*System Assessment and Validation for Emergency Responders (SAVER)*

# Handheld Multi-Gas Meters Assessment Report

*July 2016*

Homeland Security
Science and Technology

U.S. Department of Homeland Security
SAVER
System Assessment and Validation for Emergency Responders

***Prepared by Los Alamos National Laboratory***

The *Handheld Multi-Gas Meters Assessment Plan* was funded under Interagency Agreement No. HSHQPM-15-X-00143 from the U.S. Department of Homeland Security, Science and Technology Directorate.



The cover photo and images included herein were provided by Los Alamos National Laboratory. Product images are courtesy of the respective vendor.

# FOREWORD

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercially available equipment and systems, and develops knowledge products that provide relevant equipment information to the emergency responder community. The SAVER Program mission includes:

- Conducting impartial, practitioner-relevant, operationally oriented assessments and validations of emergency response equipment
- Providing information, in the form of knowledge products, that enables decision-makers and responders to better select, procure, use, and maintain emergency response equipment.

SAVER Program knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the responder community: "What equipment is available?" and "How does it perform?" These knowledge products are shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is supported by a network of Technical Agents who perform assessment and validation activities. As a SAVER Program Technical Agent, Los Alamos National Laboratory (LANL) has been tasked to provide expertise and analysis on key subject areas, including chemical detection, and radiation detection and monitoring, among others. In support of this tasking, LANL will conduct an assessment of handheld multi-gas meters as outlined in this assessment plan. Handheld multi-gas meters fall under AEL reference number #07CD-01-DPMG titled Detector, Multi-sensor Meter, Point, Chemical.

For more information on the SAVER Program or to view additional reports on handheld multi-gas meters or other technologies, visit www.dhs.gov/science-and-technology/saver.

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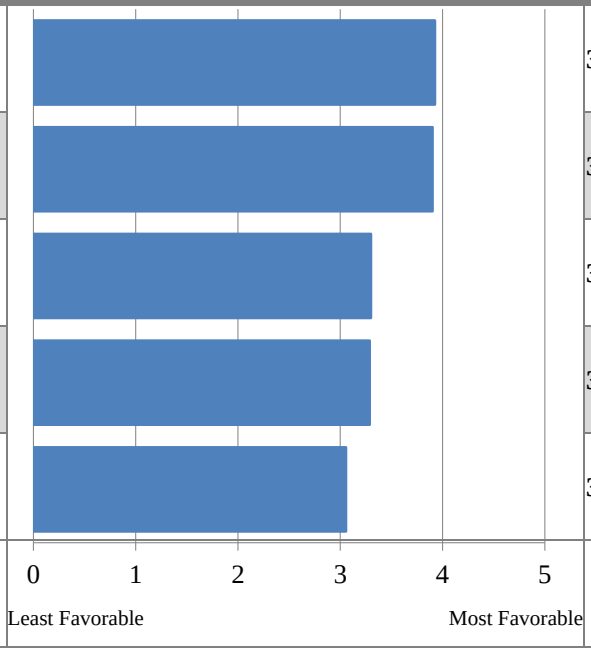
Handheld multi-gas meters (MGMs) are equipped with sensors to monitor oxygen ($O_2$) levels and additional sensors to detect the presence of combustible or toxic gases in the environment. This report is limited to operational response-type MGMs that include at least four different sensors. These sensors can vary by type and by the monitored chemical. In real time, the sensors report the concentration of monitored gases in the atmosphere near the MGM.

In April 2016 the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of MGMs.

Five MGMs were assessed by emergency responders. The criteria and scenarios used in this assessment were derived from the results of a focus group of emergency responders with experience in using MGMs. The assessment addressed 16 evaluation criteria in four SAVER categories: Usability, Capability, Maintainability, and Deployability. The overall results of the assessment are highlighted in the following table.

| Product | Overall Score | Overall | Usability | Capability | Maintainability | Deployability |
|---|---|---|---|---|---|---|
| RAE Systems by Honeywell / QRAE 3 | | **3.9** | 4.1 | 4.0 | 3.7 | 3.8 |
| Industrial Scientific / Ventis MX4 | | **3.9** | 3.8 | 3.9 | 3.8 | 4.2 |
| BW Technologies by Honeywell / Gas Alert Max XT II | | **3.3** | 3.6 | 2.8 | 3.3 | 3.6 |
| MSA / ALTAIR 4x | | **3.3** | 3.0 | 3.0 | 3.8 | 3.6 |
| Draeger Safety Inc. / X-AM 2500 | | **3.1** | 2.7 | 3.7 | 3.0 | 2.8 |



# 1. INTRODUCTION

Handheld multi-gas meters (MGMs) are equipped with sensors to monitor oxygen ($O_2$) levels and additional sensors to detect the presence of combustible or toxic gases in the environment. This report is limited to operational response-type MGMs that include at least four different sensors. These sensors can vary by type and by the monitored chemical. MGMs report the concentration of monitored gases in the atmosphere near the sensor in real time.

In April 2016 the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of MGMs. The purpose of this assessment was to obtain information on MGMs that will be useful in making operational and procurement decisions. The activities associated with this assessment were based on recommendations from a focus group of emergency responders with experience using MGMs.

## 1.1 Evaluator Information

Eight emergency responders from various jurisdictions and with at least 6 to 10 years of experience using MGMs were selected to be evaluators for the assessment. Evaluator information is listed in Table 1-1. Prior to the assessment, evaluators signed a nondisclosure agreement, conflict of interest statement, and photo release form.

