THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

The Business of Innovation

ETV Joint Verification Statement

TECHNOLOGY TYPE: **SURFACE ACOUSTIC WAVE/ELECTROCHEMICAL DETECTOR**

APPLICATION: **DETECTION OF CHEMICAL WARFARE AGENTS AND TOXIC INDUSTRIAL CHEMICALS**

TECHNOLOGY NAME: **HAZMATCAD Plus**

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The U.S. Environmental Protection Agency (EPA) supports the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies. Information and ETV documents are available at www.epa.gov/etv.

ETV works in partnership with recognized standards and testing organizations, with stakeholder groups (consisting of buyers, vendor organizations, and permitters), and with individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance (QA) protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

Subsequent to the terrorist attacks of September 11, 2001, this ETV approach has been applied to verify the performance of homeland security technologies. Monitoring and detection technologies for the protection of public buildings and other public spaces fall within the Safe Buildings Monitoring and Detection Technology Verification Program, which is funded by EPA and conducted by Battelle. In this program, Battelle recently evaluated the performance of the Microsensor Systems Inc. HAZMATCAD Plus portable detector, which uses surface acoustic wave (SAW) and electrochemical (EC) technologies for detecting chemical warfare (CW) agents and toxic industrial chemicals (TICs), respectively. This verification statement, the full report on which it is based, and the test/QA plan for this verification are available through a link on the ETV Web site (www.epa.gov/etv/centers/center11.html).

VERIFICATION TEST DESCRIPTION

The objective of this verification test of the HAZMATCAD Plus, a commercially available, portable detector, was to evaluate its ability to detect TICs and CW agents in indoor air. This verification focused on the scenario of a portable detector used by first responders to identify contaminants and guide emergency response activities after chemical contamination of a building. The following performance characteristics of the HAZMATCAD Plus were evaluated: response time, recovery time, identification accuracy, repeatability, response threshold, temperature and humidity effects, interference effects, cold-/hot-start behavior, battery life, and operational characteristics. Repeatability was assessed for the HAZMATCAD Plus responses, response times, and recovery times.

This verification test took place between May 4 and August 27, 2004.Two units of the HAZMATCAD Plus were tested simultaneously in most parts of this verification; in testing with sarin (GB), the absence of response from one HAZMATCAD Plus unit required that testing continue with just one instrument. Response time, recovery time, accuracy, and repeatability were evaluated by challenging the HAZMATCAD Plus with known vapor concentrations of target TICs and CW agents. The HAZMATCAD Plus performance at low target analyte concentrations was evaluated to assess the response threshold. Similar tests conducted over a range of temperatures and relative humidities (RHs) were used to establish the effects of these factors on detection capabilities. The effects of potential interferences in an emergency situation were assessed by sampling selected interferences both with and without the target TICs and CW agents present. The HAZMATCAD Plus was tested with a single TIC after a cold start (i.e., without the usual warm-up period) from room temperature, from cold storage conditions (5°C), and from hot storage (40°C) to evaluate the delay time before readings could be obtained and the response speed and accuracy of the HAZMATCAD Plus once readings were obtained. Battery life was determined as the time until the HAZMATCAD Plus performance degraded as battery power was exhausted, in continuous operation. Operational factors such as ease of use, data output, and cost were assessed by observations of the test personnel and through inquiries to the vendor.

Testing was limited to detecting chemicals in the vapor phase because that mode of application was judged most relevant to use by first responders. Testing was conducted in two phases: detection of TICs (conducted in a non-surety laboratory at Battelle) and detection of CW agents (conducted in a certified surety laboratory at Battelle's Hazardous Materials Research Center). The TICs used in testing were cyanogen chloride (ClCN; North Atlantic Treaty Organization [NATO] military designation CK), hydrogen cyanide (HCN; designated AC), phosgene ($COCl_2$; designated CG), chlorine ($C1_2$; no military designation), and arsine (AsH_3; designated SA). The CW agents were GB and sulfur mustard (HD). The HAZMATCAD Plus was not programmed to respond to CK, so testing with that TIC was minimal.

For relevance to use by first responders, most test procedures were conducted with challenge concentrations of the TIC or CW agent that were at or near immediately dangerous to life and health (IDLH) or similar levels. The table below summarizes the challenge concentrations used in testing. Response thresholds were tested by repeatedly stepping down in concentration.

