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U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

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DOMESTIC PREPAREDNESS PROGRAM EVALUATION OF THE RAID-M (BRUKER SAXONIA ANALYTIK GmbH RAPID ALARM AND IDENTIFICATION DEVICE - MONITOR) AGAINST CHEMICAL WARFARE AGENTS SUMMARY REPORT

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14. ABSTRACT
This report characterizes the chemical warfare (CW) agent detection characteristics of the commercially available RAID-M. This instrument is an ion mobility spectrometer designed for detection and monitoring of chemical warfare agents. The instrument was tested against HD, GB, and GA vapor under various conditions. This report provides the emergency responders concerned with CW agent detection and verification an overview of the capabilities of the RAID-M.

15. SUBJECT TERMS

HD	Chemical Warfare Agent (CWA) Detection	Interference testing
GB	Ion Mobility Spectrometer (IMS)	
GA	Detector testing	

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PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Edgewood Chemical Biological Center (ECBC), Homeland Defense Business Unit. This work was started in April 2002 and was completed in October 2002.

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SUMMARY REPORT

1. INTRODUCTION

The Department of Defense (DOD) formed the Domestic Preparedness (DP) Program in 1996 in response to Public Law 104-201. One of the objectives is to enhance federal, state, and local capabilities to respond to Nuclear, Biological and Chemical (NBC) terrorism incidents. Emergency responders who encounter either a contaminated or a potentially contaminated area must survey the area for the presence of either toxic or explosive vapors. Presently, the vapor detectors commonly used are not designed to detect and identify chemical warfare (CW) agents. Little data are available concerning the ability of these commonly used, commercially available detection devices to detect CW agents. Under the DP Expert Assistance (Test Equipment) Program, the U.S. Army Soldier and Biological Chemical Command (SBCCOM) established a program to address this need. The Applied Test Team (ATT), Aberdeen Proving Ground, Maryland, performed the testing. ATT is tasked with providing the necessary information to aid authorities in the selection of detection equipment applicable to their needs.

Reports of the instrument evaluations are posted in the Homeland Defense website (http://www.ecbc.army.mil/hld) for public access. Instruments evaluated and reported on, since 1998, include:

- MiniRAE plus from RAE Systems, Incorporated (Sunnyvale, CA)
- Passport II Organic Vapor Monitor from Mine Safety Appliance Company (Pittsburgh, PA)
- PI-101 Trace Gas Analyzer from HNU Systems, Incorporated (Newton, MA)
- TVA 1000B Toxic Vapor Analyzer (PID and FID) from Foxboro Company (Foxboro, MA)
- Draeger Colorimetric Tubes (Thioether and Phosphoric Acid Ester) from Draeger Safety, Incorporated (Pittsburgh, PA)
- Photovac MicroFID detector from Perkin-Elmer Corporation (Wellesley, MA)
- MIRAN SapphIRe Air Analyzer from Foxboro Company (Foxboro, MA)
- MSA Colorimetric Tubes (HD and Phosphoric Acid Ester) from Mine Safety Appliances Company (Pittsburgh, PA)
- M90-D1-C Chemical Warfare Detector from Environics OY, Finland
- APD2000 Detectors from Environmental Technologies Group, Incorporated (Baltimore, MD)
- SAW MiniCAD mkII from Microsensor Systems, Incorporated (Apopka, FL)
- UC AP2C Monitor from Proengin Incorporated, France

- ppbRAE Photo-Ionization Detector from RAE Systems, Incorporated (Sunnyvale, CA)
- SABRE2000 detector from Barringer Technologies, Incorporated (Warren, NJ)
- CAM (Type L) from Graseby Dynamics Ltd., United Kingdom
- VaporTracer System from Ion Track Instruments, Incorporated (Wilmington, MA)
- HAZMATCAD from Microsensor Systems, a Sawtek Company (Apopka, FL)
- GC-MS/FPD with Dynatherm System from Agilent (Columbia, MD)
- Scentoscreen GC from Sentex Systems, Incorporated (Fairfield, NJ)

In 2002, the evaluation of instruments continued using test items that were loaned to the DP program by their respective manufacturers. Viable candidate instruments were required to pass a pre-screening test. In exchange, the instruments were evaluated under the DP protocol and the manufacturers were permitted to take data during the evaluations. Instruments evaluated included:

- RAID-M from Bruker Saxonia Analytik GmbH (Leipzig, Germany)
- IMS2000 from Bruker Daltonics GmbH (Switzerland)
- Travel*IR* from SensIR Technologies (Danuby, CT)

Each of these evaluations will be reported separately. This report pertains to the evaluation of the RAID-M (Rapid Alarm and Identification Device - Monitor). A glossary of acronyms is provided at the end of the report.

2. OBJECTIVE

The objective of this report is to assess the capability and general characteristics of the RAID-M to detect CW agent vapors. The intent is to provide the emergency responders concerned with CW agent detection an overview of the detection capabilities of the instrument.