**Table 1-1. Evaluator Information**

| Evaluator | Years | State |
|---|---|---|
| Firefighter CBRNE, CT, Hazmat, ICS, WMD | 20+ | CA |
| EPA, Hazmat, CBRNE, WMD | 20+ | FL |
| Firefighter, Hazmat, CT, WMD | 20+ | MD |
| Firefighter CBRNE, WMD | 16 - 20 | NM |
| Firefighter CBRNE, CT, HERT, ICS, WMD | 16 - 20 | VA |
| Firefighter CBRNE, CT, Hazmat, ICS, WMD | 11 - 15 | VA |
| Firefighter EMT, Hazmat | 11 - 15 | NM |
| Firefighter EMT, Hazmat, | 6 - 10 | NM |

Notes:
CBRNE—chemical, biological, radiological, nuclear, and
CT—counterterrorism
EMT – Emergency Medical Technician
EPA – Environmental Protection Agency
Hazmat—hazardous materials
HERT—hospital emergency response team
ICS—incident command system
WMD—weapons of mass destruction

## 1.2 Assessment Products

Five products were selected and purchased for the assessment based on market research and the focus group's recommendations. Final selection was based on how well each product met the product selection criteria identified by the focus group. The criteria required that the products be:

- Intrinsically safe
- Accept at least four gas sensors at a time, including oxygen ($O_2$), lower explosive limit (LEL), and two toxic gas sensors
- Include available sensors for $O_2$, LEL, hydrogen sulfide ($H_2S$), and carbon monoxide (CO), at a minimum
- Configurable for hands-free, unattended operation
- Feature a pump.

The products selected for assessment met all product selection criteria.

Table 1-2 presents the products that were assessed.

**Table 1-2. Assessed Products**

| Vendor | Product | Product Image |
|---|---|---|
| BW Technologies by Honeywell | Gas Alert Max XT II |  |
| Draeger Safety Inc. | X-AM® 2500 |  |
| Industrial Scientific | Ventis™ MX4 | IMAGE AVENTIS MX FOUR  |
| Mine Safety Appliances (MSA) | ALTAIR® 4x |  |
| RAE® Systems by Honeywell | QRAE 3 |  |

# 2. EVALUATION CRITERIA

The SAVER Program assesses products based on criteria in five established categories:

- **Affordability** groups criteria related to the total cost of ownership over the life of the product. This includes purchase price, training costs, warranty costs, recurring costs, and maintenance costs
- **Capability** groups criteria related to product features or functions needed to perform one or more responder relevant tasks
- **Deployability** groups criteria related to preparing to use the product, including transport, setup, training, and operational/deployment restrictions
- **Maintainability** groups criteria related to the routine maintenance and minor repairs performed by responders, as well as included warranty terms, duration, and coverage
- **Usability** groups criteria related to ergonomics and the relative ease of use when performing one or more responder relevant tasks.

The focus group of emergency responders met in November 2015 and identified 16 evaluation criteria within four SAVER categories: Capability, Deployability, Maintainability, and Usability. They assigned a weight for each criterion's level of importance on a scale of 1 to 5, with 1 being somewhat important and 5 being of utmost importance. The SAVER categories were assigned a percentage to represent each category's importance relative to the other categories. The focus group discussed the Affordability category but did not identify any evaluation criteria for that category.

Products were assessed against 16 evaluation criteria. Table 2-1 presents the evaluation criteria and their associated weights as well as the percentages assigned to the SAVER categories. Refer to Appendix A**Error! Reference source not found.** for evaluation criteria definitions.

**Table 2-1. Evaluation Criteria**

| SAVER CATEGORIES | | | |
|---|---|---|---|
| **Usability** | **Capability** | **Maintainability** | **Deployability** |
| Overall Weight 35% | Overall Weight 27% | Overall Weight 23% | Overall Weight 15% |
| **Evaluation Criteria** | | | |
| **Alarms** Weight: 5 | **Sensors** Weight: 5 | **Calibration** Weight: 5 | **Durability** Weight: 4 |
| **Ergonomics** Weight: 5 | **Power Source** Weight: 4 | **Maintenance** Weight: 4 | **Startup** Weight: 3 |
| **User Interface** Weight: 4 | **Accessories** Weight: 4 | **Decontamination** Weight: 4 | **Training** Weight: 3 |
| **Portability** Weight: 5 | **Response Time** Weight: 3 | **Warranty and Repair** Weight: 4 | |
| | **Pump** Weight: 2 | | |

**Evaluators becoming familiar with an MGM.**

# 3. ASSESSMENT METHODOLOGY

The products were assessed over 3 days. On the first day of the assessment, a subject matter expert (SME) and facilitators presented a safety briefing and an overview of the assessment process, procedures, and schedule to the evaluators. Each product was then assessed in two phases: (1) specification assessment and (2) operational assessment.

## 3.1 Phase I/Specification Assessment

During the specification assessment, evaluators assessed each product based on product information taken from vendor literature and websites prior to the assessment.

## 3.2 Phase II/Operational Assessment

During the operational assessment, evaluators assessed each product based on their hands-on experience using the product after becoming familiar with its proper use, capabilities, and features. The SME and facilitators assisted the evaluators with product familiarization, and evaluators had access to the reference material included with each product. The products were assessed in four scenarios: (1) Setup Scenario, (2) Confined Space Scenario, (3) Material Spill Scenario, and (4) Review Scenario. Evaluators used the products one at a time and completed the assessment worksheets for each product before assessing the next product.

