Semiconductor Sensors
- PIDs
- FIDs
- Flame photometry
- Ion Mobility Spectroscopy
- Light Absorption based detectors
- Gas Chromatography

3.1 Combustion Sensors

Combustion sensors use a catalyst coated wire to ignite VOCs in a sample at a lower temperature than would normally be needed to ignite the sample. The ignition heats a wire and changes the electrical resistance of the wire. Changes in electrical resistance of the wire are measured and indicate the presence of VOCs. The use of combustion sensors require the presence of a "flame arrestor" so that ignition does not propagate out to the general atmosphere. These devices are also sensitive to catalyst poisoning from various gasses (halogen containing compounds, for instance).

3.2 Colorimetric Sensors

Colorimetric sensors use a material which is impregnated with a reactive compound that will change color when target molecules are absorbed. The chemistry of these types of detectors is usually specific for a specific chemical or chemical species, therefore it is possible that these devices may not detect a wide range of accelerants or several devices may be needed for coverage of a wider range of potential accelerants. In addition, these devices often require user attention for both sampling and for observation.

3.3 Electrochemical Sensors

Electrochemical sensors use a chemical reaction known as a redox reaction to directly produce an electrical current the reaction of reagent molecules and oxygen. These sensors are typically optimized for the detection of specific gasses and may not be able to detect a wider range of potential accelerants.

3.4 Thermal Conductivity Sensors

Thermal conductivity sensors measure a change in the thermal conductivity of a sample. These sensors are able to detect a very wide range of gasses including organic and inorganic. Although they can detect a wide range of gasses, these sensors are very non-specific; unable to distinguish between toluene and carbon dioxide (for instance). These sensors are cheap and they are often used as a detector for other methods (e.g. gas chromatograph; see below).

3.5 Semiconductor Sensors

Semiconductor sensors use the change in electrical conductivity of the surface of a thin metal oxide exposed to the atmosphere. Adsorption of target molecules changes the electrical conductivity of the thin oxide layer. These sensors are sensitive to humidity and to sensitivity loss due to poisoning.[4]

3.6 Photoionization Detectors (PIDs)

PIDs use UV light to ionize organic compounds in the sampled atmosphere. The ions are then detected by means of electrical signal. The detection of VOCs by PIDs is typically fast, on the order of a few seconds. The ppbRAE 3000 by RAE systems is a PID detector and it has a range of 1 ppb to 10,000 ppm with a 3 second response time. PIDs can also detect lower levels than their FID counterparts.[5, 6]

Note that PIDs can only detect VOCs that are capable of being ionized by the UV light. While this includes a very large number of organic compounds, there are some low molecular weight hydrocarbons that are not detectable by PIDs such as methane and ethane. [7]

3.7 Flame ionization detectors (FIDs)

FIDs are very similar to PIDs and employ the same detection methodology but instead of a UV source, they use a flame (typically hydrogen) in order to ionize materials that a PID would be unable to detect (methane and ethane for example). The detection of VOCs by FIDs is typically fast, on the order of a few seconds. However, because they use a flame, they may require the use of a flame arrestor in order to keep ignition from propagating. This can slow the detection response by slowing the diffusion of VOC into the sensing area. Another down side of FID is that they require consumables (hydrogen) to produce the flame used for ionization.

3.8 Flame Photometry Detectors

Flame photometry detectors uses a flame to burn the sample and views the spectra given off by the burning sample. These devices are typically used for the detection of chemical species such as chlorine and sulfur containing molecules. Because complete burning of hydrocarbons would produce carbon dioxide (CO2) and water (H2O), these would be expected to be common interferences in the environment and would probably be unsuitable for detection of many accelerants. Again, since a flame is involved, it may be necessary to use a flame arrestor which may slow diffusion and detection (especially for heavier hydrocarbons).

3.9 Ion Mobility Spectroscopy (IMS)

IMS detectors tend to be small detectors have a fast response time (several seconds) but they often require the use of radioactive materials as the ionization source, and may not be as discriminating as would be desired (for instance, wintergreen oil (molecular weight = 152) may be mistaken for mustard gas (molecular weight = 158).[8]

3.10 Light Absorption Based Detectors

Light Absorption based detectors for VOCs tend to be infrared (IR) absorption based detectors. These tend to be larger and heavier than many of the other detectors. One notable class of these detectors is known as a Fourier Transform Infrared Spectrometer (FTIR). In principal, they have the capability to nearly unambiguously identify individual chemicals in a sample. However, the engineering requirements of this type of equipment would seem to make them less robust than most of the other detectors. They may also require higher concentrations of the unknowns for an unambiguous identification.

