System Assessment and Validation for Emergency Responders (SAVER)

Handheld Photoionization Detectors Assessment Report

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SAVER
System Assessment and Validation for Emergency Responders

Prepared by National Security Technologies LLC

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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; and
- 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, National Security Technologies LLC (NSTec) has been tasked to provide expertise and analysis on key subject areas, including chemical, biological, radiological, nuclear, and explosives (CBRNE) detection, countermeasures, and test and evaluation, among others. In support of this tasking, NSTec developed this report to provide emergency responders with information obtained from an operationally oriented assessment of commercially available handheld photoionization detectors (PIDs), which fall under AEL reference number 07CD-01-DPPI titled Detector, Photo-Ionization (PID), Point, Volatile Organic Chemical (VOC).

Visit the SAVER section on First Responder.gov (http://www.firstresponder.gov/SAVER) for more information on the SAVER Program or to view additional reports on handheld PIDs or other technologies.

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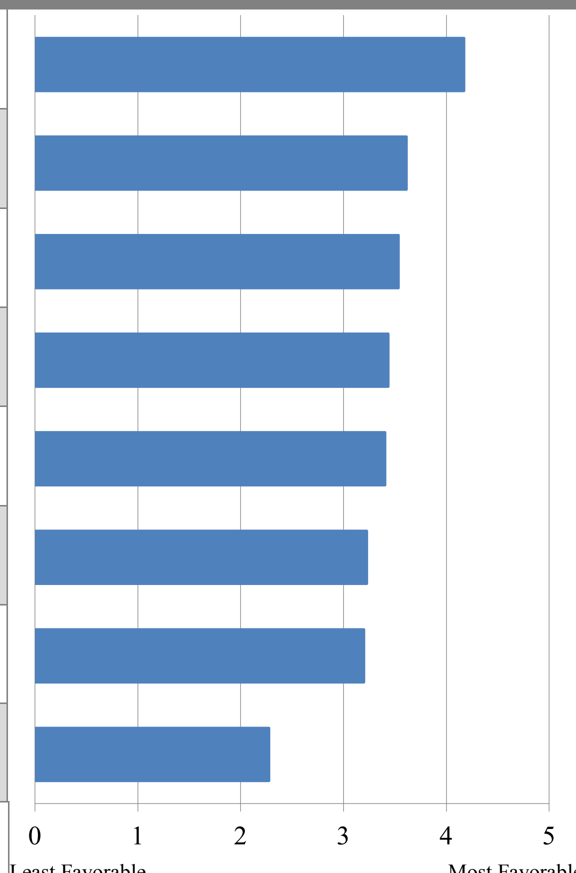
Handheld photoionization detectors (PIDs) alert emergency responders to potentially toxic atmospheres. PIDs are nonspecific gas-phase chemical detectors, with volatile organic compounds (VOCs) being the primary class of chemicals detected. VOCs are organic, carbon containing chemicals that normally exist in vapor form and can be benign or highly toxic. PIDs are low-cost, lightweight, easy-to-use handheld devices that provide rapid concentration information for VOCs ionized by a high-energy ultraviolet (UV) light source. In June 2013, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of handheld PIDs.

Eight handheld PIDs 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 using handheld PIDs. The assessment addressed 22 evaluation criteria in four SAVER categories: Capability, Deployability, Maintainability, and Usability. The overall results of the assessment are highlighted in the following table.

Product	Overall Score	Overall	Capability	Usability	Deployability	Maintainability
RAE Systems Inc. MultiRAE Pro		**4.2**	4.3	4.1	4.1	4.1
MSA Safety Sirius® Multigas Detector		**3.6**	3.5	3.6	3.8	3.8
Honeywell Analytics PHD6® Mutli-Gas Detector		**3.5**	3.4	3.6	3.7	3.5
Industrial Scientific Corporation MX6 iBrid™		**3.4**	3.5	3.1	3.7	3.7
Ion Science First-Check+		**3.4**	3.4	3.3	3.5	3.5
Dräger Safety Inc. Multi-PID 2		**3.2**	2.9	3.3	3.6	3.4
INFICON (Photovac Inc.) 2020ComboPRO™		**3.2**	2.9	3.2	3.6	3.4
PID Analyzers Model DL 102 Snap-On Photoionizer™		**2.3**	2.6	1.9	2.3	2.3

1. INTRODUCTION

Handheld photoionization detectors (PIDs) alert emergency responders to potentially toxic atmospheres. PIDs are nonspecific gas-phase chemical detectors, with volatile organic compounds (VOCs) being the primary class of chemicals detected. VOCs are organic, carbon containing chemicals that normally exist in vapor form and can be benign or highly toxic. PIDs are low-cost, lightweight, easy-to-use handheld devices that provide rapid concentration information for VOCs ionized by a high-energy ultraviolet (UV) light source. In June 2013, the System Assessment and Validation for Emergency Responders (SAVER) Program conducted an operationally oriented assessment of handheld PIDs. The purpose of this assessment was to obtain information on handheld PIDs 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 handheld PIDs, hereafter referred to as PIDs.

1.1 Evaluator Information

Eight emergency responders from various jurisdictions and with experience using PIDs 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 of Experience	State
Firefighter—HazMat, CBRNE, CT, ICS, WMD	20+	CA
Law Enforcement—CBRNE, HazMat, WMD	20+	FL
Law Enforcement—HSB/ARMOR, CBRNE	20+	NV
Firefighter—HazMat	16-20	VA
Firefighter—HazMat	11-15	CA
Law Enforcement—CBRNE, WMD	11-15	MD
Law Enforcement—HSB/ARMOR, CBRNE	11-15	NV
Incident Commander Advisor—CBRNE	6-10	DoD

Acronyms:
ARMOR—All Hazards, Regional, Multi-Agency, Operations, and Response
CBRNE—Chemical, Biological, Radiological, Nuclear, and Explosives
CT—Counter-Terrorism
DoD—Department of Defense
HazMat—Hazardous Materials
HSB—Homeland Security Bureau
ICS—Incident Command System
WMD—Weapons of Mass Destruction

1.2 Assessment Products

Eight PIDs were selected for assessment based on market research and the focus group's recommendations. These products were provided for the assessment by the product vendors. After the assessment was complete, the products were returned to the vendors. Table 1-2 presents the products that were assessed.