### 3.2.1 Setup Scenario

**Evaluators preparing for the Confined Space scenario.**

During the setup scenario, Evaluators received training from the SME and reviewed manufacturer-provided training materials and user manuals. Evaluators inspected the sturdiness of the controls and determined if the meter featured covered ports and/or a sealed battery compartment. Then, evaluators followed the manufacturer-recommended startup procedures. After the meter was ready, evaluators cycled through the available instrument modes and then powered off the meter. Evaluators then followed the manufacturer-recommended decontamination procedure (dry run – no actual chemicals). Last, the evaluators powered on the meter, caused the meter to alarm by blocking the intake with a finger, and then silenced the alarm. As appropriate in an assessment setting, evaluators performed manufacturer-recommended maintenance as specified in the user manual. For maintenance activities not appropriate in an assessment setting, they evaluated the procedures rather than performing them. Evaluators used these tasks to rate the Alarms, User Interface, Power Source, Maintenance, Decontamination, Durability, Startup and Training Criteria.

**Evaluators using the MGMs in low-light.**

**Evaluators preparing for and taking readings in the tunnel that contained the low-oxygen level box.**

Due to the potential of damaging a working sensor during replacement and to minimize equipment costs, this task occurred at the end of the assessment, though still part of the Setup Scenario. After each team took each meter through the Assessment Procedures, as a group, the evaluators followed the recommended manufacturer instructions for replacing a bad sensor with a good sensor. Where practical, the evaluators performed the task, where impractical (e.g., special screws, complex parts, or likely damage), the evaluators noted the required tasks and evaluated the apparent difficulty or issues based on the recommended procedure documentation rather than performing the task. Evaluators then followed manufacturer-recommended procedures to remove and replace the battery.

### 3.2.2 Confined Space Scenario

This scenario simulated operational use of meters in a confined space. Evaluators wore a turn-out coat, breathing rig harness (without the tank), bunker gloves, and a self-contained breathing apparatus (SCBA)-capable mask. Starting outdoors, evaluators powered on the meter and verified that it was ready for operation while noting the readability of the display in bright sunlight. Next, evaluators entered a dimly lit confined space and took several readings near vents and near the floor to determine if the space was non-hazardous (i.e., no harmful conditions were present). Evaluators then proceeded to another connected space where a box containing a low-oxygen environment was located behind an obstacle. Evaluators took a reading of the box contents to determine the conditions inside the box. The low-oxygen environment inside the box triggered the meter to alarm, and evaluators observed and then silenced the resulting alarm.

**Evaluators taking readings at the Material Spill scenario with short (left image) and long (right image) tubes**

Evaluators used these tasks to rate the Alarms, Ergonomics, User Interface and Portability Criteria.

### 3.2.3 Material Spill Scenario

This scenario simulated meter operation during a response to a material spill. The scenario occurred indoors. Evaluators assessed two containers. Evaluators attached a 1-foot tube to the meter and took measurements of a bucket containing a high-vapor pressure flammable liquid (isopropyl alcohol) and a bucket containing a low-vapor pressure flammable liquid (diesel fuel and gasoline mix) and noted the time to alarm for each before acknowledging and silencing the alarm. Then evaluators attached a 10-foot tube to the meter and measured both liquids again, noting the time to alarm for each before acknowledging and silencing the alarm. Evaluators used these tasks to rate the Alarms, Ergonomics, User Interface, Portability, Response Time and Calibration Criteria.

### 3.2.4 Review Scenario

During this scenario, evaluators reviewed the attachment options included with the meter and observed the overall size and weight of the meter to assess Portability. Evaluators also assessed Training based on how helpful the manufacturer-provided manuals and instructions were while completing the confined space and material spill scenarios. Once all evaluators assessed all meters for Portability and Training in this scenario, they inspected the meters to determine if any

damage occurred during the assessment. Evaluators also consolidated and reviewed scoring and comments for all the other stations before starting the next rotation.

## 3.3 Data Gathering and Analysis

Each evaluator was issued an assessment workbook that contained assessment procedures and worksheets for recording criteria ratings and comments. Evaluators used the following 1 to 5 scale:

1. The product *meets none* of my expectations for this criterion
2. The product *meets some* of my expectations for this criterion
3. The product *meets most* of my expectations for this criterion
4. The product *meets all* of my expectations for this criterion
5. The product *exceeds* my expectations for this criterion.

Criteria that were rated multiple times throughout the assessment were assigned final overall ratings by the evaluators. Evaluators and facilitators captured advantages and disadvantages of the assessed products as well as general comments on the MGM assessment and the assessment process. Once assessment activities were completed, evaluators had an opportunity to review their criteria ratings and comments for all products and make adjustments as necessary.

At the conclusion of the assessment activities, an overall assessment score, as well as category scores and criteria scores, were calculated for each product using the formulas referenced in Appendix B. In addition, evaluator comments for each product were reviewed and summarized for this assessment report.

# 4. ASSESSMENT RESULTS

Overall scores for the assessed products ranged from 3.1 to 3.9. Table 4-1 presents the overall assessment score and category scores for each product. Products are listed in order from highest to lowest overall assessment score throughout this section. Calculation of the overall score uses the raw scores for each category, prior to rounding. Products with the same rounded overall score are listed in order based on the raw data.