3. SCOPE

The agents used in this DP evaluation were tabun (GA), sarin (GB), and mustard (HD). These were chosen as representative CW agents. Test procedures followed the established DP Detector Test and Evaluation Protocol described in the Phase 1 Test Report.[1] The test concept was as follows:

- Determine the Minimum Detectable Level (MDL) where repeatable detection readings are achieved for each selected CW agent. The current military Joint Services Operational Requirements (JSOR)[2] served as a guide for detection sensitivity objectives.
- Investigate the effects of humidity and temperature on instrument performance.

• Observe the effects of potential interfering substances upon instrument performance both in the laboratory and in the field.

4. EQUIPMENT AND TEST PROCEDURES

4.1 Instrument Description.

The RAID-M (see Figure) is manufactured by Bruker Saxonia Analytik GmbH (Leipzig, Germany). Two units were loaned to the DP Program for inclusion in the 2002 detector evaluations. Summarizing from the Operators' Manual,[3] the RAID-M operates on the principle of ion mobility spectrometry (IMS). It is used to detect certain chemical substances in the air, to provide an automatic alarm at a preselected threshold and to monitor contaminated personnel or equipment. The RAID-M is designed for one-handed operation in both stationary and mobile situations. The RAID-M can be powered by battery or by power supply.

The RAID-M is a continuous autonomous air monitor for detecting the presence of chemical substances and reporting with visual and audible alarms. The RAID-M also identifies the detected substances by their specific agent name and gives an indication of the agent concentration. The identity of substances detected is indicated by class ("G" for nerve agents or "H" for blister agents), or else the specific agent or simulant identity is displayed. Hazard levels are indicated by an incremental hazard level display that illuminates up to eight bars. The list of detectable substances is included in a library contained in the instrument. This list may be changed by loading a user-specific library (optional).

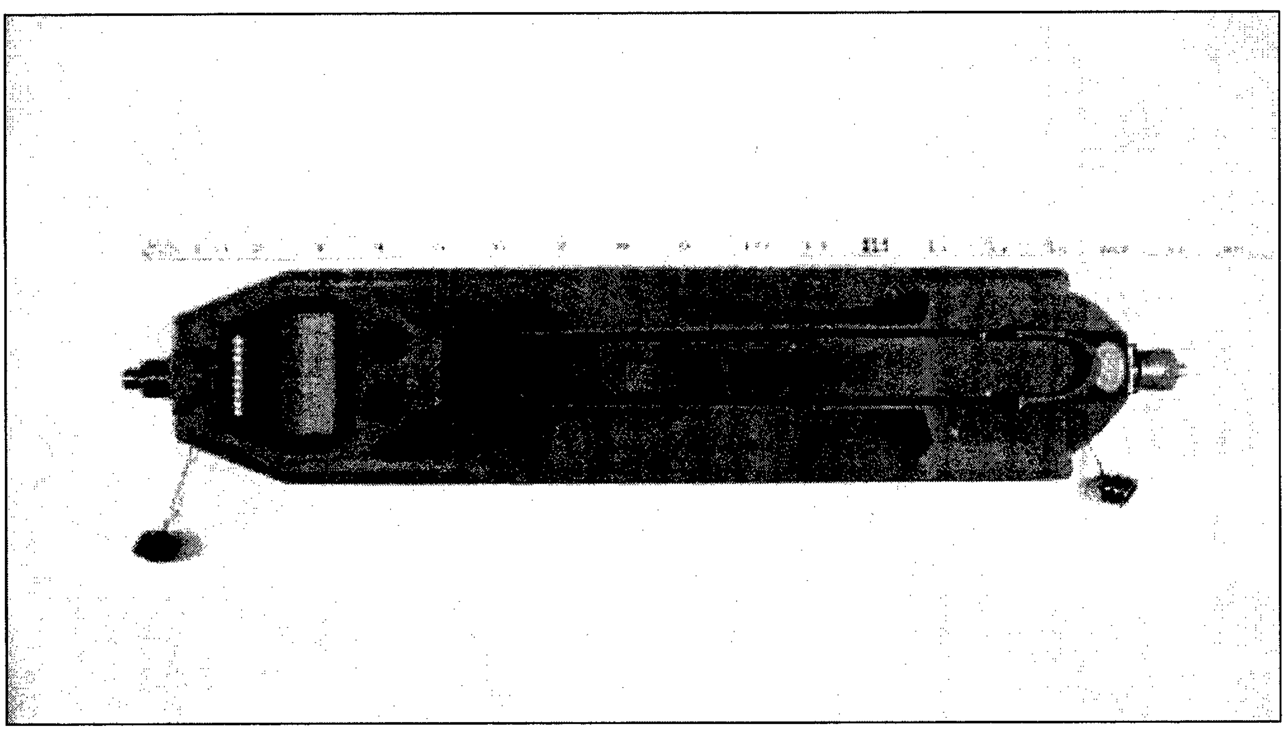

Figure. Bruker Saxonia Analytik GmbH RAID-M

The RAID-M is an IMS that measures the drift time of different ionized molecules within a drift tube at atmospheric pressure (time of flight measurement). A micro-controller and on-board analytical software perform the substance identification. The RAID-M uses within its sensor cell a radioactive source (^{63}Ni Beta radiator), which is required for the ionization process.