Table 1-2. Assessed Products

Vendor	Product	Product Image
Dräger Safety Inc.	Multi-PID 2	
Honeywell Analytics	PHD6® Multi-Gas Detector	
Industrial Scientific Corporation	MX6 iBrid™	
INFICON (Photovac Inc.)	2020ComboPRO™	
Ion Science LLC	FirstCheck+	
MSA Safety	Sirius® Multigas Detector	
PID Analyzers LLC (HNU)	Model DL 102 Snap-On Photoionizer™	
RAE Systems Inc.	MultiRAE Pro	

2. EVALUATION CRITERIA

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

- **Affordability** groups criteria related to life-cycle costs of a piece of equipment or system;
- **Capability** groups criteria related to the power, capacity, or features available for a piece of equipment or system to perform or assist the responder in performing one or more relevant tasks;
- **Deployability** groups criteria related to the movement, installation, or implementation of a piece of equipment or system by responders at the site of its intended use;
- **Maintainability** groups criteria related to the maintenance and restoration of a piece of equipment or system to operational condition by responders; and
- **Usability** groups criteria related to the quality of the responders' experience with the operational employment of a piece of equipment or system. This includes the relative ease of use, efficiency, and overall satisfaction of the responders with the equipment or system.

The focus group of emergency responders met in December 2012 and identified 25 evaluation criteria within five SAVER categories: Affordability, 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.

Products were assessed against 22 evaluation criteria. The three Affordability criteria recommended by the focus group were not assessed because cost data were difficult to obtain, agencies have varying budgets, and costs are department- and user-specific. Since all of the criteria from the Affordability category were omitted from the assessment, the weights of the remaining categories were each increased by 5 percent. 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 for evaluation criteria considerations.

Table 2-1. Evaluation Criteria

SAVER CATEGORIES				
Capability	**Usability**	**Affordability**	**Deployability**	**Maintainability**
Overall Weight 35%	Overall Weight 30%	Overall Weight 0%	Overall Weight 20%	Overall Weight 15%
Evaluation Criteria				
Performance Weight: 4	**User Interface** Weight: 4	**Initial Costs** Not Assessed	**Operational Environment and Ruggedness** Weight: 5	**Maintenance Tasks** Weight: 3
Multi-Sensor Capability Weight: 4	**Ergonomics** Weight: 4	**Maintenance Costs** Not Assessed	**Start-Up** Weight: 3	**Warranty and Repair** Weight: 3
Alarm Communication Weight: 3	**Alerts and Notifications** Weight: 3	**Consumable Costs** Not Assessed	**Portability** Weight: 3	**Support** Weight: 3
Detection Range Weight: 3	**System Diagnostics** Weight: 3			
Chemical Library Weight: 3	**Software** Weight: 2			
Communication Interface Weight: 3	**Accessories** Weight: 2			
Power Source Weight: 2				
Data Logging Weight: 2				
Data Transfer Weight: 2				
Data Storage Weight: 2				

3. ASSESSMENT METHODOLOGY

The products were assessed over 3 days. On the first day of the assessment, subject matter experts (SMEs) and facilitators presented a safety briefing and an overview of the assessment process, procedures, and schedule to the evaluators (Figure 3-1). 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 the products using vendor-provided information and specifications. Product information was confirmed by vendors prior to the assessment.

3.2 Phase II/Operational Assessment

During the operational assessment, evaluators assessed the products based on their hands-on experience using the product after becoming familiar with its proper use, capabilities, and features. The SMEs and facilitators assisted the evaluators with product familiarization and evaluators had access to reference material included with each product. The SMEs acted as safety officers during the assessment by providing daily safety briefings and ensuring the safety of the evaluators and assessment facilitators. The PIDs were assessed based on information gathered by the SMEs prior to the assessment and during rotations through four stations.

Figure 3-1. Emergency Responders Receiving Overview of Assessment Procedures

Evaluators were divided into three teams: two teams of three evaluators and one team of two evaluators. On the first rotation, two teams were assigned three PIDs and one team was assigned two PIDs. Each team was also assigned facilitators that were SMEs on the assigned PIDs. After the first rotation, the facilitators/SMEs stayed with a given set of PIDs and teams rotated through the PID/facilitator pairings. After three rotations, each evaluator had assessed each of the eight PIDs.

Each 3-hour rotation consisted of four stations as described in Sections 3.2.2 through 3.2.5. At the beginning of each rotation, evaluators were trained at the Base Station by the facilitators/SMEs assigned to their team. Each team was then assigned to different beginning stations (i.e., Station One, Two, or Three) for the remaining operational assessment tasks.

Each station included activities representative of the following handheld PID applications identified by the focus group:

- Hazardous materials (HazMat) community
  - Handheld deployment to a spill or event to characterize, map, and monitor the spill and area
  - Ability to mount a PID onto an unmanned aerial vehicle for airborne plume mapping;
- Personnel safety
  - Attach a PID to personnel to monitor conditions
  - Mount a PID on a robot to collect data prior to emergency responder entry;
- Monitor confined spaces–both 1) over short (minutes to hours), and 2) long (days) time periods;
- Plume detection–includes spills, area monitoring, and detection at the perimeter;
- Well dive–search for body decomposition gases in a well or deep, confined space;
- Leak detection–locate and characterize a point source;
- Spill response–verify a spill occurred, characterize its location and size, and verify the results of the cleanup; and
- Odor complaint–verify the presence of chemicals.

The stations also included general activities that are common to many scenarios, such as how the PIDs behave when a detector becomes saturated or encountering adverse conditions such as plugged tubes; how configurable the PID is with respect to alerts or alarms both for detection and for unit health or operation; and how easy it is to setup and use the PID in various conditions such as selecting detection ranges or navigating libraries.

3.2.1 Information Gathering

The SMEs performed the following tasks recommended by the focus group prior to the assessment to conserve time. The following information was provided to the evaluators for rating:

- Verified detection of a selected chemical in the 10 parts per billion (ppb) to 100 parts per million (ppm) concentration range;
- Characterized operation under battery power (e.g., operating time from full charge to low battery to simulate an area monitoring scenario, approximate recharge time from full discharge); and
- Verified the range and type of wireless communications and determined if the PID interfaced to standard communication protocols.

3.2.2 Base Station

At the base station, the evaluators reviewed the reference material for the PID, received a product familiarization overview from the SME, and performed activities to become familiar with the PID (Figure 3-2). Evaluators then powered on the PIDs and evaluated start-up procedures, including start-up time and any user input required on start-up (Figure 3-3). Evaluators created a file on the PID for the base station results and evaluated the options and difficulty of creating files as well as the ability to add information to these files, such as meaningful file names or the location where the measurements were taken.

At the conclusion of a rotation, evaluators returned to the base station to review their ratings.

