Voluntary Consensus Standards for Chemical Detectors

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1.0 Introduction

In the event of a toxic chemical release, either through an act of terrorism, industrial accident, or natural disaster, effective incident management requires accurate real-time chemical analysis of the materials in question. To help ensure that proper evacuation and decontamination procedures can be initiated, it is critical for first responders and soldiers to have chemical detection equipment which enables the identification of the chemical hazard, the threat level, and the boundaries of the contaminated area. Furthermore, the detection equipment must operate reliably and accurately, and the users must have confidence in the equipment. Correctly identifying and quantifying hazardous chemical vapors in the field is challenging; there are hundreds of industrial chemicals that are toxic at low concentrations from parts-per-million to sub parts-per-billion concentrations.[1,2] Environmental conditions and commonly occurring benign chemicals can impact the measurement of vapors of interest by either masking the presence of a toxic material (false negative) or, conversely, by triggering an alarm when toxic materials are not present (false positive). These false negative alarms expose people to significant health risks while false positive alarms cause user loss of confidence in the equipment and unnecessary and costly evacuations.

With 207 chemical detectors listed in the *Guide for the Selection of Chemical Detection Equipment for Emergency First Responders*,[3] there are many options for detection equipment purchasers. For example, there are up to 10 different types of chemical measurement technologies used in point detectors for chemical warfare agents (CWA), toxic industrial chemicals (TIC), and toxic industrial materials (TIM). While the diversity of equipment is advantageous, it also presents a significant challenge; it is difficult to directly compare the instrument capabilities and to assess which detector best suits an organization's specific priorities. It is important to emphasize that the product summaries and evaluations in the *Guide* are based solely on vendor-supplied information and there is no process to verify that the equipment will perform as advertised. Several recent studies suggest that the goals of clear, concise purchasing information to first responders are not currently met.[4-6] Additionally, a 2011 MITRE Corporation study for the Department of Homeland Security Science and Technology Directorate (DHS S&T), Chemical and Biological Division (CBD) identified 339 different sensors. The study found that commensurable comparisons of chemical detectors were difficult due to the lack of independent data that could be correlated (false alarm rates, sensitivity, reliability, etc.) from the various vendors. To help guarantee the safety of the public, incident response personnel, and warfighters, it is critical that chemical detectors function as advertised, meet key performance requirements, and that users have complete confidence that the equipment provides accurate and reliable information.

There are three primary groups to consider during the development of chemical detection performance standards, specifically: 1) Responders must have confidence in chemical detectors that meet the standard and are able to compare generated data; 2) Industry requires an equitable means to demonstrate that products meet responders' needs; and 3) Vendors require a means to test new technologies and compare capabilities. In similar situations, where underperforming products are potentially dangerous or place people at risk, a standards-based conformity assessment process can

provide an effective method to quality-assure the products.[7] To ensure that detection equipment performs as required, the National Science and Technology Council (NTSC) Committee on Homeland and National Security recently published *A National Strategy for Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Standards*[8] that describes the Federal vision to create a comprehensive structure for the coordination, establishment, and implementation of CBRNE equipment standards by 2020.

2.0 Consensus Performance Standards

Voluntary Consensus Standards (VCS) for chemical detector performance define measurable system attributes which strike a balance between user requirements, threat and risk assessments, and technology capabilities. The DHS Chemical Detection Standards Subject Area Working Group (SSAWG) coordinates information gathering from a variety of sources, including: On-the-ground responders, responder leadership, subject matter experts, detector manufacturers, and Federal funding sponsors. The DHS Chemical Security Analysis Center (CSAC) provides threat and risk assessments while the DHS S&T Chemical and Biological Division assesses both state-of-the-art and potential next generation detector capabilities. Figure 1 shows the VCS development architecture listing the performance standards, test and evaluation standards, and laboratory accreditation processes that will be used to identify qualified chemical vapor detectors.

