



**Homeland  
Security**

Science and Technology

# Summary

**U.S. Department of Homeland Security**



**System Assessment and Validation for Emergency Responders**

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 operational tests on commercial equipment and systems and provides those results along with other relevant equipment information to the emergency response community in an operationally useful form. SAVER provides information on equipment that falls within the categories listed in the DHS Authorized Equipment List (AEL).

The SAVER Program is supported by a network of technical agents who perform assessment and validation activities. Further, SAVER focuses primarily on two main questions for the emergency responder community: "What equipment is available?" and "How does it perform?"

To contact the SAVER Program Support Office

Telephone: 877-336-2752

E-mail: [saver@dhs.gov](mailto:saver@dhs.gov)

Visit the SAVER Web site:

<https://www.rkb.us/saver>

Reference herein to any specific commercial products, processes, or services by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement, recommendation, or favoring by the United States Government. Neither the United States Government nor any of its employees make any warranty, express or implied, including but not limited to the warranties of merchantability and fitness for a particular purpose for any specific commercial product, process, or service referenced herein.

## Colorimetric Tube and Chip Chemical Detection Kits

*In order to provide emergency responders with information on currently available chemical detection kit capabilities, limitations, and usability, the Center for Domestic Preparedness (CDP) conducted a comparative assessment of colorimetric tube and chip chemical detection kits for the SAVER Program in August 2008. Detailed findings are provided in the complete Assessment Report on Colorimetric Tube and Chip Chemical Detection Kits, which is available by request at <https://www.rkb.us/saver>.*

### Background

Colorimetric tube technology has been used for many years to sample for specific gases in a specific area, such as a hazardous leak in an industrial setting. A chemical reagent changes colors to indicate the existence of hazardous vapors. This technology is typically used independently to confirm a qualitative analysis. Disposal of used or expired tubes should be in accordance with the relevant disposal regulations valid in the corresponding area or jurisdiction.

Colorimetric tubes are sealed glass tubes, generally about 4 inches long and about 1/4-inch in diameter (depending on the manufacturer). A volume of gas is drawn into the tube via an accompanying pump. Tubes require a specific volume of gas to be sampled depending on the substance for which they are testing, which in turn determines the number of strokes to be performed by the pump. Each tube contains chemicals that react with a specific compound (e.g., carbon monoxide, ammonium hydroxide) to form a color or stain inside the tube. Once the volume of the sampled gas is drawn through the tube, the amount of color change read on a linear scale of the colorimetric tube is measured in parts per million (ppm) and/or percentages. The indicator in ppm allows an estimate of the vapor concentration in an atmosphere.

### Assessment

A focus group of nine emergency response practitioners from various regions of the country met in June 2008 to identify equipment selection criteria, evaluation criteria, and assessment scenarios. Based on focus group recommendations, the comparative assessment focused on both manual and powered colorimetric tube and chip kits. However, due to the significant differences between the manual and powered kits, the colorimetric tube and chip kits were assessed separately.

The CDP selected the following manual models for assessment:

- RAE Systems LP-1200 Piston Hand Pump Kit
- Gastec Corporation GV-100S-TR Pump Kit
- Sensidyne, LP Model AP-20S Gas Detection Pump Kit
- Draeger Safety Clandestine Lab Simultest Kit

- Kitagawa America Model AP-20 Sampling Pump
- Mine Safety Appliances (MSA) Kwik-Draw<sup>®</sup> Detector Tube Pump.

The following powered colorimetric tube and chip kits were also selected and included in the assessment:

- Draeger Safety Accuro<sup>®</sup> Bellows Pump and Quantimeter 1000
- Draeger Safety Chip Measurement System.

Six emergency responders served as assessment evaluators. The evaluators were divided into three teams of two, with one data recorder assigned to each team for assessment of the manual kits.

Once the manual portion of the assessment was completed, the evaluators assessed the powered systems. Evaluators were grouped into two three-person teams and completed three stations.

## Assessment Results

Evaluators rated the colorimetric tube and chip kits based on the evaluation criteria established by the focus group (see table 1). Each recommended criterion was assigned to one of the five SAVER categories, and each SAVER category was assigned a weighting factor to indicate its impact on the total composite score. Higher scores indicate better performance. To see how each colorimetric tube scored within the specific evaluation criteria assigned to the SAVER Program Categories, see table 2 (on page 7).

### SAVER Program Category Definitions

**Affordability:** This category groups criteria related to life-cycle costs of a piece of equipment or system.

**Capability:** This category 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 responder-relevant tasks.

**Deployability:** This category 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:** This category groups criteria related to the maintenance and restoration of a piece of equipment or system to operational conditions by responders.