Figure 3-2. PID Familiarization

Figure 3-3. Evaluating PID Start-Up

3.2.3 Station One

Evaluators created a file on the PID for station one. Evaluators noted the device weight, ergonomics, and ease of device operation by taking measurements of isopropyl alcohol in open containers above head level, at foot level, at a point source in an awkward location, and down into a large drum (Figure 3-4). Evaluators wearing gloves and masks changed the alarm levels of the device to evaluate the device's different alarm modes (e.g., different sounds for different alarm types, different behavior on alarm, alarm acknowledgement methods). The evaluators also determined if alarms could be heard or seen when wearing personal protective equipment (PPE) (Figure 3-5). Evaluators assessed the readability of the display through a PPE mask.

Figure 3-4. Evaluating Ergonomics During One-Handed Measurements

Figure 3-5. Changing Alarm Levels While Wearing PPE

3.2.4 Station Two

Evaluators created a file on the PID for station two. They attached a 6-foot tube to the PID, noted if the pump speed was adjustable, verified that the device could draw a sample through the tube, and evaluated the time to take a sample through the tube (Figure 3-6). Evaluators blocked the tube and assessed the behavior of the device under failure modes. The blocked tube, in addition to being a failure mode, simulated a clogged filter. Evaluators took a reading in a bottle of isopropyl alcohol and evaluated the behavior of the detector when it was saturated.

Evaluators took readings outdoors in sunlight and in a room with no lights to assess the readability of the display in sunlight and low-light conditions (Figure 3-7). To the extent possible, they evaluated the readability of the display under potential adverse conditions such as temperature changes caused by going from an air-conditioned room to direct sunlight.

Figure 3-6. Drawing Sample Through 6-Foot Tube

Figure 3-7. Preparing to Evaluate Display in Low-Light Conditions

3.2.5 Station Three

Evaluators connected the PID to a computer using the available methods for that PID (e.g., cable, wireless, docking station). Evaluators downloaded files from the PID to assess file readability, to evaluate ease of transferring data to a computer, and to determine if the PID interfaced to standard communication protocols such as wireless or wired connections (Figure 3-8). Evaluation of wireless communication range and types, along with communication protocol assessments, were facilitated by information gathered prior to the assessment by SMEs.

Evaluators removed and reinstalled batteries and filters to evaluate the difficulty of expected minor field repairs or maintenance activities (Figure 3-9). Evaluators assessed any accessories provided by the vendors such as docking stations, wrist straps, vest attachments, or other attachment points or straps. Evaluators analyzed the procedures for changing lamps to the extent possible for a given PID, but did not change the lamps because of the potential to damage a lamp bulb.

Figure 3-8. Docking PID to Connect to a Computer

Figure 3-9. Changing PID Batteries

3.3 Data Gathering and Analysis

Each evaluator was issued an assessment workbook that contained vendor-provided information and specifications, assessment procedures, and worksheets for recording criteria ratings and comments. Evaluators used the following 1 to 5 scale to rate each product:

1. *Meets none* of my expectations for this criterion;
2. *Meets some* of my expectations for this criterion;
3. *Meets most* of my expectations for this criterion;
4. *Meets all* of my expectations for this criterion; and
5. *Exceeds* my expectations for this criterion.

Criteria that were rated multiple times throughout the assessment were assigned final overall ratings by the evaluators. Facilitators captured advantages and disadvantages for the assessed products as well as general comments on the PID's 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 2.3 to 4.2. 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 in order based on the raw data.

Table 4-1. Assessment Results

Product	Overall	Capability	Usability	Deployability	Maintainability
RAE Systems Inc. MultiRAE Pro	**4.2**	4.3	4.1	4.1	4.1
MSA Safety Sirius® Multigas Detector	**3.6**	3.5	3.6	3.8	3.8
Honeywell Analytics PHD6® Mutli-Gas Detector	**3.5**	3.4	3.6	3.7	3.5
Industrial Scientific Corporation MX6 iBrid™	**3.4**	3.5	3.1	3.7	3.7
Ion Science First-Check+	**3.4**	3.4	3.3	3.5	3.5
Dräger Safety Inc. Multi-PID 2	**3.2**	2.9	3.3	3.6	3.4
INFICON (Photovac Inc.) 2020ComboPRO™	**3.2**	2.9	3.2	3.6	3.4
PID Analyzers Model DL 102 Snap-On Photoionizer™	**2.3**	2.6	1.9	2.3	2.3

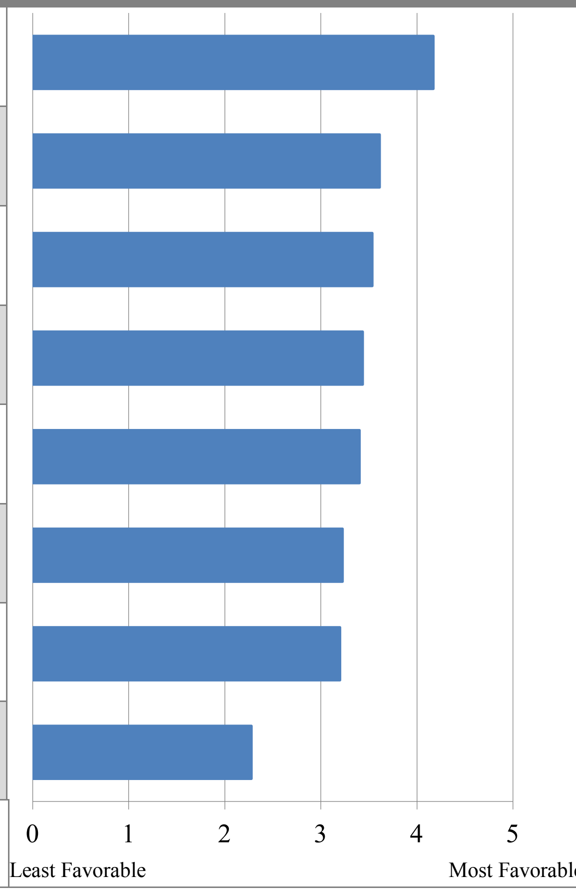


Table 4-2 presents the criteria ratings for each product. The ratings are graphically represented by colored and shaded circles. A green, fully shaded circle represents the highest rating. Refer to Appendix A for evaluation criteria considerations. For product information, specifications, and cost, see the SAVER program's *Handheld Photoionization Detectors Market Survey Report*, which is available at http://www.firstresponder.gov/SAVER.