**Table 4-1. Assessment Results**

| Product | Overall Score | Overall | Usability | Capability | Maintainability | Deployability |
|---|---|---|---|---|---|---|
| RAE Systems by Honeywell / QRAE 3 | | **3.9** | 4.1 | 4.0 | 3.7 | 3.8 |
| Industrial Scientific / Ventis MX4 | | **3.9** | 3.8 | 3.9 | 3.8 | 4.2 |
| BW Technologies by Honeywell / Gas Alert Max XT II | | **3.3** | 3.6 | 2.8 | 3.3 | 3.6 |
| MSA / ALTAIR 4x | | **3.3** | 3.0 | 3.0 | 3.8 | 3.6 |
| Draeger Safety Inc. / X-AM 2500 | | **3.1** | 2.7 | 3.7 | 3.0 | 2.8 |

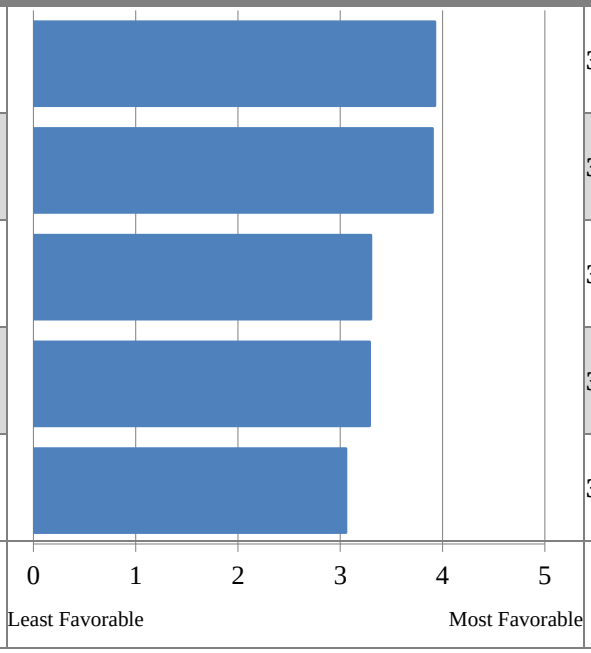



Table 4-2 presents the criteria ratings for each product. The ratings are graphically represented by colored and shaded circles. A green, fully shaded circle represents the highest rating. Refer to Appendix A for evaluation criteria definitions. Appendix A presents vendor-provided key specifications for the assessed products.

## Table 4-2. Criteria Ratings

| KEY<br>Least Favorable → Most Favorable |  |  |  |  |  |
|---|---|---|---|---|---|

| Category | Evaluation Criteria | QRAE 3 | Ventis MX4 | Gas Alert Max XT II | ALTAIR 4x | X-AM 2500 |
|---|---|---|---|---|---|---|
| **Usability** | Alarms | ● | ◕ | ◕ | ◑ | ◑ |
| | Ergonomics | ◕ | ◕ | ◑ | ◔ | ◑ |
| | User Interface | ◕ | ◕ | ◕ | ◕ | ◑ |
| | Portability | ◕ | ◕ | ◕ | ◑ | ◑ |
| **Capability** | Sensors | ◕ | ◕ | ◑ | ◑ | ◕ |
| | Power Source | ◕ | ● | ◔ | ◔ | ◕ |
| | Accessories | ◕ | ◕ | ◕ | ◕ | ◕ |
| | Response Time | ◕ | ◕ | ◑ | ◑ | ◕ |
| | Pump | ◕ | ◕ | ◑ | ◑ | ◑ |
| **Maintainability** | Calibration | ◕ | ◕ | ◕ | ◑ | ◑ |
| | Maintenance | ◕ | ◕ | ◔ | ◕ | ◑ |
| | Decontamination | ◑ | ◕ | ◕ | ◑ | ◑ |
| | Warranty and Repair | ◕ | ◕ | ◕ | ● | ◕ |
| **Deployability** | Durability | ◕ | ● | ◕ | ◑ | ◑ |
| | Startup | ◕ | ◕ | ◕ | ◕ | ◔ |
| | Training | ◕ | ◕ | ◑ | ◕ | ◑ |

## Table 4-3. Key Specifications

| Vendor | Product | Price as Assessed | # of Sim. Sensors | Weight (oz) | $O_2$ Sensor | %LEL Sensor | $H_2S$ Sensor | CO Sensor | Other Available Sensors |
|---|---|---|---|---|---|---|---|---|---|
| RAE | QRAE 3 | MGM $925; Confined Space Kit $220 | 4 | 14.5 | ✓ | ✓ | ✓ | ✓ | $NH_3$, $SO_2$, HCN, $PH_3$, $Cl_2$, $NO_2$ |
| Industrial Scientific | Ventis MX4 | MGM $1,375; Asssories $165 | 4 | 13.4 | ✓ | ✓ | ✓ | ✓ | $SO_2$, $NO_2$, combined CO/$H_2$ |
| BW Technologies by Honeywell | Gas Alert Max XT II | MGM $748; Confined Space Kit $475; | 4 | 11.1 | ✓ | ✓ | ✓ | ✓ | None |
| MSA | ALTAIR® 4x | MGM $1,061, Sampling Probe $249; Sampling Lines $138; Xcell Gas Sensors $208; Optional Pump $425 | 4 | 7.9 | ✓ | ✓ | ✓ | ✓ | $NO_2$ |
| Draeger | X-AM 2500 | MGM $2,306; Accessories $164 | 5 | 8 – 9 | ✓ | ✓ | ✓ | ✓ | $NH_3$, NO, $NO_2$, $SO_2$, $PH_3$, HCN, $CO_2$, $Cl_2$, $H_2$, Organic vapors, $COCl_2$, and $O_3$. |

Notes:
$Cl_2$ – Chlorine
$COCl_2$ - phosgene
CO – Carbon Monoxide
$CO_2$ – Carbon Dioxide
$CH_4$ – Methane
$H_2$ – hydrogen
$H_2S$ – Hydrogen Sulfide
HCN – Hydrogen Cyanide
$NH_3$ – ammonia
NO – Nitrogen Oxide
$NO_2$ – Nitrogen Dioxide
$O_2$ – Oxygen
$O_3$ – Ozone
$PH_3$ – Phosphine
$SO_2$ – Sulfur Dioxide

Information in the table is based on the assessed products.