**Usability:** This category 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.

Because the manual and powered systems used vastly different technologies, direct comparison of the two powered systems was judged to be impractical. As a result, the powered systems were not scored against one another and only evaluator comments were collected.

Evaluation criteria that were deemed “not assessable” for the manual colorimetric tube systems were eliminated from the scoring and the scores were

**Table 1. Colorimetric Tube and Chip Chemical Detection Kits Assessment Results<sup>1</sup>**

Colormetric Tube	Composite Score	Affordability (20% Weighting)	Capability (25% Weighting)	Deployability (20% Weighting)	Maintainability (15% Weighting)	Usability (20% Weighting)
RAE Systems	73	68	75	87	57	75
Gastec	71	61	71	90	49	78
Sensidyne	70	64	69	86	48	76
Draeger	68	56	74	85	50	70
Kitagawa	68	62	66	87	44	76
MSA	62	56	62	78	48	65

Note:

<sup>1</sup> Scores contained in the assessment report may be displayed differently. For the purposes of the SAVER Summary, all SAVER category scores are normalized using a 100-point scale and rounded to the nearest whole number.

adjusted to compensate for the weighting factors of the eliminated criteria. The SAVER category and composite scores are shown in table 1. Higher scores indicate better equipment performance.

The following sections provide a brief summary of the evaluator comments and feedback on each colorimetric tube and chip kit. The sections present the kits from the highest to lowest composite score. For the purposes of this SAVER Summary, the category scores are normalized and rounded to the nearest whole number. The complete assessment report includes a breakdown of evaluator comments by individual criterion.

## Manual Colorimetric Tube and Chip Chemical Detection Kits

### RAE Systems

The RAE Systems was scored as the highest manual colorimetric tube and chip kit overall by the evaluators, and the highest in the capability, maintainability, and affordability categories. The RAE Systems device was user-friendly, easy for the evaluators to hold with one hand, and the tubes were easy to grasp while wearing personal protective equipment (PPE). The RAE Systems pump draw mechanism utilized a flow indicator with markings from 50 to 100 milliliters (ml) to ensure the correct number of pump strokes. The pump draw mechanism operated smoothly and did not hinder the evaluators' grip or control of the pump. In addition, the evaluators noted that repeated operation of the pump would be unlikely to cause hand fatigue since the period between readings would allow ample time for rest.

The average cost of a box of the assessed colorimetric tubes was approximately \$32, which evaluators noted


was the lowest price of colorimetric tubes among the assessed kits, and had an average shelf life of two years.


Evaluators also noted a couple of disadvantages for the RAE System. For instance, the evaluators were unable to locate information regarding warranty coverage or storage requirements for the system. The evaluators also reported that the pump draw mechanism on the RAE Systems pump was harder to pull than other models assessed.

### Gastec

The Gastec received the second highest overall score. The Gastec scored highest in the usability and deployability categories. The evaluators noted that they were able to accurately operate the kit after reading the two page operating instructions. The butyl rubber gloves worn by the evaluators made it difficult for them to grasp the colorimetric tubes, but the evaluators noted that the tubes were easily fitted into the pump while wearing PPE. The evaluators agreed the pump itself was easy to grip and the pump draw mechanism was easy to operate. The evaluators also agreed that the kit is light enough for one person to carry and that the kit can be easily transported.

The evaluators identified the carrying case as a disadvantage of the Gastec kit, stating that the soft case could potentially allow damage to the components inside. An additional disadvantage of the Gastec kit was the price of the assessed colorimetric tubes, which ranged from \$65 to \$67 a box. Although the evaluators believed that the price of the tubes would not hinder their jurisdictions from purchasing the Gastec kit, they did comment that the tubes were more expensive than the other assessed models.


	<p><b>↑</b> Pros</p> <ul style="list-style-type: none"> <li>• Inexpensive</li> <li>• Thorough user manual with step-by-step instructions</li> <li>• Clear tube labeling</li> <li>• Tubes easy to read</li> <li>• Included storage container for tubes</li> <li>• Durable pump shaft</li> <li>• Easy to see visual flow indicator</li> </ul>
	<p><b>↓</b> Cons</p> <ul style="list-style-type: none"> <li>• Handle difficult to pull</li> <li>• Oversized case</li> <li>• Shallow cutter reservoir</li> <li>• No maintenance schedule in manual</li> </ul>
<b>RAE Systems</b>	<b>Composite Assessment Score: 73</b>