4.2 Calibration.

Operating procedures were followed according to the operator's handbook. No daily instrument calibration, except for a confidence check, is required by the manufacturer to place the RAID-M into operation. When the instrument is switched on and the internal self-test is successful, the RAID-M automatically starts measuring in the SAMPLE mode (measurement). The instrument is then ready for a confidence test. The instrument performance is verified daily using the blue confidence pen and the yellow confidence pen (confidence test samples) provided by the manufacturer. The blue confidence pen contains the simulant for the "G" (nerve) agents and yellow confidence pen contains the simulant for "H" (blister) agent. If the detector is working properly, an alarm will occur after a 3 sec exposure to each of these simulants. When the alarm level is reached the alarm will sound and a visual warning is displayed (flashing red light). The RAID-M changes automatically to back flush when the amount of agent or simulant reaches a certain level. This is indicated with the back flush symbol in the status field. When the alarm is cleared from one confidence pen, the process is repeated using the other confidence pen. The confidence pen simulants are identified in the library and are indicated on the display unit of the RAID-M with the appropriate 'GSI' for nerve (G) simulant and HSI for blister (H) simulant. Care must be taken so that the pen does not physically come into contact with the air inlet itself.

4.3 Agent Vapor Challenge.

The agent challenges were conducted using the Multi-Purpose Chemical Agent Vapor Generation System[4] using Chemical Agent Standard Analytical Reference Material (CASARM) grade or the highest purity CW agents available. Agent challenge followed successful instrument warm up and confidence check. The vapor generator system permits testing of the instrument with humidity and temperature-conditioned air without agent vapor before challenging it with similarly conditioned air containing the CW agent vapor. This is to assure that the background air does not interfere with the instrument.

The RAID-M air inlet was placed under the cup-like sampling port of the vapor generator and exposed to the conditioned air to establish a stable background before agent challenges. Agent challenge begins when the solenoids of the vapor generation system are energized to switch the air streams from conditioned air only to similarly conditioned air containing the agent. The instrument immediately begins to sample. The time that the detector was exposed to the agent vapor until it first alarmed was recorded as the response time. The time required for the instrument to stop alarming after the sample run was noted as the recovery time.

The instruments were tested with the agents GA, GB, and HD at several concentration levels at ambient temperatures (20-27 °C) and 50% RH to determine the MDL for each agent. The instruments were then tested at the determined MDL concentrations, ambient temperatures, and both <5% and >78% RH conditions to observe potential humidity effects. Each unit was tested three times under each condition when possible. Two units, 019 and 025, were provided for testing. These two units were tested at this facility (ATT) previously this year under a separate Test Services Agreement (TSA) No. 0204T following the procedure outlined in the DP protocol. Results from this TSA have been incorporated into this report since the test conditions were quite similar to the DP Program.

High temperature tests were conducted at +45 °C for GA, GB, and HD. The effects of low temperature were assessed by testing at –19 °C for GA, -20 °C for GB, and 0 °C for HD. Although HD freezes at approximately +15 °C, the calculated HD volatility of 92 mg/m^3 at 0 °C easily produces a vapor concentration higher than the 2 mg/m^3 JSOR detection criterion, allowing the instrument to be evaluated against HD down to 0 °C.

4.4 Agent Vapor Quantification.

The generated agent vapor concentrations were analyzed independently and reported in the data tables. The vapor concentration was quantified by utilizing the manual sample collection methodology[5] using the Miniature Continuous Air Monitoring System (MINICAMS®) manufactured by O. I. Analytical, Inc. (Birmingham, AL). The MINICAMS® is equipped with a flame photometric detector (FPD), and was operated in either phosphorus mode for the GA and GB agents or sulfur mode for HD.

The MINICAMS® normally monitors air by collection through sample lines and subsequently adsorbing the CW agent onto the solid sorbent contained in a glass tube referred to as the pre-concentrator tube (PCT). The PCT is located after the MINICAMS® inlet. The concentrated sample is periodically heat desorbed into a gas chromatographic capillary column for subsequent separation, identification, and quantification.

For manual sample collection, the PCT was removed from the MINICAMS® during the sampling cycle and connected to a measured suction source to draw the vapor sample directly from the agent generator. The PCT was then re-inserted into the MINICAMS® for analysis. This "manual sample collection" methodology eliminates potential loss of sample along the sampling lines and the inlet assembly when the MINICAMS® is used as an analytical instrument.

The calibration of the MINICAMS® was performed daily using the appropriate standards for the agent of interest. The measured mass equivalent (derived from the MINICAMS chromatogram) divided by the total volume (flow rate multiplied by time) of the vapor sample drawn through the PCT produced the sample concentration that converts into milligrams/cubic meter.