The process of collecting and distilling input from the large number of diverse federal, state, and local responder communities is difficult. Currently, the majority of the requirements are identified through meetings and workshops with a limited number of responder communities on an as needed basis. Several more formalized avenues for gathering information from the user communities are also being tapped including: 1) the Inter-Agency Board for Equipment Standardization and Interoperability (IAB) which maintains the Standardized Equipment List (SEL) for CBRNE equipment; 2) the DHS S&T Capstone Integrated Product Teams (IPTs) for First Responders and for Chemical/Biological Defense which consist of DHS customers and key stakeholders; 3) the International Association of Fire Chiefs (IAFC) which provides a discussion forum for first responders and 4) the Department of Defense (DOD) Joint Requirements Office (JRO) Capability Development Documents.

VCS Performance Standards are being developed and disseminated through ASTM International. Currently, ASTM E2411-07, *Standard Specification for Chemical Warfare Vapor Detector*,[9] specifies the criteria for CWA point detectors. ASTM E2411-07 addresses equipment for a wide range of applications including four operational modes: personal, fixed installation, vehicle-mounted, and survey detectors and follows a "one-size-fits-all" approach. A new set of performance standards, based on ASTM E2411-07 and recent DOD detector Performance Specifications, but more directly aligned to specific operational scenarios and current federal priorities, is being developed. ASTM work product 33681, *The Standard Specification for Handheld Point Chemical Vapor Detectors (HPCVD) for Homeland Security Applications* has been developed by a joint team from DHS, the National Institute of Standards and Technology (NIST), the DOD, and the MITRE Corporation with input from the detector community, is currently in balloting for acceptance. A significant benefit of using VCS bodies is that they have an established and required periodic review of all standards, enabling the community to address dynamic threats, changing technologies and evolving operations.