	<p><b>↑</b> Pros</p> <ul style="list-style-type: none"> <li>• Ergonomic design</li> <li>• Easy to see tube color contrast</li> <li>• Clear tube labeling</li> <li>• Tubes easy to read</li> <li>• Easy to see visual flow indicator</li> </ul>
	<p><b>↓</b> Cons</p> <ul style="list-style-type: none"> <li>• Difficult to use tip cutter</li> <li>• No maintenance schedule in manual</li> </ul>
<b>Gastec</b>	<b>Composite Assessment Score: 71</b>

## Sensidyne

The Sensidyne received the third highest overall score. The Sensidyne pump was compact enough for the evaluators to hold in one hand while wearing PPE. The pump handle design made it comfortable and easy to grip. The evaluators stated that the pump draw mechanism was easily pulled and operated smoothly. They agreed that it did not hinder the operator's grip or control of the pump, stating that the design allowed the pump to be securely grasped during operation.


A disadvantage of the Sensidyne kit included the shifting of the built-in tube cutter on the pump, which resulted in an uneven tube cut. The evaluators reported that glass became lodged in the cutter, requiring the operator to manually remove the glass fragment before cutting a new tube. Evaluators felt that these glass fragments could compromise the PPE gloves during extrication.

	↑ <b>Pros</b>	<ul style="list-style-type: none"> <li>Ergonomic design</li> <li>Convenient carrying case with belt loop</li> <li>Good user manual</li> <li>Easy to empty tip cutter reservoir</li> <li>Easy to grip pump handle</li> </ul>
	↓ <b>Cons</b>	<ul style="list-style-type: none"> <li>Tubes difficult to read</li> <li>Difficult to operate while wearing PPE</li> <li>Numerous pulls required to draw sample</li> <li>Hard to detect tube color changes</li> <li>No maintenance schedule in manual</li> </ul>
<b>Sensidyne</b>	<b>Composite Assessment Score: 70</b>	

## Draeger

Multiple steps were required for operation but the evaluators stated that the instructions were easy to follow. The five tubes for the Draeger kit were seated in a rubber holder and evaluators noted that this made the tubes easy to grasp while wearing PPE. The Draeger tubes were easily read while wearing SCBA or an APR and the reagent color in the tubes was easily distinguished.


The evaluators stated that the manual was not very clear and that the descriptions and pictures in the literature were vague. Additional disadvantages included the 15-minute leakage test and the difficult to use 5-tube cutter.

	↑ <b>Pros</b>	<ul style="list-style-type: none"> <li>Extension hose for multiple tubes</li> <li>Good case design</li> <li>Step-by-step instructions</li> <li>Clear tube labeling</li> <li>Quick reference guide on back of simolest set</li> </ul>
	↓ <b>Cons</b>	<ul style="list-style-type: none"> <li>Counter difficult to reset</li> <li>Expensive</li> <li>Only detects presence, not concentration</li> <li>Two-person operation</li> <li>No maintenance schedule in manual</li> </ul>
<b>Draeger</b>	<b>Composite Assessment Score: 68</b>	

## Kitagawa

The Kitagawa received the second lowest overall score. The evaluators commented that the small detector tubes fit tightly in the pump, but were hard to grasp. The wide design and rubber pump handle made it easy to grip and operate while wearing PPE. The training materials included with the kit provided sufficient information for the evaluators to operate the equipment. The evaluators stated that the user manual was well organized and easy to follow, contained step-by-step instructions, and color pictures. Evaluators agreed that the kit required only minimal training for proficient operation.

A disadvantage of the Kitagawa was using the tube cutter while wearing PPE. The evaluators reported that the spinning tube cutter caused uneven cuts and pieces of broken tube would fall out of the tube cutter if the lid was not securely closed.




	↑ <b>Pros</b>	<ul style="list-style-type: none"> <li>Ergonomic design</li> <li>Convenient carrying case with belt loop</li> <li>Good user manual</li> <li>Easy to empty tip cutter reservoir</li> <li>White handle easy to see in dark environments</li> </ul>
	↓ <b>Cons</b>	<ul style="list-style-type: none"> <li>Tubes difficult to read</li> <li>Difficult to use while wearing PPE</li> <li>Numerous pulls required to draw sample</li> <li>Hard to detect tube color changes</li> <li>No maintenance schedule in manual</li> </ul>
<b>Kitagawa</b>	<b>Composite Assessment Score: 68</b>	

## MSA

The MSA received the lowest overall score. However, the evaluators agreed that the MSA kit was simple and intuitive to use. The tubes were large enough to allow for easy handling and were easy to grasp and install while wearing PPE. MSA training materials included with the kit provided the evaluators with sufficient information to operate the kit. The evaluators commented that the user manual was well organized and easy to follow. The evaluators agreed that the kit required only minimal training for proficient operation.