4.5 Field Interference Tests.

The instruments were tested outdoors in the presence of common potential interferents such as the vapors from gasoline, diesel fuel, jet propulsion fuel (JP8), kerosene, Aqueous Film Forming Foam (AFFF, used for fire fighting) and household chlorine bleach. Vapor from a 10% calcium hypochlorite solution (HTH slurry, a chlorinating decontaminant for CW agents), engine exhausts, burning fuels, and other burning materials were also tested. The objective was to assess the ability of the instruments to withstand outdoor environments and to resist false alarm responses when exposed to the selected substances. In these tests, no CW agent was present.

The field tests were conducted outdoors at M-Field of the Edgewood Area, Aberdeen Proving Ground, in September 2002. These experiments involved open containers, truck engines, and fires producing smoke plumes, which were sampled by the detectors at various distances downwind. The RAID-M units were exposed to either the smoke or fume test plume to achieve moderate concentrations (e.g., 1-4 ft for vapor fumes and 8-15 ft for smokes).

Confidence checks were performed on each unit at the beginning of each testing day. The two units were exposed to each interferent for approximately 5 min for three trials when possible. Testing continued with the next challenge after the instruments were thoroughly recovered from prior exposure.

4.6 Laboratory Interference Tests.

The laboratory interference tests were designed to assess the effect on the detectors of vapor exposure from potential interfering substances. The substances were chosen based on the likelihood of their presence during an emergency response by first responders. Additionally, tests were conducted to assess the CW agent detection capability in the presence of these interferent vapors. Only HD and one nerve agent, GA, were tested in the laboratory interference testing due to time constraints.

The RAID-M units were tested against 1% of the saturated headspace concentrations of gasoline, JP8, diesel fuel, household chlorine bleach, floor wax, AFFF, Spray 9 cleaner, Windex, toluene, antifreeze and vinegar vapors. They were also tested against 25 ppm NH_3 (ammonia). If the detector false alarmed at 1% concentration, it was tested at the 0.1% concentration of the substance.

To generate the respective vapor concentrations, a dry air stream carried the headspace vapor of the substance by sweeping it over the liquid in a tube or through the liquid in a bubbler to prepare the interferent gas mixture. For example, 30 ml/min or 3 ml/min of this vapor saturated air diluted to 3 L/min with conditioned air for interferent only tests or diluted with the CW agent stream for interferent plus agent tests produce either the 1% or 0.1% concentration of interferent test mixture, respectively. The 25 ppm ammonia was derived from an analyzed 1% NH_3 (10,000 ppm) compressed gas cylinder diluted with the appropriate amount of the conditioned air. The two units were tested three times with each combination of agent plus interferent at ambient temperatures and 50% RH.

5. RESULTS AND DISCUSSION

5.1 Minimum Detectable Levels (MDL).

The MDL values, with corresponding response times for the RAID-M units tested, are shown in Table 1 for each agent at ambient temperatures and 50 % RH. The MDL values represent the lowest CW agent concentration where identification of the CW agents occurred consistently for three trials. Concentrations are shown in both milligrams per cubic meter (mg/m^3) and parts-per-million (ppm) units. For comparison, the current military (JSOR) requirements[2] for CW agent sensitivity for point detection alarms, the U.S. Army's established values for Immediate Danger to Life or Health (IDLH), and the Airborne Exposure Limit (AEL) are also listed in Table 1. Army Regulation (AR) 385-61[5] is the source for the IDLH and AEL values for GA and GB, and the AEL value for HD. The AR 385-61 does not establish an IDLH for HD due to concerns over carcinogenicity.

The RAID-M units detected HD at 0.062 mg/m^3 in < 9 sec, which is well below the concentration and time requirements of the JSOR. The units detected GA at 0.072 mg/m^3 in < 74 sec and GB at 0.037 mg/m^3 in < 41 sec, which are both better (lower) than the JSOR and IDLH requirements. However, one of the units identified the GA detection as GB during the three trials. The units detected HD and GB in < 6 sec, and GA in < 67 sec at the approximate JSOR level. The units were unable to detect the AEL levels for GA, GB, or HD.

Table 1. Minimum Detectable Level (MDL) and Range of Response Times at Ambient Temperatures and 50% RH for the RAID-M

AGENT	Concentration in milligrams per cubic meter, mg/m^3, with parts per million values in parentheses (ppm), and Response Times			
	MDL	JSOR*	IDLH**	AEL***
HD	0.062 (0.0096) in 5-9 sec	2.0 (0.300) in 120 sec	N/A	0.003 (0.0005) up to 8 hr
GA	0.072**** (0.0107) in 32-74 sec	0.1 (0.015) in 30 sec	0.2 (0.03) up to 30 min	0.0001 (0.000015) up to 8 hr
GB	0.037 (0.0064) in 8-41 sec	0.1 (0.017) in 30 sec	0.2 (0.03) up to 30 min	0.0001 (0.000017) up to 8 hr

*Joint Service Operational Requirements for detectors.

**Immediate Danger to Life or Health values from the unclassified Army Regulation (AR) 385-61, Feb 1997, to determine level of CW protection. Personnel must wear either the full ensemble with SCBA for operations or full-face piece respirator for escape.