## 4.1 RAE Systems by Honeywell QRAE 3

The QRAE 3 received an overall assessment score of 3.9. The QRAE 3 cost $925 with the optional Confined Space Kit for $220.

The following sections, broken out by SAVER category, summarize the assessment results


*Image courtesy of RAE Systems Inc.*

**Usability**

The QRAE 3 received a Usability rating of 4.1. The following information is based on evaluator comments:

- The instrument has good ergonomics and fits the hand well. It is easy to use even with gloves
- The buttons are easy to use, large enough for gloved hands, and have good tactile feedback
- The instrument includes multiple alarm settings including a "man down" alarm
- The display allows easy differentiation among the alarms and indicates high or low alarm modes
- The menu is easy to navigate
- The instrument has a rigid probe that when attached allows one-handed operation
- The auto-backlight works well in dark areas but can be insensitive to low light
- It is difficult to acknowledge and silence alarms
- It is easy to cover the speaker with gloved finger preventing the alarm from being audible.

**Capability**

The QRAE 3 received a Capability rating of 4.0. The following information is based on evaluator comments:

- The instrument has a large selection of gas sensors
- It is very easy to change the battery, but there is no option for using alkaline (disposable) batteries
- The pump has a high and low speed and there is an available manual pump
- The standard warranty is 3 years
- The instrument has a very fast response time though both short and long tubing (less than 7 seconds through a 10-foot tube)
- The CO and $H_2S$ sensors were cross-sensitive to the diesel fuel and take a long time to clear.

**Maintainability**

The QRAE 3 received a Maintainability rating of 3.7. The following information is based on evaluator comments:

- The sensors are easy to replace
- The instrument only requires a 6-month calibration interval (manufacturers suggested minimum)
- Meter cannot be locked down for fresh air calibration – the meter could be accidentally reconfigured in the field if not locked down
- Because of niches and crevasses, instrument decontamination or wipe-down would be more difficult, (although one evaluator noted it would be easy to wipe down).

**Deployabilty**

The QRAE 3 received a Deployability rating of 3.8. The following information is based on evaluator comments:

- The sensor seems rugged, with a hardened plastic and good tactile feedback on the controls
- Start-up procedures are easy as the instrument walks the user through all required procedures
- Start-up, including sensor warm-up and fresh air calibration, takes just over 2 minutes which is relatively fast
- It comes with a comprehensive quick start guide for both training and to remind users of correct procedures. The manual is easy to follow and includes pictures (which the evaluators found to be very helpful).

## 4.2 Industrial Scientific Ventis MX4

The Ventis MX4 received an overall assessment score of 3.9. The Ventis MX4 cost $1,375 with optional accessories and spare parts that cost $165.

The sections below, broken out by SAVER category, summarize the assessment results.

*Image courtesy of Industrial Scientific.*

**Usability**

The Ventis MX4 received a Usability rating of 3.8. The following information is based on evaluator comments:

- The rugged rubberized exterior makes the MGM easy to hold. The shape is ergonomic
- It has a good size and could be carried in a gear pocket
- The controls provide tactile feedback, though the controls at the bottom of the MGM make it hard to operate with one hand
- The instrument has variable visible, audible, and vibrating alarms that are easy to differentiate and recognize

- The menus are easy to read and understand
- The screen illumination is good and the screen is easily readable from multiple angles
- The backlight must be set to continuous or it will shut off within a minute.

**Capability**

The Ventis MX4 received a Capability rating of 3.9. The following information is based on evaluator comments:

- The MGM has a large number of available sensors but neither HCN or ammonia are available
- It has multiple battery options including disposable (alkaline) cells
- Wet decontamination is not recommended by the manufacturer, but a wipe-down is allowed
- It had a fast response and clear time for alarms even through the 10-foot tube
- A conversion kit is required for diffusion mode (all assessments were made in pumped mode)
- It has a standard 2-year warranty on instrument and sensors.

**Maintainability**

The Ventis MX4 received a Capability rating of 3.8. The following information is based on evaluator comments:

- It is easy to replace sensors with the provided tools
- The startup procedures are easy to follow and quick
- The instrument requires monthly calibration and includes reminders when calibration is due
- Instrument calibration is easy. With optional accessories calibration can be automated
- Decontamination seems to be simple though some disassembly would be required.

**Deployabilty**

The Ventis MX4 received a Deployability rating of 4.2. The following information is based on evaluator comments:

- It has very good overall ruggedness and durability
- It has simple one-button (5 second hold) startup with a 40-second total start time
- The startup procedures are easy to follow
- The manuals are easy to follow and the included pictures are helpful. The amount of training to get a basic understanding of the unit is minimal
- This is the only instrument assessed that is certified intrinsically safe for combustible dust atmospheres (i.e., grain and coal dust).

## 4.3 BW Technologies by Honeywell Gas Alert Max XT II

The Gas Alert Max XT II received an overall assessment score of 3.3. The Gas Alert Max XT II cost $748 with an optional Confined Space kit for $475.