Problems with the tube cutter were more pronounced with the MSA than with the other detector kits. For example, evaluators stated that the cutter filled with glass rapidly, left jagged tube edges, and was not adequately marked on the instructional diagram.

Evaluators commented that two hands were needed to operate the pump and they also noted possible pinch points. The evaluators also stated that the stroke counter on the MSA was difficult to see while wearing PPE.

	 <b>Pros</b>	<ul style="list-style-type: none"> <li>• Lightweight</li> <li>• Convenient carrying strap</li> <li>• Large, easy to read tubes</li> <li>• Tubes easy to install</li> </ul>
	 <b>Cons</b>	<ul style="list-style-type: none"> <li>• Potential pinch points</li> <li>• Tubes difficult to remove</li> <li>• Broken tips jammed cutter</li> <li>• Numerous pulls required to draw sample</li> <li>• Confusing tube labeling</li> <li>• No maintenance schedule in manual</li> </ul>
<b>MSA</b>	<b>Composite Assessment Score: 62</b>	

## Powered Colorimetric Tube and Chip Chemical Detection Kits




Due to the vast differences in the manual and powered technologies, direct comparison of the two powered systems was judged as being impractical. Therefore, the powered kits were not scored against one another. Instead, evaluators completed surveys and provided feedback on each of the powered colorimetric tube and chip kits.

### Chip Measurement System

Evaluators agreed that the Chip Measurement System is easy to grasp and is big enough to be held securely

while wearing PPE. They also noted that the tubes are easy to grasp and they are easily fitted into the pump. An additional feature of the Chip Measurement System is an audible and visual alarm to alert the operator when a sample exceeds a safe concentration level. Also, the Chip Measurement System includes the capability to internally record test results for future reference, the ability to record enough of the needed information (e.g., chemical sampled, concentration, etc.), and easy to recall data functions. The evaluators stated that data logging enhanced emergency response operations and that the logging function was easy to operate.


Disadvantages of the Chip Measurement System included lack of information on upgrade options and available accessories. An additional Chip Measurement System shortcoming was that no storage case was included with the kit.

	 <b>Pros</b>	<ul style="list-style-type: none"> <li>• Lightweight, easy to hold</li> <li>• Fast readings</li> <li>• Backlit screen</li> <li>• Step-by-step instructions/prompts</li> <li>• Minimal training required</li> <li>• Audible and visual alarms</li> </ul>
	 <b>Cons</b>	<ul style="list-style-type: none"> <li>• Chips difficult to install</li> <li>• No specific warranty information provided</li> <li>• Small hand strap</li> <li>• Additional equipment needed (screwdriver)</li> </ul>
<b>Chip Measurement System</b>		

### Quantimeter

The evaluators identified the capability to use multiple tubes simultaneously as an advantage of the Quantimeter. Another advantage included the easy adjustment of pump strokes. The evaluators agreed that the Quantimeter was compact, comfortable to carry, and fit well in one hand. The display screen readings were easy for the evaluators to interpret. Evaluators stated that the Quantimeter tubes can be quickly and easily replaced and that the tube cutter is easy to use while wearing PPE.

A disadvantage of the Quantimeter was that the display is difficult to read while wearing respiratory protection. The evaluators also noted that the location of the display made the screen difficult to read if the device was placed on a table during operation.

	↑ <b>Pros</b>	<ul style="list-style-type: none"> <li>• Lightweight, easy to hold</li> <li>• Hands-free use</li> <li>• Minimal training required</li> <li>• Long battery life</li> <li>• Simple pump</li> </ul>
	↓ <b>Cons</b>	<ul style="list-style-type: none"> <li>• Small display</li> <li>• Time-consuming leak test</li> <li>• No completion alarm</li> <li>• Little information on provided tubes</li> <li>• Menu advance too fast</li> </ul>
<b>Quantimeter</b>		