***Airborne Exposure Limit values from AR 385-61 to determine masking requirements. Personnel can operate for up to 8 hr unmasked.

****Unit 25 alarmed for GA but identified as GB.

5.2 Temperature and Humidity Effects.

Tables 2, 3, and 4 show the results of the RAID-M evaluation under various test conditions for agents HD, GA, and GB, respectively. Humidity effects tests were conducted at ambient temperatures and <5, ~50, and >78 % RH. The RAID-M manual states an operational temperature range of –20 to +45 °C for their instrument. The instruments were tested at these temperature extremes, within the operational range.

Table 2. RAID-M Responses to HD Vapor Concentrations Under Various Conditions

Average Conditions		HD Challenge Concentration		Response Time (sec)	Clear Time (sec)	Hazard Indicator Bars
Temperature, °C	% RH	mg/m³	ppm			
0	0	0.413	0.058	4-13	6-34	2-3
		2.024	0.285	3-6	10-37	5-8
		26.219	3.694	2-4	25-82	8
22-27	5	0.036	0.006	6-17	3-6	1
		2.280	0.353	2-5	15-18	8
		40.060	6.203	2-4	93-130	8
	50	0.062	0.010	5-9	3-5	1
		2.290	0.354	2-5	7-18	8
		35.959	5.568	2-6	32-55	8
	84-90	0.082	0.013	7-21	5-8	1
		2.153	0.333	2-5	7-13	3-8
		35.279	5.462	2-5	18-36	3-8
45	45	1.038	0.170	4-9	4-13	1-2
		2.364	0.388	4-7	3-16	2-5
		14.290	2.345	2-6	12-36	4-8

Table 3. RAID-M Responses to GA Vapor Concentrations Under Various Conditions

Average Conditions		GA Challenge Concentration		Response Time (sec)	Clear Time (sec)	Hazard Indicator Bars
Temperature, °C	% RH	mg/m³	ppm			
-19	1	0.071	0.009	74-100	8-46	1*
-19	1	0.116	0.015	45-87	6-50	1*
22-24	4	0.061	0.009	28-67	9-28	1**
	49-53	0.072	0.011	32-74	8-16	1**
		0.134	0.020	17-67	10-30	1-2***
		0.999	0.149	6-7	50-105	8****
	78	0.117	0.018	18-101	4-18	1
45	34	0.158	0.026	54-79	6-9	1*

*Unit 25 failed to power on correctly, therefore only Unit 19 tested.

**Unit 25 alarmed GB only.

***Unit 25 alternated between I bar GA and 2 bar GB.

****Unit 25 alarmed 2 bars GA, then 8 bars GB.

Table 4. RAID-M Responses to GB Vapor Concentrations Under Various Conditions

Average Conditions		GB Challenge Concentration		Response Time (sec)	Clear Time (sec)	Hazard Indicator Bars
Temperature, °C	% RH	mg/m^3	ppm			
-20	0	0.105	0.016	18-31	3-7	1
		0.132	0.196	4-10	34-75	4-8
22	5	0.035	0.006	10-27	34	1
		0.098	0.017	4-7	3-6	1
		1.230	0.213	2-6	26-41	7-8
	50	0.037	0.006	8-41	2-5	1
		0.107	0.019	4-6	3-7	1
		0.920	0.159	2-6	14-25	8
	88	0.035	0.006	7-16	3-5	1
		0.100	0.017	4-6	5-12	1
		1.210	0.209	2-4	20-26	8
45	45	0.099	0.019	13-29	2-20	1
		1.290	0.240	1-13	0-190	2-7

The concentrations used to determine the temperature and humidity effects were based on the previously determined MDLs. Positive detection response is defined as three consistent responses in three independent trials for the agent at the temperature and RH so specified for both RAID-M units. The corresponding range of response times for the two units is given in each table.

Table 2 shows that the RAID-M demonstrated HD detection at ambient temperature and low RH levels (< 5%) below the previously determined MDLs. HD detection slightly above previously determined MDLs was noted at ambient temperature and high RH levels (> 84%). It appears that low and high temperatures had adverse effects on HD detection, requiring higher concentrations to cause an alarm. Concentrations six times higher than the MDL were required to cause an alarm at 0 °C, and concentrations seventeen times higher that the MDL were needed to cause an alarm at 45 °C. Recovery times for HD exposure, except at high concentrations, were < 34 sec. At high concentrations, the units required up to 130 sec for recovery.

Table 3 shows that the RAID-M demonstrated GA detection close to previously determined MDLs at low temperature and RH extremes. Higher RH at ambient temperature had very slight adverse effects on GA detection, requiring slightly higher concentrations to cause an alarm. Unit 25 experienced error messages and could not be powered on prior to low and high temperature testing. Therefore, Unit 25 could not be tested at high temperature or low temperature, and the data presented is from Unit 19 only. It appears that high temperature adversely affected GA detection, requiring twice the MDL concentration to cause an alarm. Recovery times for GA exposure, except at high concentrations, were < 50 sec. At high concentrations, the units required up to 105 sec for recovery.