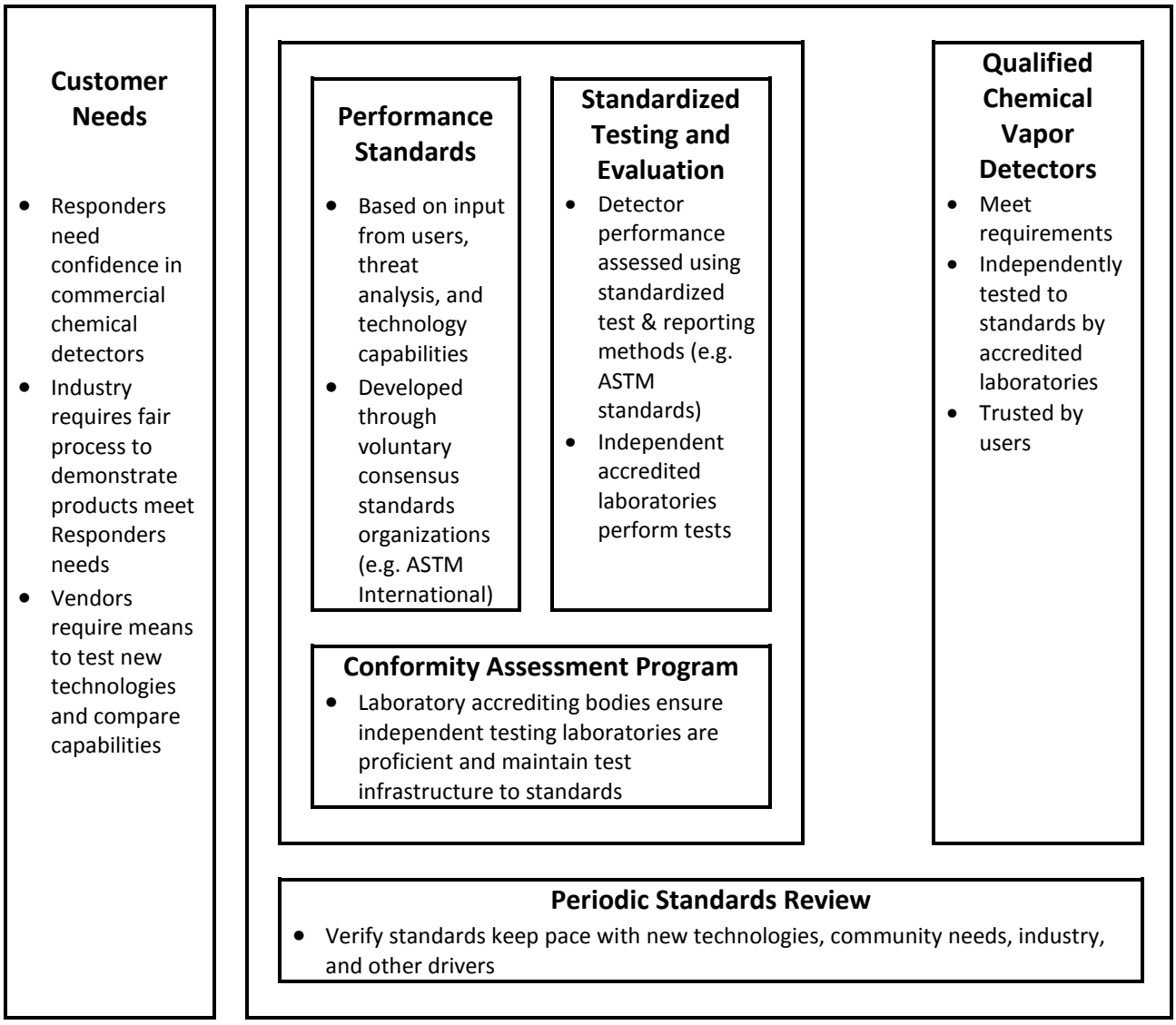

Figure 1. Voluntary Consensus Standard Development Architecture

The HPCVD performance standard addresses a wide range of detector properties including more general attributes (e.g. size, weight, power, reliability, etc.) and technical capabilities (e.g. chemicals detected, sensitivity, response time, false alarm rate, etc.). For the technical capabilities, the new performance standard is based on health-based recommendations developed by the National Advisory Committee for the Development of Acute Exposure Guideline Levels (AEGL) for Hazardous Substance.[10] The AEGL values provide guidance for short term exposure scenarios, such as accidental chemical spills that can involve the general public, including elderly and children and other individuals who may be more susceptible to injury or death. AEGL values are primarily based on acute toxicology data and not sub-chronic or chronic data and the values identify varying threshold exposure concentrations and exposure times associated with toxic effects with varying degrees of severity. Within this framework, end-users are able to identify priority chemicals and detection levels based on their specific operations. In a

similar fashion, vendors will be able to state specific detector capabilities related to the target AEGL detection goals. These vapor concentrations also define the test criteria for the evaluation program.

Performance requirements beyond the chemical and chemical concentration which triggers an alarm impact the design and functionality of chemical detectors. The other technical properties included in the HPCVD performance standard are: Detector response time, clear down time, detection success rate, mean time between false alarm, etc. Environmental factors often impact readings from chemical detectors, therefore operating conditions such as the ambient temperature, relative humidity, and pressure ranges are specified in the performance standard. Additionally, non-toxic and relatively benign chemical vapors are often present in the ambient atmosphere. These commonly occurring vapors can modulate a chemical detector's response to threat compounds causing the detector to either miss the presence of a toxic material (false negative alarm) or alarm when toxic materials are not present (false positive alarm). Overall, the HPCVD performance standard defines the operating ranges and performance criteria that the detector must conform to in order to be certified to the ASTM standard.

3.0 Standards Based Test & Evaluation

Standardized test methods and reporting ensure that independent equipment evaluations are properly designed to guarantee that: 1) the procedure actually tests the intended property; 2) the tests with validated materials are uniform; and 3) the results are reported in a standard manner to facilitate data interpretation and comparisons. For example, if a given detector is tested at one accredited laboratory, the results will agree with results from similar tests executed at another accredited laboratory. The testing protocols must include sufficient details to eliminate any potential ambiguities and allow technically competent individuals to reproduce the tests and results in different laboratories. Reference methods, materials, and data must be available, as they are key tools used by testing personnel to establish and maintain equivalent measurements. Periodic inter-laboratory comparisons should be executed to help verify that results from different testing laboratories are equivalent and remain comparable over time.