Table 4-2. Criteria Ratings

KEY

Least Favorable → Most Favorable

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Category	Evaluation Criteria	MultiRAE Pro	Sirius® Multigas Detector	PHD6® Mutli-Gas Detector	MX6 iBrid™	First-Check+	Multi-PID 2™	2020 ComboPRO	Model DL 102 Snap-On Photo-ionizer™
Capability	Performance	●	◕	◕	◑	◕	◕	◕	◑
	Multi-Sensor Capability	●	◕	◕	◕	◕	◔	◔	◑
	Alarm Communication	●	◑	◕	◑	◔	◑	◑	◔
	Detection Range	◕	◕	◑	◑	◕	◑	◑	◑
	Chemical Library	◕	◕	◑	◑	◕	◑	◑	◑
	Communication Interface	●	◑	◑	◑	◑	◔	◔	◔
	Power Source	◕	◕	◕	◕	◑	◑	◑	◔
	Data Logging	◕	Not Assessed	◑	◕	◑	◑	◑	◔
	Data Transfer	◕	Not Assessed	◕	◕	◑	◑	◑	◑
	Data Storage	◑	◑	◑	◑	◑	◑	◑	◔
Usability	User Interface	◕	◕	◕	◑	◑	◑	◑	◔
	Ergonomics	◕	◕	◕	◔	◕	◕	◕	◔
	Alerts & Notifications	◕	◕	◑	◑	◑	◑	◑	◔
	System Diagnostics	◕	◕	◕	◑	◑	◑	◑	◔

KEY

Least Favorable → Most Favorable

○ ◔ ◑ ◕ ●

Category	Evaluation Criteria	MultiRAE Pro	Sirius® Multigas Detector	PHD6® Mutli-Gas Detector	MX6 iBrid™	First-Check+	Multi-PID 2™	2020 ComboPRO	Model DL 102 Snap-On Photo-ionizer™
Usability	Software	◕	Not Assessed	◕	◕	◑	◑	◑	◔
	Accessories	◕	◕	◕	◕	◑	◑	◑	◔
Deployability	Op Environment & Ruggedness	◕	◕	◕	◑	◑	◑	◑	◔
	Start-Up	◕	◕	◕	◕	◑	◕	◕	◑
	Portability	◕	◕	◕	◕	◕	◕	◕	◔
Maintainability	Maintenance Tasks	◕	◕	◑	◕	◕	◕	◕	◔
	Warranty and Repair	◕	◕	◕	◕	◕	◑	◑	◔
	Support	◕	◕	◕	◕	◑	◑	◑	◔

4.1 RAE Systems Inc. MultiRAE Pro

The MultiRAE Pro received an overall assessment score of 4.2.

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

Image courtesy of RAE Systems Inc.

Capability

The MultiRAE Pro received a Capability score of 4.3. The following information is based on evaluator comments:

- The PID was quick to alarm but took approximately 2 minutes to recover from saturation;
- In alarm mode the detector could be set to vibrate, the alarms were loud with blinking lights, but the volume was not adjustable;
- The chemical library was easy to use and could be password protected. However, the selected gas name was not presented in the VOC ppm results window. Since the library listed chemicals alphabetically, accessing chemicals near the end of the alphabet was tedious;
- The PID had an alkaline battery adapter for use with common batteries; and
- Data logging had a number of options that were easy to set and it was easy to create files. However, file titles were preformatted and customized titles required the use of the computer software.

Usability

The MultiRAE Pro received a Usability score of 4.1. The following information is based on evaluator comments:

- The PID had a well-organized, intuitive, and easy-to-use graphical user interface, but the button configuration was not intuitive. The display was bright, its orientation automatically adjusted, and auto-backlight worked well, but the screen font was small and difficult to read;
- Buttons were well spaced and had good tactile prominence and feedback. The detector fit well in the hand; however, an evaluator with small hands noted that one-handed operation was difficult. The rubberized case was very nice and attachment options were sufficient but more options would be useful; and
- The software displayed good graphical data and could run calibration reports and data log reports. It was easy to change PID settings using the software.

Deployability

The MultiRAE Pro received a Deployability score of 4.1. The following information is based on evaluator comments:

- Start-up included a step-by-step self-check that would not let the detector be used before it was ready. This provided a thorough check but increased the start-up time; and
- The PID had great carry options that were geared toward emergency responders. However, it was somewhat heavy and bulky because of the rubberized case.

Maintainability

The MultiRAE Pro received a Maintainability score of 4.1. The following information is based on evaluator comments:

- Battery and filter replacement was easy and did not require a screwdriver. Fresh-air calibration took over 60 seconds to complete; and
- The user manual was helpful and easy to read with good instructions on trouble shooting.

4.2 MSA Safety Sirius® Multigas Detector

The Sirius Multigas Detector received an overall assessment score of 3.6.

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

Image courtesy of MSA Safety

Capability

The Sirius Multigas Detector received a Capability score of 3.5. The following information is based on evaluator comments:

- Performance was good, but pump speed was not adjustable, which increased the time to recover from saturation to approximately 2 minutes;
- The Top 5 chemical feature of the large chemical library was beneficial, but the library could only be accessed through the start-up menu. Chemical abbreviations made reading, navigation, and searching the library difficult;
- Alarm notification was great and required acknowledgement; however, the PID did not have a stealth mode and the user had to restart the PID to change alarm modes or levels; and
- Data logging and transfer were not assessed because files had to be created on a computer, which required software and a docking station that was not provided by the vendor for the assessment.

Usability

The Sirius Multigas Detector received a Usability score of 3.6. The following information is based on evaluator comments:

- The PID had a rugged rubber case, great clips/straps, and good ergonomics and button placement. However, the flexible sample tube required the use of two hands and the PID was difficult to use while wearing gloves because the tactile feedback from the buttons was minimal; and
- The Software criterion was not assessed. Software was not provided by the vendor for the assessment.

Deployability

The Sirius Multigas Detector received a Deployability score of 3.8. The following information is based on evaluator comments:

- Start-up required minimal user interaction and included a step-by-step self-check, but was somewhat slow and the detection range had to be set during start-up; and

- The size and weight of the PID were good and it had great carry options that were geared toward emergency responders. However, the neck strap could be hazardous and a hand strap is preferred.

Maintainability

The Sirius Multigas Detector received a Maintainability score of 3.8. The following information is based on evaluator comments:

- Changing batteries and filters in the field was easy and required no tools; and
- The user manual was complete and well organized for both novice and experienced users.

4.3 Honeywell Analytics PHD6® Multi-Gas Detector

The PHD6 Multi-Gas Detector received an overall assessment score of 3.5.