Table 4 shows that the RAID-M demonstrated GB detection at previous MDLs at both high and low RH extremes in ambient temperatures. It appears that high and low temperatures had adverse effects on GB detection. Concentrations slightly higher than twice the MDL were required to cause an alarm at both the high (45 °C) and low (-20 °C) temperatures tested. Recovery times for GB exposure, except at high concentration at high temperature, were < 75 sec. At high concentration and temperature, the units required up to 190 sec for recovery.

5.3 Field Interference Tests.

The results of the field test interferent exposures are presented in Table 5 as number of alarms per number of trials. A false positive response indicates that the instrument showed agent detection response in the absence of CW agent when challenged with potential interferent substances. Field test conditions were 20-27 °C (68–81 °F) and 33-77 % RH, with gentle winds. Confidence checks were performed on both units at the start of each day.

Table 5. RAID-M Field Interference Testing Summary

INTERFERENT	Alarms/Trials, False Response ID	
	Unit 19	Unit 25
AFFF (6%) vapor	Not Working*	1/3 G
Clorox (6% bleach) vapor	Not Working*	0/3
Burning cardboard	2/3 L, VX	3/3 L
Burning cloth	1/3 L	3/3 L
Diesel revving - exhaust	Not Working*	0/3
Diesel vapor	0/3	0/3
Burning diesel	0/3	0/3
Gasoline engine idling - exhaust	Not Working*	0/3
Gasoline engine revving - exhaust	Not Working*	0/3
Gasoline vapor	0/3	0/3
Burning gasoline	1/3 H	0/3
HTH (10% calcium hypochlorite) vapor	0/3	0/3
JP8 vapor	0/3	0/3
Burning JP8	1/3 L	1/3 L
Kerosene vapor	Not Working*	0/3
Burning kerosene	Not Working*	0/3
Burning tire	1/3 L	0/3
Doused burning tire	1/1 VX	1/1 VX
Burning wood	3/3 L	2/3 L, VX
Doused burning wood	1/1 HSI	1/1 L
TOTAL Alarms/Trials	11/35 (31%)	12/56 (21%)

* Detector exhibited error message, "E051Dose Pump Error".

Each unit was tested three times with a 5-min exposure time against the listed interferents, when possible. As shown, the units were tested only one time against the doused fire and against the doused burning tire due to time constraints. During the test Unit 19 exhibited an error message "E051 Dose Pump Error" on various occasions. This error appeared for approximately 1/3 of the interferents tested. When it did not appear, the unit functioned properly. No maintenance engineers were available on site to troubleshoot this unit so it was reintroduced into the testing sequence when it was not displaying the error message.

Because the smokes appeared to coat the intake filters of the units, they were manually blown clean after each smoke test. Neither unit alarmed when exposed to bleach vapor, revving diesel exhaust, diesel vapor, burning diesel, gas exhaust revving, gas exhaust idling, gas vapor, HTH 10% vapor, JP8 vapor, kerosene vapor, and burning kerosene. A G alarm was noted when exposed to AFFF only. An L or VX alarm was noted when exposed to any burning item as well as the doused burning items. An H alarm was noted only on Unit 19 when exposed to burning gasoline and doused burning wood. The overall false positive alarm rates for both detectors across all tests were 23 of 91 trials (25%). The false positive alarm rates across all tests for Unit 19 was 11 of 35 trials (31%) and 12 of 56 trials (21%) for Unit 25.

Post field test responses against CW agent vapor challenges showed the RAID-M units to have no adverse residual effects from the field tests. Response characteristics were similar to the pre-field test results.

5.4 Laboratory Interference Tests.

The laboratory interference tests were conducted at ambient temperatures (22-30 °C) and approximately 50 % RH. The RAID-M units were tested against both HD and GA using concentrations above the previously determined MDL. The instruments were exposed to each interferent at 1% of saturation. If the units showed no response to an interferent then the units were exposed to the respective CW agent in the presence of the interferent. If 1% of saturation interfered with the instrument, the interferent was reduced to 0.1% of saturation. Each test was repeated three times.

Table 6 presents the results of exposing the RAID-M instruments to several potential interferents both in the presence of and without HD agent. The HD hazard indicator bar responses with corresponding response times are given for both agent-only detection response and agent-plus-interferent detection response.

The RAID-M units produced a false positive alarm to the following interferent substances at 1% of saturation: AFFF alarmed GA, floor wax alarmed GSI (Simulant), and JP8 alarmed VX. The 1% vinegar vapor prevented the units from detecting HD. However, one unit correctly responded to HD after the vinegar was reduced to the 0.1% saturation level, but at much lower number of bars. The units did not show a false positive alarm to any of the interferent substances at 0.1% of saturation during the tests.