*Image courtesy of BW Technologies*

The following sections, broken out by SAVER category, summarize the assessment results

**Usability**

The Gas Alert Max XT II received a Usability rating of 3.6. The following information is based on evaluator comments:

- The ergonomic design permits one-handed operation
- It only includes a proprietary rechargeable battery with no battery alternatives, such as disposables
- It has good response and clearance times
- The instrument provides different audible alarms in the event of multiple simultaneous detections
- This MGM has only one button, making operation easy, but the button can be difficult to locate with protective gloves
- Identifying which sensor is alarming can be difficult because only the sensor label (not the numerical reading) flashes and the label is fairly small
- It alarms, vibrates, and produces a tone. If a tone is already being sounded, a different tone is produced for a separate alert/alarm. Alarm reset is easy with a simple button press
- The rigid probe connects with tubing instead of directly to the body, requiring two-handed operation.

**Capability**

The Gas Alert Max XT II received a Capability rating of 2.8. The following information is based on evaluator comments:

- It is limited to the four standard sensors, no additional sensors are available
- The proprietary battery must be purchased to receive battery installation instructions
- It has relatively quick detection and alarm but it did not alarm on isopropyl alcohol
- There is no easy way to convert to diffusion mode, if pump fails.

**Maintainability**

The Gas Alert Max XT II received a Capability rating of 3.3. The following information is based on evaluator comments:

- It has a simple calibration with a six-month recommended calibration interval
- The startup time and fresh air calibration is fast and easy – approximately 45 seconds
- Replacing sensors requires a large sequence of steps
- The MGM can be submerged which increases the decontamination ability.

**Deployabilty**

The Gas Alert Max XT II received a Deployability rating of 3.6. The following information is based on evaluator comments:

- The instrument seems simple and rugged
- The startup procedures are easy
- The manual is easy to follow but does not include a table of contents, no QuickStart guide is included, and some operations require the technical manual for information.

## 4.4 MSA ALTAIR 4X

The ALTAIR 4X received an overall assessment score of 3.3. The ALTAIR 4X cost $1,061 with option sampling probes $249, sampling lines $138, Xcell Gas Sensors $208, and the optional pump $425.

The evaluators noted this would have been a good diffusion-only MGM.

The sections below, broken out by SAVER category, summarize the assessment results.

**Left image is the ALTAIR 4X, the right image showns the sensor with the optional pump**

*Image courtesy of MSA*

**Usability**

The ALTAIR 4X received a Usability rating of 3.0. The following information is based on evaluator comments:

- It is easy to navigate with simple button commands
- The screen is easy to see and read
- The high and low alarms are difficult to differentiate
- It demonstrated very poor performance when isopropanol was used
- There were major problems with CO and $H_2S$ dual sensor as they were cross-sensitive to the diesel fuel and took a long time to clear
- The target area of the buttons is small and hard to push with a heavy glove but this was not problematic when wearing nitrile gloves
- The buttons on pump are difficult to locate with gloves
- The separate pump module requires two-hand operation; it is awkward to hold both units (meter and pump) in one hand
- The backlight does not stay on long enough in default configuration
- The optional glow-in-the dark casing is a great feature if the instrument is misplaced in the dark.

**Capability**

The ALTAIR 4X received a Capability rating of 3.0. The following information is based on evaluator comments:

- Additional sensors are available (but not HCN or ammonia)
- It is easy to switch to diffusion mode if the pump fails
- The response time is good for both the 1-foot and 10-foot tubes
- The battery is not replaceable and only last 300 cycles
- The instrument did not alarm on LEL for isopropyl alcohol
- During the assessment the CO/$H_2S$ dual sensor failed.

**Maintainability**

The ALTAIR 4X received a Capability rating of 3.8. The following information is based on evaluator comments:

- The calibration procedure is easy but the manufacture does not specify a calibration interval
- The auto-calibration feature meets expectations
- The sensors are easily changed
- It has a three-year warranty which includes the sensors
- The instrument has many nooks and crannies making decontamination potentially difficult.

**Deployabilty**

The ALTAIR 4X received a Deployability rating of 3.6. The following information is based on evaluator comments:

- It has a drop rating 20 feet for the sensor and 10 feet for the pump
- The startup procedure is simple took approximately 60 seconds
- It has a good manual with flowcharts and operational pictures
- The provided training material is effective and includes a QuickStart guide.

## 4.5 Draeger Safety Inc. X-AM 2500

The X-AM 2500 received an overall assessment score of 3.1. The X-AM 2500 cost $2,306 which included the price of the optional pump also included were optional replacement sensors and accessories for $164.

The evaluators noted this would have been one of the better diffusion-only MGMs.

The sections below, broken out by SAVER category, summarize the assessment results.

**Left image is the X-AM 2500, the right image showns the sensor in the optional pump**

*Image courtesy of Draeger Saftey Inc.*

**Usability**

The X-AM 2500 received a Usability rating of 2.7. The following information is based on evaluator comments:

- The complete unit with the pump assembly is lightweight but the configuration of the buttons and size of the buttons make them difficult to operate with gloves on
- With attached pump, the unit is not very ergonomic
- The pump attachment mutes the audible and vibrational alarms. High and low alarms are indicated by non-intuitive codes
- The navigation menus for setup, calibration, and bump testing are cumbersome
- The buttons are small, lack tactile feedback, and are difficult to use in gloves
- The display is very readable, but includes no multiple readouts (i.e., TWA, peaks, etc.)
- The diffusion instrument is small and light. The pump attachment seems like an afterthought; it is bulky, not ergonomic, and is difficult to decontaminate.