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

Image courtesy of Honeywell Analytics

Capability

The PHD6 Multi-Gas Detector received a Capability score of 3.4. The following information is based on evaluator comments:

- The PID was quick to alarm and recover from saturation;
- The alarms were very loud, but vibrate mode did not disable the audible alarm. Therefore, it is not suitable for stealth assignments;
- The PID had an alkaline battery adapter for use with common batteries;
- Data transfer was easy but required a docking station;
- The PID only had a ppm detection range; it did not have a ppb detection range;
- The PID had an extensive chemical library. However, the library was somewhat difficult to navigate since it listed chemicals alphabetically. Accessing chemicals near the end of the alphabet was tedious;
- Data logging was fairly easy, but there were a lot of subcategories to navigate through to get to files. Also, the data logging had to be configured on a computer and could not be configured on the PID; and
- The PID had internal data storage, but it did not have removable data storage.

Usability

The PHD6 Multi-Gas Detector received a Usability score of 3.6. The following information is based on evaluator comments:

- The PID had a very bright, backlit display, and the display's orientation could be adjusted for use in awkward positions. However, the metal plate on the PID reflected too much sunlight. Menu navigation was not intuitive and somewhat difficult, therefore, user training would be required prior to use of this PID;
- Buttons were well spaced but small and difficult to use while wearing gloves. The PID had a nice shape and rubberized grip; and

- The software displayed good graphical data that was easy to understand but report generation and data management was difficult.

Deployability

The PHD6 Multi-Gas Detector received a Deployability score of 3.7. The following information is based on evaluator comments:

- The PID specifications indicate an upper operating temperature of 110 degrees Fahrenheit (˚F), however, during the assessment this PID shut down when the ambient air temperature was in the high 70’s ˚F;
- Start-up was quick and easy and included a mandatory blocked pump test that evaluators appreciated; and
- The size and weight of the PID were good, but it needed a carrying case.

Maintainability

The PHD6 Multi-Gas Detector received a Maintainability score of 3.5. The following information is based on evaluator comments:

- The user manual and chemical chart were very good; and
- Filters were easily changed.

4.4 Industrial Scientific Corporation MX6 iBrid™

The MX6 iBrid received an overall assessment score of 3.4.

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

Image courtesy of Industrial Scientific Corporation

Capability

The MX6 iBrid received a Capability score of 3.5. The following information is based on evaluator comments:

- Battery life was long, and the PID had an alkaline battery adapter for use with common batteries;
- New data logging sessions or files could easily be started, but entering metadata was difficult because of limited buttons on the PID. Adding metadata to files was much easier using a computer;
- Data transfer was easy but required a docking station;
- The pump speed was not adjustable, which increased the time to recover from saturation;
- Alarms could not be completely turned off and alarm levels were difficult to change while wearing PPE;
- The PID’s stealth mode was capable with a visual alarm;
- It only had a ppm detection range; it did not have a ppb detection range; and
- The chemical library was easy to navigate.

Usability

The MX6 iBrid received a Usability score of 3.1. The following information is based on evaluator comments:

- The software was very good and easy to learn;
- The availability of attachment and carrying accessories was good;
- The display resolution was great, menu navigation was intuitive, and the display's orientation was adjustable. However, the display was small and sometimes difficult to read in sunlight (e.g., alarm gas name in red font);
- An alarm could not be silenced until the PID cleared; and
- Buttons had good tactile feedback but were small, crowded, and difficult to use while wearing gloves. The PID felt secure when being held but was somewhat boxy. If the display's orientation was changed, the user's hand covered the exhaust on a standard grip.

Deployability

The MX6 iBrid received a Deployability score of 3.7. The following information is based on evaluator comments:

- Start-up was easy with simple confidence (bump) and pump tests that had step-by-step commands; and
- The size and weight of the PID were good.

Maintainability

The MX6 iBrid received a Maintainability score of 3.7. The following information is based on evaluator comments:

- It was easy to access filters and the interior of the PID for maintenance. Battery replacement was easy; and
- The user manual was well written and had an excellent quick-start sheet.

4.5 Ion Science LLC FirstCheck+

The FirstCheck+ received an overall assessment score of 3.4.

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

Image courtesy of Ion Science LLC

Capability

The FirstCheck+ received a Capability score of 3.4. The following information is based on evaluator comments:

- Performance was good, but pump speed was not adjustable;
- The chemical library was easy to navigate, but it had too many icons and not enough descriptive text;
- Battery life was good, and the PID had an alkaline battery adapter for use with common batteries;

- Creating data files and adjusting data logging frequency required use of a computer, so these activities had to be performed before deployment and could not be changed during use;
- Data transfer was relatively easy, although some evaluators experienced difficulties connecting to the computer using the infrared (IR) connection and would prefer a docking station or physical connection; and
- Alarms were not easily configured in the field. The PID did not have vibration or stealth modes, and there was no way to shut off the alarm entirely. Alarm volume was not adjustable, and alarms were difficult to hear and see, especially while wearing PPE.

Usability

The FirstCheck+ received a Usability score of 3.3. The following information is based on evaluator comments:

- The PID had good ergonomics and button placement. Buttons were a good size and had good tactile prominence and feedback. However, a lanyard or strap was not included, and the exhaust port was easily blocked when the PID was held. In addition, a rubberized grip is preferred to make the unit easier to hold when wearing gloves;
- The display was bright, but it was small and did not have auto-backlight. Menu navigation required an understanding of the icons in the icon-only interface, which was difficult for some of the evaluators who would prefer text options; and
- Software had basic functionality. Downloaded files were in a proprietary format that required proprietary software to view.

Deployability

The FirstCheck+ received a Deployability score of 3.5. The following information is based on evaluator comments:

- The PID was very lightweight and well sized for handheld operations; and
- Start-up was quick. However, the PID did not perform any calibration or self-check during start-up, which made the evaluators unsure that the PID was ready to use. The PID had to be connected to a computer to perform a confidence (bump) test, which could not be performed during use.

Maintainability

The FirstCheck+ received a Maintainability score of 3.5. The following information is based on evaluator comments:

- Battery replacement required a screwdriver, but the single screw anchored the battery well; and
- The user manual was easy to understand, but it was missing a troubleshooting section.

4.6 Dräger Safety Inc. Multi-PID 2

The Multi-PID 2 received an overall assessment score of 3.2.

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

Image courtesy of Dräger Safety Inc.

Capability

The Multi-PID 2 received a Capability score of 2.9. The following information is based on evaluator comments:

- Alarms were difficult to hear and see, especially while wearing PPE;
- The PID had both ppb and ppm detection ranges, but no autoscaling;
- Chemical library navigation was fairly easy after receiving training, but no backward navigation was available;
- Data logging frequency was adjustable, and evaluators were able to "tag" individual readings with pre-configured information and time stamps. However, file names and metadata could not be added while using the PID; and
- Data transfer was complex and used serial cables.