3.11 Gas Chromatography (GC)

Gas Chromatography (GC) detects chemical compounds in the sample mixture by attempting to separate the mixture into its constituent components. The separation occurs in a component known as a column, and the speed at which each component is able to pass through the column helps to identify the component. The column itself does not detect the gasses, it only separates them. The detection of the gasses occurs when the components exit the columns. Thermal conductivity sensors (see above) are a widely used as the sensor in GCs, but other sensors can be used as well (such as FTIR, IMS, PIDs…). These devices tend to be larger and heavier than several of the other devices, and they often require the use of a consumable known as a "carrier gas" (however note that AccuSense by SEER Technology uses filtered ambient air, thus eliminated the need for a carrier gas). In addition detection times are typically on the order of minutes (Accusense has a cycle time of three minutes).

4.0 ARSON INVESTIGATION EQUIPMENT

Another potential area that warrants further study for this application is the area of arson investigation. One of the tale-tale signs of arson is the use of accelerants to start fires. Often times these accelerants are not completely burned in the fire and are able to be detected.[9] Specially trained canines are often utilized to aid in the detection of accelerants during an arson investigation. However there may be circumstances where the use of canines is not desirable. In this case, equipment designed for the detection of accelerants may be used for accelerant detection.[4, 10]

5.0 CONCLUSIONS AND RECOMMENDATIONS

Although many of the technologies may be applicable in specific situations, PIDs offer hand-held, high sensitivity devices for the detection of a wide range of VOCs that are commonly used as accelerants. PIDs are unable to identify the chemical substance or the chemical make-up of the VOCs detected, but they may offer an initial "potential trouble" signal that would warrant further investigation. This technology might be a good technology to focus investigation efforts as to the applicability of detection of accelerants carried by individuals.

Arson investigation organizations and groups may also offer a potential rich source of information about accelerant detectors used after a fire has been extinguished. It's possible that the same equipment utilized in these investigations may also be directly utilized in the detection of accelerants carried by individuals.

---

[1] Paul White, Metropolitan Police, New Scotland Yard, "Use of Fire as a potential terrorist tactical weapon," Email to Bruce Blair NLECTC National (March 27, 2012).

[2] SSBT CoE, ManTech International Corporation*; Assessment of Portable HAZMAT Sensors for First Responders* (March 1, 2012).

[3] inter FIRE Online, *"Appendix II: Twenty Common Ignitable Liquids used as Fire Accelerants,"* http://www.interfire.org/res_file/aec_20ig.asp (Accessed April 5, 2012).

[4] RAE Systems, *"Application Note AP-207; PIDs as Arson Investigation Tools,"* Available at http://www.afcintl.com/pdf/rae/ap207.pdf (Accessed April 5, 2012).

[5] RAE Systems, *"ppbRAE 3000: Portable VOC Monitor for ppb Measurement,"* http://www.raesystems.com/products/ppbrae-3000 (Last Accessed April 5, 2012).

[6] RAE Systems, *"Application Note AP-226,"* Available at http://docs.pksafety.com/ap226_rae_pid_fid_comparison.pdf (Accessed April 5, 2012).

[7] Environmental Protection Agency, *"SOP#:2114: Photoionization Detector (PID) HNU",* Available at http://www.dem.ri.gov/pubs/sops/wmsr2114.pdf (Accessed April 5, 2012).

[8] KD Analytical, *"Ion Mobility Spectroscopy (IMS) Instrument: Maintenance Management, Support, Training and Repair"* http://www.kdanalytical.com/instruments/technology/ims.aspx (Last Accessed April 5, 2012).

[9] Forensic Science Central, *"Fire Investigation,"* http://www.forensicsciencecentral.co.uk/fireinvestigation.shtml (Last Accessed April 5, 2012).

---

[10] Fire Engineering, *"The Fire Service and Counterterrorism: Technology,"* http://www.fireengineering.com/articles/2008/06/the-fire-service-and-counterterrorism-technology.html (Accessed April 5, 2012).