The number of chemicals and the vapor concentration ranges of interest make chemical detector testing a complex and costly endeavor requiring a significant amount of laboratory infrastructure. Laboratories certified to handle Toxic Industrial Chemicals (TICs) and Chemical Weapon Agents (CWAs) must be able to deliver to the detector under test the correct chemical vapor concentrations at operationally relevant temperatures; relative humidity levels; pressures; and with common background chemicals at appropriate concentrations. The currently certified CWA test facilities have developed a variety of test plans, standard operating procedures, and reports describing their capabilities and procedures. These reports provide a foundation for building the ASTM International guides and/or practices. NIST has also developed a small scale chemical detector test capability to facilitate the standards development process and to help establish the comparability of measurements throughout the testing communities. Verification and evaluation of other detector attributes, such as, reliability, electromagnetic compatibility, and environmental hardness are more "cut and dried" and must occur along with chemical testing. There are several ASTM and DOD specifications applicable to each of these ruggedness attributes which will be cited as appropriate in the final detector test and evaluation standard.

4.0 Conclusion

A joint team from the DHS, NIST, DOD, and the MITRE Corporation has moved forward on the development of consensus standards to meet the needs of First Responders per the architecture of the *National Strategy*. Figure 1 above outlines the specific standards needed to verify the performance of chemical detectors through quality-assured independent laboratory testing to ensure that qualified chemical vapor detectors are available for civilian and military first responders/HazMat teams. The establishment of performance standards, test methods, testing laboratory requirements, reporting methods, and accredited testing laboratories will provide the infrastructure needed to ensure that commercial chemical detectors conform to standards and satisfy mission requirements. The Standard Specification for Handheld Point Chemical Vapor Detectors for Homeland Security Applications (HPCVD) is currently in ASTM balloting as the initial voluntary consensus standard. The test results will be reported in a standardized format, enabling federal, state, local, tribal, and territorial agencies to make more informed procurement decisions through direct comparisons of independently demonstrated equipment capabilities. Lastly, the process in Figure 1 can be generalized and applied other HazMat related equipment and products that encompass the hierarchy of Homeland Security and DOD mission elements.

References

1. Pipeline and Hazardous Materials Safety Administration, U. S. D. o. T. *2008 Emergency Response Guidebook;* 2008 ed.; U.S. Department of Transportation: Washington, D.C. 20590, 2008.

2. National Institute for Occupational Safety and Health (NIOSH) *NIOSH Pocket Guide to Chemical Hazards;* 2011.

3. Fatah, A. A.; et.al. *Guide for the Selection of Chemical Detection Equipment for Emergency Responders, 3rd Edition*;Guide 100-06; U.S. Department of Homeland Security: 07.

4. Fox, S.; Daum, K.; Miller, C.; Cortez, M. *Emergency First Responders' Experience with Colorimetric Detection Methods*; Idaho National Laboratory: Idaho Falls, Idaho 83415, 07.

5. Carrano, J. *Chemical and Biological Sensor Standards Study*; Defense Advanced Research Projects Agency: 04.

6. Carrano, J.; Jeys, T. *Chemical and Biological Sensor Standards Study II*; Defense Advanced Research Projects Agency and Defense Threat Reduction Agency: 10.

7. Gillerman, G. Making the Confidence Connection. *Standardization News,* 2004.

8. National Science & Technology Council Committee on Homeland & National Security *A National Strategy for CBRNE Standards*; 11.

9. *E2411-07 Standard Specification for Chemical Warfare Vapor Detector (CWVD)*; ASTM International: West Conshohocken, PA, USA, 07.

10. Committee on Acute Exposure Guideline Levels; Committee on Toxicology; National Research Council *Acute Exposure Guideline Levels for Selected Airborne Contaminants Volume 9*; National Academies Press: 10.