QA oversight of verification testing was provided by Battelle and EPA. Battelle QA staff conducted a technical systems audit (TSA), a performance evaluation audit, and a data quality audit of all the test data. An independent TSA was also conducted by EPA.

Target TIC and CW Agent Challenge Concentrations

Chemical	Concentrations	Type of Level
AC	50 parts per million (ppm) [50 milligrams per cubic meter (mg/m^3)]	IDLH(a)
CK	20 ppm (50 mg/m^3)	IDLH
CG	2 ppm (8 mg/m^3)	IDLH
SA	3 ppm (10 mg/m^3)	IDLH
Cl_2	10 ppm (30 mg/m^3)	IDLH
GB	0.39 ppm (2.2 mg/m^3)	11*IDLH
HD	0.6 ppm (4 mg/m^3)	7*AEGL(b)

(a) IDLH value for CK estimated from value for AC.
(b) AEGL = Acute Exposure Guideline Level; AEGL-2 levels are those expected to produce a serious hindrance to efforts to escape in the general population. The AEGL-2 value of 0.09 ppm (0.6 mg/m^3) for HD is based on a 10-minute exposure.

TECHNOLOGY DESCRIPTION

The following description of the HAZMATCAD Plus was provided by the vendor and does not represent verified information.

The HAZMATCAD Plus is a hybrid system using SAW sensors and ECs to detect CW agents and TICs, respectively. SAW sensors are small, solid-state devices that are extremely sensitive to minute changes in mass. These devices are coated with specific polymers that selectively absorb contaminants. The polymer surface responds rapidly and reversibly to nerve and blister agents. Using an array of three coated SAW sensors provides a response pattern that is unique to CW agents. The architecture of the SAW system allows for a high level of specificity in a complex sample. A preconcentrator is used to prepare sample for delivery to the SAW array. In this test the HAZMATCAD Plus was operated in its “Fast” response mode, which employs a 20-second preconcentration cycle. The ECs are semi-selective and provide a rapid response to contaminants. Amperometric ECs use an electrolyte that is sealed behind a gas-permeable membrane. Gases and vapors diffuse through the membrane and dissolve in the electrolyte. Subsequent oxidation/reduction processes release electrons that are collected at an electrode. The resulting current signal is proportional to the amount of gas or vapor sampled.

HAZMATCAD Plus software logs and date stamps all alarms or system faults. The HAZMATCAD Plus weighs 1.5 kilograms (3.4 pounds) including batteries.

VERIFICATION OF PERFORMANCE

The performance of the HAZMATCAD Plus is summarized below.

Response Time: In nearly all cases, the HAZMATCAD Plus provided an audible and visual alarm within 3 to 20 seconds after exposure to AC, CG, SA, or Cl_2 over the range of temperature and humidity tested (5 to 35°C; <20 to >80% RH). Over the different temperatures and humidities, response time ranges for GB and HD were from 21 to 42 seconds and 15 to 177 seconds, respectively. Over the ranges of 5 to 35ºC and <20 to >80% RH, temperature and RH had no practically significant effect on response time for any TIC or CW agent. Response times for AC were unaffected by operating the HAZMATCAD Plus from a cold start (i.e., with insufficient warm-up time).

Recovery Time: HAZMATCAD Plus recovery times (i.e., the time needed for the HAZMATCAD Plus to return to baseline after the end of exposure to a TIC or CW agent) varied widely, depending on the TIC or CW agent sampled and also on the sampling conditions. Recovery times differed considerably from one TIC to another. For

AC, modeled recovery times ranged from 76 to 361 seconds; for CG, from 36 to 57 seconds; for SA, from 23 to 25 seconds; and for Cl_2, 49 to 73 seconds. The effect of temperature on recovery time was small, except for AC, for which recovery times increased by about a factor of four as temperature decreased from 35°C to 5°C. Temperature had an effect on recovery time for GB and HD, with recovery times at 35°C less than half of those at 5°C or 22°C. All TICs had recovery times less than about 90 seconds under all RH conditions, with the exception of a modeled mean recovery time for AC of 131 seconds at medium (50%) RH. Recovery time for GB was slightly longer at higher humidity, whereas HD showed the opposite trend, with recovery time increased by about 50% at low (<20%) RH relative to high (>80%) RH. In operation from a cold start at normal temperature and humidity, the recovery time for AC was lengthened to over 600 seconds.