Usability

The Multi-PID 2 received a Usability score of 3.3. The following information is based on evaluator comments:

- The PID had good ergonomics and a good grip design. Button size and placement were good, but more tactile feedback was needed. The PID could be used with one hand, but the exhaust port was easily blocked when the PID was held. In addition, a rubberized surface for easier holding when wearing PPE is preferred;
- Menu navigation was very intuitive, and there was password protection. The display was big, but it was difficult to read and not bright enough. The backlight had to be manually turned on before entering a dark area;
- Alarms were limited; there was no alert or alarm for saturation or a blocked pump; and
- Software had basic functionality but did not support configuration of the PID from the computer.

Deployability

The Multi-PID 2 received a Deployability score of 3.6. The following information is based on evaluator comments:

- Start-up was quick and easy, but there were no self-checks. It did not go to a standard configuration on start-up, but to the last-used state.

Maintainability

The Multi-PID 2 received a Maintainability score of 3.4. The following information is based on evaluator comments:

- Battery compartment and lamp cover screws were not secured and fell out when they were loosened during maintenance tasks; and

- The user manual was average.

4.7 INFICON (Photovac Inc.) 2020ComboPRO

The 2020ComboPRO received an overall assessment score of 3.2.

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

Image courtesy of INFICON (Photovac Inc.)

Capability

The 2020ComboPRO received a Capability score of 2.9. The following information is based on evaluator comments:

- The PID was quick to alarm and recover from saturation, but pump speed was not adjustable;
- It did not have a stealth mode, and alarm configuration was complex. Alarm volume was not adjustable, and alarms were difficult to hear and see;
- The PID had both ppb and ppm detection ranges, but no autoscaling;
- Chemical library navigation was fairly easy after receiving training. It was easy to select gases, but no backward navigation was available;
- The PID had a car charger, but it did not have a standard alkaline battery option available;
- Data logging frequency was adjustable, and evaluators were able to “tag” individual readings with pre-configured information, but data logging files could not be configured on the PID. File names, date/time stamps, and metadata could not be added while using the PID; and
- Data transfer was complex and used serial cables. USB connectivity is preferred for simplicity.

Usability

The 2020ComboPRO received a Usability score of 3.2. The following information is based on evaluator comments:

- The PID had excellent ergonomics. Buttons were big and had good tactile feedback. The semi-flexible probe allowed for one-handed use, but the exhaust port was easily blocked when the PID was held. In addition, a rubberized surface for easier holding when wearing PPE is preferred;
- The display was easy to read in sunlight but more difficult in the dark. The backlight had to be manually turned on before entering a dark area. Menu navigation was easy, but there was no password protection;
- Error notifications described the issue in plain text; however, the PID would clear alarms prior to them being acknowledged by the user, potentially resulting in alarms being missed; and
- The software provided for transfer of data from the PID, but did not include data analysis or allow configuration of the PID from the computer.

Deployability

The 2020ComboPRO received a Deployability score of 3.6. The following information is based on evaluator comments:

- Start-up, including calibration, was very quick and easy.

Maintainability

The 2020ComboPRO received a Maintainability score of 3.4. The following information is based on evaluator comments:

- The maintenance tasks were fairly simple, but the filters were delicate and required care during field changing; and
- The user manual was very detailed, including useful screen shots, instructions with flow charts, troubleshooting procedures, and contact information. However, it also included several languages, making it very large and somewhat difficult to navigate.

4.8 PID Analyzers LLC (HNU) Model DL 102 Snap-On Photoionizer™

The Model DL 102 Snap-On Photoionizer received an overall assessment score of 2.3.

Image courtesy of PID Analyzers LLC (HNU)

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

Capability

The Model DL 102 Snap-On Photoionizer received a Capability score of 2.6. The following information is based on evaluator comments:

- The chemical library was fairly easy to access, but the abbreviations were confusing. In addition, the small display made chemical library navigation difficult, and no backward navigation was available;
- Alarm volume was not adjustable, and alarms were difficult to hear and see, especially while wearing PPE. There was no light to indicate that the PID was alarming, and the alarm message on the display was difficult to read. In addition, the PID did not have vibration or stealth modes;
- Data logging files were "tagged" with site numbers, but the file name could not be changed, and most data file and logging options had to be configured using a computer. File names, date/time stamps, and metadata could not be added while using the PID; and
- Data transfer was complex and required a serial cable.

Usability

The Model DL 102 Snap-On Photoionizer received a Usability score of 1.9. The following information is based on evaluator comments:

- The very small display made for a difficult user interface with hard-to-read scrolling text and non-intuitive menu organization. Display readability was minimal in both sunlight and a dark room. In addition, there was no password protection;

- Buttons were difficult to use while wearing PPE due to their size, spacing, and limited tactile prominence and feedback. The PID could not be used with one hand. Its smooth finish and shape made it difficult to hold, and there were no straps or clips available;
- Alarms were only minimally configurable, and they did not require acknowledgement. The PID did not indicate saturation, a blocked pump, or a blocked exhaust port;
- System diagnostics were not descriptive; and
- Software had basic functionality. It was difficult to convert data to graphics or other file formats.

Deployability

The Model DL 102 Snap-On Photoionizer received a Deployability score of 2.3. The following information is based on evaluator comments:

- Start-up was quick and easy, however, it was not clear that the PID performed a self-check; and
- The PID was too big and bulky.

Maintainability

The Model DL 102 Snap-On Photoionizer received a Maintainability score of 2.3. The following information is based on evaluator comments:

- The battery and filter were not easy to change in the field. Battery replacement required tools; and
- The user manual was not written for an emergency responder. It was not intuitive, and it did not describe the software.

5. SUMMARY

Evaluators noted that all the assessed PIDs had detection times within expectations and all had extensive chemical libraries. Also, if the chemical detected by the PID is known, human health-specific alarm levels can be set on the device to alert the user. Due to technology limitations, some common gases, such as methane, are not detected by PIDs. All PIDs are non-specific detectors; they do not identify chemicals. They act as gross chemical detectors to identify if a gas is present. If the gas identity is known, PIDs report a concentration.

None of the PIDs assessed had removable storage for data storage or transfer and only one, the RAE Systems Inc. MultiRAE Pro, had a standard USB port to transfer data to another device.

For all the assessed PIDs, training and operation were relatively easy for chemical sensors, and evaluators noted that specialized training is not required for PID use in general.