**Capability**

The X-AM 2500 received a Capability rating of 3.7. The following information is based on evaluator comments:

- It has multiple battery options, including rechargeable and disposable options
- The response times are very good
- There are numerous accessories and bump/calibration dock are available
- The monitor performed as expected and the response times seem reasonable
- You can operate instrument in diffusion mode or pump mode; however, the pump housing is bulky, not ergonomic, and seems very difficult to decontaminate. The pump cannot be turned off, if the instrument is connected.

**Maintainability**

The X-AM 2500 received a Capability rating of 3.0. The following information is based on evaluator comments:

- The different sensors have different calibration frequencies
- The calibration menu navigation is awkward and difficult to follow
- The instrument must be connected to PC in order to replace sensors
- The MGM requires the instrument password for fresh air calibration
- The instrument can be decontaminated by water rinse, increasing ease of decontamination (meter only, pump has many nooks and crannies, but must be only wet-wiped)
- There is a 3-year warranty, including the sensors.

**Deployabilty**

The X-AM 2500 received a Deployability rating of 2.8. The following information is based on evaluator comments:

- While instrument seems very durable, the pump housing appears to be very fragile and easily broken if dropped
- It had a very slow startup (3-15 minutes depending on situation) to ready sensors for fresh air calibration
- The manual is very detailed and technical but is difficult to understand. There are no illustrations to assist with user understanding
- The device modes and operation extensively utilize symbols and codes, requiring user memorization or reference to supporting documentation.

# 5. SUMMARY

The advantages and disadvantages for the assessed products are highlighted in Table 5-1.

Emergency responder agencies that consider purchasing MGMs should carefully research each product's overall capabilities and limitations in relation to their agency's operational needs.

**Table 5-1. Product Advantages and Disadvantages**

| Vendor/Product | Advantages | Disadvantages |
|---|---|---|
|  <br>RAE Systems by Honeywell. **QRAE 3**<br>Price as tested: $925; Confined Space Kit $220<br>Overall Score: 3.9 | • Wide variety of sensors available<br>• "Man down" alarm (motion sensor that alarms when not moving for set period)<br>• Optional wireless remote monitoring for alarms<br>• Optional setting for auto-backlight in dim light<br>• Simultaneous sensor calibration<br>• Easy to use buttons with bunker gloves<br>• Easy alarm differentiation<br>• User-replaceable pump<br>• Auto screen rotation, when sensor is held upside down | • No diffusion only mode (a different diffusion-only model is available)<br>• Limited battery options<br>• Hard to read screen at an angle<br>• Difficult to decontaminate because of indentations and seams<br>• Not rated for quick submersion<br>• Small screen<br>• Cannot acknowledge and silence alarms<br>• False alarms on some sensors take a long time to clear |
|  <br>Industrial Scientific **Ventis MX4**<br>Price as tested: $1,375; Accessories $165<br>Overall Score: 3.9 | • Rugged<br>• Rated for Class I Div II combustible dust environments<br>• Number of battery options including disposable alkaline<br>• Large selection of optional sensors<br>• Highly distinguishable alarms<br>• Good ergonomics<br>• PC can be used for setup<br>• Alarm lights bright and easy to see<br>• Rubberized exterior provides secure grip<br>• Raised buttons provide good feel with gloves<br>• Can be submerged for decontamination | • Button location awkward when using bunker gloves<br>• Cannot acknowledge and silence alarms<br>• Meter backlight only turns on with an activated alarm or button push<br>• Meter cover is bulky and difficult to remove<br>• Need conversion kit for diffusion-only option<br>• Provided carrying case is not rugged<br>• Easy to accidentally cover alarm speaker with gloves<br>• Buttons are smaller |

| Vendor/Product | Advantages | Disadvantages |
|---|---|---|
|  <br>BW Technologies by Honeywell. **Gas Alert Max XT II**<br>Price as tested: $748; Confined Space Kit $475<br>Overall Score: 3.3 | • Rugged<br>• Single button operation<br>• Large legible display<br>• Fast startup<br>• Startup shows gases monitored, alarm levels, STEL, and TWA values<br>• Can be submerged for decontamination (IP67 certified) | • No additional optional sensors<br>• No battery options<br>• Button location is awkward with bunker gloves<br>• Cannot acknowledge silence alarm<br>• Difficult to attach hose with gloves on<br>• Difficult to switch to diffusion mode, if pump fails<br>• Manuals had no index and were difficult to navigate<br>• Must completely disassemble meter to change sensors |
|  <br>MSA **ALTAIR 4X**<br>Price as tested: $1,061; Sample Probe $249; Sampling Lines $138, Xcell Sensors $208, Optional Pump $425<br>Overall Score: 3.3 | • Very good diffusion-only meter<br>• "Man down" alarm (motion sensor that alarms when not moving for set period)<br>• Meter rated for 20-foot drop tests<br>• Glow-in-the-dark case available<br>• End of sensor life displayed on screen<br>• 24 hour run time (diffusion meter)<br>• Manual clear and has flow-charts<br>• Pump is separate from meter<br>• Small and light with good ergonomics<br>• Available probe useful for area sampling<br>• Diffusion or aspiration modes | • Cannot be used for low-flashpoint vapors<br>• Optional pump requires two-handed operation<br>• Dual-sensor cross-sensitivity could not be cleared<br>• Poor hose connections to pump<br>• Must use a combination sensor to get 4 sensors<br>• Pump is separate from meter<br>• Buttons difficult to see<br>• Pump is easy to disconnect unintentionally<br>• Separate pump requires 2-hand operation<br>• Buttons difficult to push with gloves and provide no tactile feedback<br>• CO and $H_2S$ sensors alarms during isopropyl test and takes a very long time to clear |