Accuracy: The HAZMATCAD Plus was nearly 100% accurate in identifying the TIC being sampled under all temperature and humidity conditions, with only one erroneous reading among nearly 250 data points. For HD, the response was 100% accurate under all temperature and humidity settings. For GB, one unit of the HAZMATCAD Plus did not alarm during testing. With the other unit, 100% accuracy was achieved for all conditions except the high humidity tests, where unstable responses or no responses were recorded.

(The Microsensor Systems vendor attributed this instability for GB at high humidity to a possible decrease in the collection efficiency of the concentrator in the SAW portion of the HAZMATCAD Plus as a result of exposure to the TICs during testing.)

Repeatability: The repeatability, or consistency, of HAZMATCAD Plus response, response times, and recovery times also was evaluated. Repeatability of response was always perfect under all levels of temperature and humidity for AC, CG, and SA. Cl_2 exhibited more variability in response. Repeatability of response for GB and HD was unaffected by temperature level. At the different humidity levels, HD had a consistent response. For GB, the response from the one HAZMATCAD Plus unit was consistent at low and medium humidities, but either no response or an unstable response was reported for GB at the high humidity. The modeled repeatability of response times for both TICs and CW agents showed no effect from the different levels of temperature or humidity. The modeled repeatability of recovery times for AC, CG, SA, GB, and HD showed no effect from the different temperature levels. The effect of temperature on the repeatability of recovery time was significant for Cl_2, with the recovery time most repeatable under medium temperature. The modeled repeatability of recovery times for CG, SA, Cl_2, GB, and HD showed no effect from the different humidity levels. The effect of humidity on the repeatability of recovery time was significant for AC, with the greatest variability for recovery time under medium humidity.

Response Threshold: The response thresholds of the HAZMATCAD Plus were 0.6 to 1.25 ppm for AC; 0.3 to 0.6 ppm for CG; 0.2 to 0.4 ppm for SA; 0.5 to 1 ppm for Cl_2, 0.6 to 1.1 mg/m^3 for GB; and 0.6 to 1.6 mg/m^3 and 1.6 to 4 mg/m^3 for HD on Units 22 and 27, respectively.

Temperature and Humidity Effects: The effects of temperature and RH on the HAZMATCAD Plus TIC response were small, with the largest effect that, at high temperature or high humidity, Cl_2 produced some Low rather than Medium responses. Temperature and RH also had no effect on HD response. For GB at low temperature, the response was consistently High, while at medium and high temperature, the response was consistently Medium. For GB at high humidity, the response was either an unstable response or no response.

Interference Effects: No false positive responses occurred. In terms of false negatives, however, neither HAZMATCAD Plus unit responded to GB in the presence of air freshener and latex paint fumes or to HD in the presence of ammonia cleaner and latex paint fumes. Interferents had almost no effect on response times for the TICs. The interferents showed an effect on the recovery time primarily for Cl_2, with all interferents increasing the Cl_2 recovery time substantially.

Cold-/Hot-Start Behavior: Operating the HAZMATCAD Plus with insufficient warm-up time showed no effect on the instrument response or response times for AC, regardless of whether the cold start occurred after storage at 5ºC, at room temperature, or at 40ºC. There was a strong effect on recovery time depending on start state, with the longest recovery time occurring at the room temperature cold-start condition. The delay time (time for the HAZMATCAD Plus unit to be ready for a first reading after start-up) ranged from 16 to 40 seconds.

Battery Life: The useful operating lives for fully charged batteries in two HAZMATCAD Plus units in continuous operation were found to be 9 hours and 49 minutes and 10 hours and 53 minutes, respectively. Both units showed rapid response and consistent readings throughout this test until the last few minutes of useful battery life.

Operational Characteristics: In general, the HAZMATCAD Plus was easy to use, gave clear alarms and a readable and informative display, and provided useful error messages. Batteries are easy to obtain and install, and new batteries can be installed without interrupting continuous operation. The only operational limitation was the failure of one unit to respond during GB testing.

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