Table 6. RAID-M Responses to 2 mg/m^3 (0.3 ppm) HD Vapor With and Without Interferents at Ambient Temperatures and 50% RH

Interferent			HD Challenge Without Interferent		HD Challenge Plus Interferent	
Interferent	Response, Number of Bars and Agent ID	Response Time	Response, Number of Bars and Agent ID	Response Time (sec)	Response, Number of Bars and Agent ID	Response Time (sec)
1% AFFF	1 GA*	3-4 min	8 HD	3	8 HD**	3-4
0.1% AFFF	None		8 HD	3-5	8 HD	3-4
25 ppm Ammonia	None		8 HD, Unit 25 8 AC, Unit 19	3-5	8 HD, Unit 25 8 AC, Unit 19	4-6
1% Antifreeze	None		2-8 HD	3-5	1-4 HD	4-9
1% Bleach	None		8 HD	3-4	8 HD	3-5
1% Diesel	None		8 HD	2-4	8 HD	2-5
1% Floor Wax	1 GSI	0.5-2 min	Not tested due to interference			
0.1% Floor Wax	None		8 HD, Unit 25 8 AC, Unit 19	4-7	8 HD, Unit 25 8 AC, Unit 19	4-6
1% Gasoline	None		8 HD	3-5	4-8 HD	3-6
1% JP8	3 VX	0.5-1 min	Not tested due to interference			
0.1% JP8	None		8 HD	4-5	4-8 HD	3-5
1% Spray 9™	None		8 HD	3-4	6-8 HD	3-5
1% Toluene	None		8 HD	3-5	8 HD	2-5
1% Vinegar	None		8 HD	4-5	No Response	
0.1% Vinegar	None		7-8 HD	4-6	1 HD***	6-15
1% Windex™	None		8 HD	4-5	8 HD	4-5

**False response for 1 out of 3 trials for both units.
***Both units false alarmed IGA in 1 out of 2 trials.
****Unit 19, 1 out of 3 trials showed no alarm.

Table 7 presents the results of exposing the RAID-M instruments to several potential interferents both with and without GA agent. If the units showed no response to an interferent then the units were exposed to GA in the presence of the interferent. The range of GA responses with corresponding response times are given for both agent-only detection response and agent-plus-interferent detection response.

Table 7. RAID-M Responses to 0.1 mg/m^3 (0.02 ppm) GA Vapor With and Without Interferents at Ambient Temperatures and 50 % RH

Interferent			GA Challenge Without Interferent		GA Challenge Plus Interferent	
Interferent	Response, Number of Bars and Agent ID	Response Time	Response, Number of Bars and Agent ID	Response Time, (sec)	Response, Number of Bars and Agent ID	Response Time, (sec)
1% AFFF	1 GA*	2-3 min	1 GA, Unit 19 1 GB, Unit 25	12-20	1 GA, Unit 19 1 GB, Unit 25	8-28
0.1% AFFF	None		1 GA, Unit 19 1 GB, Unit 25	10-18	1 GA, Unit 19 1 GB, Unit 25	9-18
25 ppm Ammonia	None		1 GA**	14-21	1 GA***	16-28
1% Antifreeze	None		1 GA, Unit 19 1 GB, Unit 25	11-23	1 GA, Unit 19 1 GB, Unit 25	16-28
1% Bleach	None		1 GA, Unit 19 1 GB, Unit 25	17-24	1 GA, Unit 19 1 GB, Unit 25	17-26
1% Diesel	None		1 GA, Unit 19 1 GB, Unit 25	18-22	1 GA, Unit 19 1 GB, Unit 25	17-22
1% Floor Wax	1 GSI	2-2.5 min	Not tested due to interference			
0.1% Floor Wax	None		1 GA, Unit 19 1 GB, Unit 25	11-18	1 GA, Unit 19 1 GB, Unit 25	8-19
1% Gasoline	None		1 GA, Unit 19 1 GB, Unit 25	11-19	1 GA, Unit 19 No response, Unit 25****	33-66
0.1% Gasoline	None		1 GA, Unit 19 1 GB, Unit 25	13-19	1 GA, Unit 19 1 GB, Unit 25	16-47
1% JP8	6 VX, Unit 19 only	4 min	Not tested due to interference on Unit 19			
0.1% JP8	None		1 GA, Unit 19 1 GB, Unit 25	12-19	1 GA, Unit 19 1 GB, Unit 25	15-21
1% Spray Nine	7 VX, Unit 25 only	<0.5 min	Not tested due to interference on Unit 25			
0.1% Spray Nine	1-5 VX, Unit 25 only	1-4 min	1 GA, Unit 19	18-21	4-5 GB, Unit 19 only	13-24
1% Toluene	None		1 GA, Unit 19 1 GB, Unit 25	14-20	1 GA, Unit 19 1 GB, Unit 25	16-22
1% Vinegar	None		1 GA, Unit 19 1 GB, Unit 25	16-30	1 GA, Unit 19 1 GB, Unit 25	16-27
1% Windex	2 GSI, Unit 19 1 VX, Unit 25	<1 min	Not tested due to interference			
0.1% Windex	1 VX, Unit 25 only	1-4 min	1 GA, Unit 19	18-123	1 GA, Unit 19	30-105

*False response for 1 out of 3 trials for both units.