| Vendor/Product | Advantages | Disadvantages |
|---|---|---|
|  <br>Draeger Safety Inc. **X-AM 2500**<br>Price as tested: $2,306 (included optional pump); Asssories $164<br>Overall score: 3.1 | • Very good diffusion-only meter<br>• Large selection of optional sensors<br>• Has diffusion-only mode<br>• Number of battery options | • Long startup time<br>• Does not display peak readings (only current value)<br>• Button location is awkward with button gloves<br>• Sensor and pump assembly seem fragile<br>• Sensor and pump assembly are cumbersome and bulky |

# APPENDIX A. EVALUATION CRITERIA DEFINITIONS

The focus group identified sixteen evaluation criteria, which are defined as described below.

**USABILITY**

**Alarms** refers to the ease of resetting the meter when it alarms, as well as the amount of time required, the presence of failed sensor and blocked pump alarms, the ease of differentiating between alarms for different sensors (e.g., oxygen and lower explosive limit [LEL] alarms), and the ease of recognizing an alarm condition based on how the alarms are communicated.

**Ergonomics** refers to the ease of holding and operating the meter while wearing gloves. Ergonomics also refers to the size and location of controls, as well as the controls featuring tactile feedback (e.g., click when pressed).

**User Interface** refers to the meter featuring illuminated controls, multiple display readout options, and an easy to navigate menu. User Interface also refers to the size and readability (e.g., font size, contrast, backlit display) of the display screen in different lighting conditions and while wearing personal protective equipment (PPE).

**Portability** refers to the overall size and weight of the meter, as well as the included attachment options.

**CAPABILITY**

**Sensors** refers to the number and type of chemical sensors available.

**Power Source** refers to the battery runtime, power options (i.e., AC and DC power options), and battery type(s) (i.e., rechargeable or single use, commercially available or proprietary) used by the meter. Power Source also refers to the ease of replacing the batteries, including whether or not tools are required to access the battery compartment.

**Accessories** refers to the accessories available for an additional cost from the manufacturer, such as extension tubes and docking stations.

**Response Time** refers to the amount of time required before the meter alarms when a monitored chemical is present. Participants noted the importance of assessing Response Time with different tube lengths.

**Pump** refers to available pump operations options (e.g., high and low speeds) and if a diffusion sampling mode is available (i.e., pump off).

**MAINTAINABILITY**

**Calibration** refers to the ease of calibrating the meter and the required calibration frequency. Calibration also refers to the meter featuring an automated calibration mode (i.e., quick-calibration mode) and automated health check.

**Maintenance** refers to the ease of performing manufacturer-recommended maintenance and the required frequency. Maintenance also refers to the ease of changing the sensors.

**Decontamination** refers to the steps required to decontaminate the detector as well as the apparent effectiveness of the process (i.e., submersible, wipe down, or dry decontamination only).

**Warranty and Repair** refers to the availability of extended warranties, service contracts, and repair services, as well as if loaner meters are available when the meter is sent in for repair.

**DEPLOYABILITY**

**Durability** refers to the overall ruggedness of the meter, including the sturdiness of its controls and if it features covered ports and/or a sealed battery compartment. Durability also refers to the meter's water resistance (i.e., Ingress Protection [IP] rating) and shock resistance.

**Startup** refers to the ease of performing startup procedures and the amount of time required to prepare the meter for use.

**Training** refers to the effectiveness and availability of training materials, the required amount of training to operate the system, and the amount of recurring training expected. Training also refers to the general format, comprehensiveness, and extensiveness of the manufacturer-provided manuals and instructions, including if operational pictures are included.

# APPENDIX B. OVERALL ASSESSMENT SCORE CALCULATION

The overall score for each product was calculated using the product's averaged criterion ratings and category scores. An average rating for each criterion was calculated by summing the Evaluators' ratings and dividing the sum by the number of responses. Category scores for each product were calculated by multiplying the average criterion rating by the weight assigned to the criterion by the focus group, resulting in a weighted criterion score. The sum of the weighted criterion scores was then be divided by the sum of the weights for each criterion in the category as seen in the formula and example below.

**Category Score Formula**

$$\frac{\sum(Average\ Criterion\ Rating \times Criterion\ Weight)}{\sum(Criterion\ Weights)} = Category\ Score$$

**Category Score Example[1]**

$$\frac{(4.3\times4)+(5\times4)+(4\times3)+(4.5\times3)+(4.5\times3)}{4+4+3+3+3} = 4.5$$

To determine the overall assessment score for each product, each category score was multiplied by the percentage assigned to the category by the focus group. The resulting weighted category scores was summed to determine an overall assessment score as seen in the formula and example below.

**Overall Assessment Score Formula**

$$\sum(Category\ Score \times Category\ Percentage) = Overall\ Assessment\ Score$$

**Overall Assessment Score Example[1]**

| *Capability* | *Usability* | *Affordability* | *Maintainability* | *Deployability* | |
|---|---|---|---|---|---|
| $(4.0\times33\%)$ | + $(4.2\times27\%)$ | + $(4.2\times20\%)$ | + $(3.8\times13\%)$ | + $(4.5\times7\%)$ | = 4.1 |

[1]Examples are for illustration purposes only. Formulas vary depending on the number of criteria and categories assessed and the criteria and category weights.