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

Table 5-1. Product Advantages and Disadvantages

Vendor/Products	Advantages	Disadvantages
 RAE Systems Inc. MultiRAE Pro Overall Score: 4.2	• Very easy maintenance • Very good and configurable alarms with available stealth mode and man-down alarm • Good display with auto screen rotation and auto backlight • Has USB port for data transfer • Buttons are adequately spaced, good tactile prominence and feedback • Fast clear down and very fast readings through 6-foot long hose • Wireless communications support real-time reporting • GPS available • Can add custom correction factors for new chemicals • Chemical library is password protected • Has a swivel clip and a number of attachments • A rubberized case is provided • Has flexible sample probe that will stay bent for positioning (noted as very useful) • Many different battery options and can use common AA batteries with adapter	• Chemical name does not display on the main screen when a chemical is selected from the library • Button layout is not as expected
 MSA Safety Sirius® Multigas Detector Overall Score: 3.6	• Data can be encrypted • Lamp was easily accessible for maintenance and other maintenance tasks were simple • Multiple attachment points • Ruggedized • Can network with other sensors • Loud audible alarm • Has stealth mode • Good visual alarms • Many different battery options and can use common AA batteries with adapter	• Menus difficult to navigate • Sampling probe requires two-handed operation • Buttons have low tactile prominence and feedback
 Honeywell Analytics PHD6® Multi-Gas Detector Overall Score: 3.5	• Good display in dark room • Good visual alarm and one of the loudest alarms of the PIDs assessed • Has both a pump and diffusion mode • Data can be transferred as text file • Menus are simple and easy to navigate • Ability to rotate the screen • Many different battery options and can use common AA batteries with adapter	• Menu scrolling was difficult, easy to overshoot items, buttons too sensitive • Menu access was difficult, the same button to access menu turns device off • Buttons and screen are small and buttons lack tactile prominence • Files with specific names or information can only be created using a computer

Vendor/Products		Advantages	Disadvantages
	Industrial Scientific Corporation MX6 iBrid™	• Menu navigation was simple with intuitive formats, similar to common PC interfaces • Color screen auto rotates and works well in the dark • Could turn off individual sensors • Has both a pump and diffusion mode • Could review data on PID including graphs, all alarms, and data • Could add user comments into data log files • A large number of sensor options (25) • Data can be exported in text or Excel format • Many different battery options and can use common AA batteries with adapter	• Color screen difficult to read in sunlight • Entire screen flashes during alarm, difficult to read and tell which sensor is alarming, especially difficult in the sunlight • Buttons too small and close together • Silver case caused bad reflections in sunlight • Shape makes one-handed operation difficult • Screwdriver required to remove battery
Overall Score: 3.4			
	Ion Science LLC FirstCheck+	• Light weight and ergonomic • Can graph data on unit • Buttons have good tactile prominence and excellent tactile feedback (they click) • Many different battery options and can use common AA batteries with adapter	• Device is sealed–all service must go to vendor • No accessory attachment points • Calibration must be done on a computer • Files cannot be exported as text since they are proprietary files • Only infrared (IR) data transfer and requires additional reader • Visual alarm light is too small • Menu is icon based, easy to use but confusing until icons are learned • May not understand error notification because of icons • If not set prior to entering a dark room, the alarm did not light screen • No real time reporting • Battery removal requires a screwdriver
Overall Score: 3.4			

Vendor/Products		Advantages	Disadvantages
	Dräger Safety Inc. Multi-PID 2	• Parts per billion (PPB) scale • Button layout and menu navigation was very good • Ergonomics were good • Can collect gas samples for analysis using other techniques • Data can be downloaded as a text file	• Foreign manufacturer, which may not be bought with some grants • Black-on-green display was very difficult to read in low light and almost impossible when wearing personal protective equipment (PPE) • Backlight must be set before going into dark and it is difficult to see the menus to turn it on • Backlight was not bright enough • Exhaust port can be easily blocked by common holding positions • Could not create specific file names or sessions • Warning light cannot be seen from many positions • Alarms are not loud enough for industrial settings or when wearing PPE • Battery removal requires a screwdriver • No stealth mode
Overall Score: 3.2			
	INFICON (Photovac Inc.) 2020ComboPRO	• INFICON 2020ComboPRO and Dräger Safety Inc. Multi-PID 2 appear to be identical • PPB scale • Button layout and menu navigation was very good • Ergonomics were good • Can collect gas samples for analysis using other techniques • Data can be downloaded as a text file	• Black-on-green display was very difficult to read in dark room and almost impossible when wearing PPE • Backlight must be set before going into darkness since the menus cannot be seen • Backlight was not bright enough • Exhaust port can be easily blocked by common holding positions • Could not create specific file names or sessions • Warning light cannot be seen from many positions • Alarms are not loud enough for industrial settings or when wearing PPE • Battery removal requires a screwdriver • No stealth mode
Overall Score: 3.2			

Vendor/Products		Advantages	Disadvantages
	PID Analyzers LLC (HNU) Model DL 102 Snap-On Photoionizer™	• Quick start-up • Very simple operations • Fast response and fast clear • Allows real-time telemetry with cable (good for fixed location monitoring)	• No self-checks • Ergonomics bad, hard to hold, slippery if wet, difficult to use with one hand, two hands required for many functions • Scrolling text difficult to read and screen font too small • Library abbreviations not intuitive • No visual alarm • Multiple gases read on multiple screens • Combinations of buttons must be pressed for menu navigation • Audible alarms are too quiet • No accessory attachment points • No stealth mode • Buttons lack tactile prominence • Battery removal requires a screwdriver
Overall Score: 2.3			

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

APPENDIX A. EVALUATION CRITERIA CONSIDERATIONS

Criterion	Specification Assessment	Information Gathering	Base Station	Station One	Station Two	Station Three	Consideration
Capability							
Performance					✓		C-1 Does the time to detect a chemical and communicate an alarm meet expectations? C-2 Does the time to recover from saturation meet expectations? C-3 Does the pump automatically shut off if it becomes blocked?
	✓				✓		C-4 Does the PID have an adjustable pump speed?
Multi-Sensor Capability	✓						C-5 Do the number and type of compound- or hazard-specific sensors that the PID can be connected to meet expectations?
Alarm Communication	✓						C-6 Do the number and type of available alarm modes meet expectations?
				✓			C-7 How configurable are the alarm modes? C-8 Does the PID have a stealth mode? C-9 Does the volume of the alarms meet expectations? C-10 How easily can alarm levels be changed and heard/seen while wearing PPE?
Detection Range	✓	✓					C-11 Does the concentration range in which the PID can detect volatile chemical compounds meet expectations?
					✓		C-12 How easily can the operator select the concentration range used for detection?
	✓				✓		C-13 Does the PID have automatic range selection and auto-scaling?
Chemical Library	✓						C-14 Does the number of chemicals in the library meet expectations? C-15 Can the libraries be updated? C-16 Can mission-specific libraries be configured? C-17 Can user-specific libraries be created?
			✓				C-18 How easy is chemical library navigation?
Communication Interface	✓	✓					C-19 Do the communication interfaces of the PID meet expectations? C-20 Can communications be encrypted? C-21 Can the PID be linked to a network in the field?
Power Source	✓						C-22 Do the types and availability of power options meet expectations? C-23 Do the number and type of charging options meet expectations? C-24 Do external power sources meet expectations?
		✓					C-25 Do battery life and recharge time meet expectations?