**Unit 25 responded GB instead of GA in 2 out of 3 trials.

***Unit 25 responded GB instead of GA in 1 out of 3 trials.

****False negative response with agent at 1%, therefore interferent lowered to 0.1%.

The RAID-M units showed a false positive alarm to the following interferent substances at 1% of saturation: AFFF, floor wax, JP8, Spray Nine and Windex. The units also produced a false positive alarm to Windex and Spray Nine at 0.1% of saturation during these tests.

6. CONCLUSIONS

Conclusions are based solely on the results observed during this testing. Aspects of the detectors other than those described were not investigated.

Civilian first responders and HAZMAT personnel use Immediate Danger to Life or Health (IDLH) values to determine levels of protection for selection of personal protective equipment during consequence management of an incident. The minimum detection limit (MDL) of the RAID-M was below the IDLH and the current Joint Service Operational Requirement (JSOR) for point sampling detectors for all agents tested at ambient conditions. An approximately six-fold loss of sensitivity was noted at low temperature testing using HD and an approximately seventeen-fold loss of sensitivity was noted at high temperature testing using HD. No difficulty was noted at low or high temperature testing of GA. An approximately three-fold loss of sensitivity was noted at low and at high temperature testing using GB. The important thing to note is that even with these slight difficulties, detection was at or below the IDLH and JSOR levels. Most responses occurred in < 1 min. The instruments are sensitive and can detect chemical warfare (CW) agents quickly at ambient temperature. The RAID-M units were unable to detect HD, GA, or GB at the Airborne Exposure Limit (AEL) concentrations.

The overall false positive alarm rate observed during the field tests for both detectors was 25% (23 of 91). Field interferent testing showed false positive responses to most smokes but not burning fuels, indicating that the instrument might give false CW detection responses during smoky emergency situations when there may not be actual CW agent vapor present.

The controlled laboratory environment tests with potential interferent substance vapors showed false responses to 1% saturation of some interferents tested, as well as false responses to 0.1% saturation of some interferents. This is not an uncommon occurrence with interferent testing of vapor detectors. The ability to detect agent in the presence of a potentially interfering vapor, when the vapor itself does not cause a false alarm, was demonstrated. Only 1% vinegar vapor interference prevented detection of HD. HD detection response resumed when the vinegar vapor was lowered to the 0.1% level.

The RAID-M offers fast and sensitive detection warning for the presence of the CW agents tested, however the false responses to the interferents tested is a concern.

LITERATURE CITED

1. Longworth, Terri L. *Testing of Commercially Available Detectors Against Chemical Warfare Agents: Summary Report*; ECBC-TR-033, U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, 1999; UNCLASSIFIED Report (AD-A364 123).

2. United States Army Training and Doctrine Command, HQDA, Fort Monroe, VA, 3 Aug 90, *subject: Joint Service Operational Requirement (JSOR) for the Automatic Chemical Agent Detector Alarm (ACADA).*

3. *Operator's Handbook IMS2000™*, Bruker Daltonics GmbH, Switzerland, 2001.

4. Ong, Kwok Y. *Multi-Purpose Chemical Agent Vapor Generation System*; ERDEC-TR-424, U.S. Army Edgewood Research, Development and Engineering Center: Aberdeen Proving Ground, MD, 1997; UNCLASSIFIED Report (AD-B227 407).

5. *The Army Chemical Agent Safety Program*; Army Regulation 385-61; February 1997.

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GLOSSARY OF TERMS AND ACRONYMS

AEL	Airborne exposure limit
AFFF	Aqueous film forming foam, used for fire fighting
AR	Army regulation
ATT	Applied Test Team
CASARM	Chemical agent standard analytical reference material
CW	Chemical Warfare
DOD	Department of Defense
DP	Domestic Preparedness
FPD	Flame photometric detector
GA	Tabun, a CW agent
GB	Sarin, a CW agent
GS	A CW agent
GSI	"G" agent simulant response
HAZMAT	Hazardous materials
HD	Mustard, a CW agent
HSI	"H" agent simulant response
HTH slurry	Calcium hypochlorite solution, a chlorinating decontaminant for CW agents
IDLH	Immediate danger to life or health
IPE	Individual protective equipment
JP8	Jet propulsion fuel
JSOR	Joint Service Operational Requirements for Detectors
L	Lewisite, a CW agent
L/min	Liters per minute
MDL	Minimum detectable level
mg/m^3	Milligrams per cubic meter
MINICAMS®	Trade name for a chemical agent detector, the "Miniature Continuous Air Monitoring System"
mL/min	Milliliters per minute
NBC	Nuclear, biological and chemical
PCT	Pre-concentrator tube
ppm	Parts per million
RH	Relative humidity
Sarin	A CW agent, also called GB
SBCCOM	U.S. Army Soldier and Biological Chemical Command
SCBA	Self-contained breathing apparatus
TWA	Time-weighted average
VX	A CW agent