Criterion	Specification Assessment	Information Gathering	Base Station	Station One	Station Two	Station Three	Consideration
Data Logging			✓	✓	✓		C-26 How easily can files be created for a specific deployment or measurement? C-27 How easily can files be named and date/time stamped with operator-selected titles? C-28 How easily can metadata and user input be added to the files?
	✓		✓	✓	✓		C-29 Does the range and adjustability of data logging frequency meet expectations?
		✓					C-30 Does what happens when file storage is full meet expectations?
Data Transfer						✓	C-31 Does the ease of data transfer meet expectations? C-32 Does the ease of connection using the cable or wireless interface meet expectations?
	✓					✓	C-33 Does data transfer require software to be installed?
Data Storage	✓		✓				C-34 Are data stored internally or on removable storage media?
	✓	✓					C-35 Does the data storage format meet expectations?
Usability							
User Interface				✓	✓		U-36 Do display readability and brightness meet expectations?
					✓		U-37 Does the ease of setting alarm limits, recording intervals, and other parameters meet expectations?
			✓	✓	✓	✓	U-38 Do menu navigation, understandability, and organization meet expectations?
						✓	U-39 Does the ease of password entry or changing the password meet expectations?
		✓					U-40 Can the PID be pre-configured and locked down? U-41 Can an advanced mode be password protected?
			✓				U-42 Can the PID be used and configured with minimal training?
Ergonomics	✓		✓				U-43 Do the number and type of attachment points, clips, and/or straps meet expectations?
			✓	✓	✓	✓	U-44 Do the size and shape of the user-input buttons meet expectations? U-45 Do the tactile feel and feedback from the buttons meet expectations?
				✓			U-46 How easily can the PID be operated with one hand? U-47 How easily can the PID be operated with gloves or other PPE?

Criterion	Specification Assessment	Information Gathering	Base Station	Station One	Station Two	Station Three	Consideration
Alerts and Notifications	✓			✓			U-48 Are alarm levels configurable? U-49 Do the available alarms meet expectations? U-50 Can alarms be acknowledged remotely? U-51 Can alarms be silenced or suppressed for short periods?
					✓		U-52 Do the error notifications describe the issue in plain text? U-53 Do alerts and notifications upon saturation or overload meet expectations? U-54 Do alerts and notifications upon failure (blocked tube) meet expectations?
System Diagnostics	✓				✓		U-55 Do the types of PID health notifications meet expectations?
	✓						U-56 Can PID health notifications be configured?
Software						✓	U-57 Does the real-time reporting during measurements and post-measurement analysis meet expectations? U-58 Do the types and usefulness of the graphics output meet expectations? U-59 Does the text or data layout meet expectations? U-60 Does the ease of configuring the PID from a computer meet expectations?
		✓					U-61 Can the software be operated and run without administrative rights?
	✓						U-62 Does the software need to be pre-loaded on a computer or can it be loaded from the PID?
Accessories	✓						U-63 Does the variety of available accessories meet expectations?
Deployability							
Operational Environment and Ruggedness					✓		D-73 How does the environment affect the function of the PID?
	✓						D-74 Does the PID's water resistance meet expectations? D-75 Does the PID's drop and impact resistance meet expectations? D-76 Do the recommended decontamination methods meet expectations?
Start-up			✓			✓	D-77 Does the PID's start-up time meet expectations? D-78 Do the ready procedures required when starting the PID meet expectations? D-79 Do the procedures and methods for performing a confidence (bump) test meet expectations? D-80 Does the PID's self-check meet expectations?
		✓					D-81 Can the PID be configured to start in a previously selected mode?
Portability			✓	✓	✓		D-82 Do the size and weight of the PID meet expectations? D-83 How easy is the PID to carry or move?

Criterion	Specification Assessment	Information Gathering	Base Station	Station One	Station Two	Station Three	Consideration
Maintainability							
Maintenance Tasks	✓						M-84 Do the ease of and requirements for calibration meet expectations?
					✓		M-85 Does the ease of changing tubes in the field meet expectations?
						✓	M-86 Does the ease of changing batteries and filters in the field meet expectations?
Warranty and Repair	✓						M-87 Do the available maintenance contracts meet expectations? M-88 Do the locations of service centers meet expectations? M-89 Is a loaner device provided by the vendor if the PID requires repair?
Support	✓						M-90 Does the availability of technical support meet expectations? M-91 Does the availability of reach-back support meet expectations? M-92 Do the durations and variety of available vendor training meet expectations? M-93 How often is the training offered? M-94 Do the available certifications meet expectations?
			✓				M-95 How useful are the user manual and support documents?

APPENDIX B. ASSESSMENT SCORING FORMULAS

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 divided by the sum of the weights for each criterion in the category as seen in the formula and example below.

Category Score Formula

$$\frac{\sum\left(\text{Average Criterion Rating} \times \text{Criterion Weight}\right)}{\sum\left(\text{Criterion Weights}\right)} = \begin{matrix}\text{Category}\\ \text{Score}\end{matrix}$$

Category Score Example[1]

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

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 were summed to determine an overall assessment score as seen in the formula and example below.

Overall Score Formula

$$\sum\left(\text{Category Score} \times \text{Category Percentage}\right) = \begin{matrix}\text{Overall Assessment}\\ \text{Score}\end{matrix}$$

Overall Score Example[1]

$$\underset{\text{Capability}}{(4.0 \times 33\%)} + \underset{\text{Usability}}{(4.2 \times 27\%)} + \underset{\text{Affordability}}{(4.2 \times 20\%)} + \underset{\text{Maintainability}}{(3.8 \times 10\%)} + \underset{\text{Deployability}}{(4.5 \times 10\%)} = 4.1$$

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