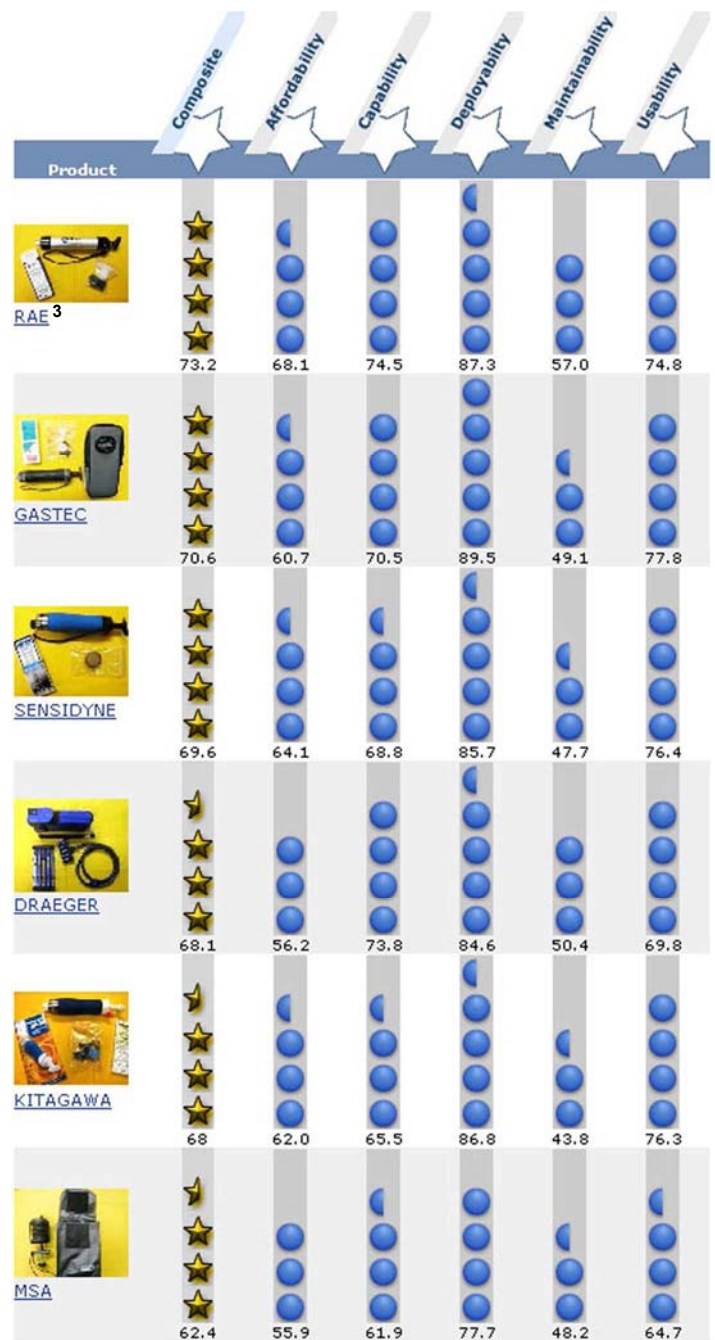
## Conclusion

The purpose of this comparative assessment was to evaluate the effectiveness of selected colorimetric kits used in emergency response operations. The assessment was based on a scenario-driven exercise requiring the use of colorimetric tube and chip chemical detection kits.

Evaluators were able to successfully complete the assessment tasks using each of the selected kits, but each kit exhibited different characteristics. An analysis of evaluator comments and scores revealed these common observations concerning the assessed kits:

- Evaluators felt that a colorimetric tube and chip kit should be easy to grasp without causing fatigue after extended use.
- Separate cutters were considered practical accessories, as was consumable lists and cost information.
- Automatic counters were said to be critical features, and color cards should be provided to allow comparison of tube color changes.
- Evaluators agreed that tube “readability” is a key factor, and that stains should last a sufficient amount of time to record accurate readings.
- Evaluators agreed that low light operations may limit usability of colorimetric devices due to the inability to see color changes.
- They also noted that consideration should be taken for both the tube and pump cost when making procurement decisions.

## QuickLook Snapshot<sup>2</sup>



### Notes:

<sup>2</sup> The SAVER QuickLook, available on the SAVER Web site, allows users to select the SAVER categories that are most important to their department and view results according to their specific needs.

<sup>3</sup> Scores contained in the assessment report may be displayed differently. For purposes of the QuickLook, all SAVER category scores are normalized using a 100-point scale.

For additional information on the assessment and to access other reports in the series, visit the SAVER Web site (<https://www.rkb.us/saver>).

**Table 2. SAVER Category and Criteria Scores**

KEY							
Least Favorable		Most Favorable					
							
		RAE Systems	Gastec	Sensidyne	Dräger	Kitagawa	MSA
Assessment Criteria							
<b>Affordability</b>							
Tube cost							
Maintenance cost							
Training cost							
Unit lifespan							
Warranty cost							
Accessory cost							
<b>Capability</b>							
Operating conditions							
Tube selection							
Reading time							
Multiple tubes simultaneously							
Clearly identifiable tubes							
Reading accuracy length							
Tube verification							
<b>Deployability</b>							
Storage requirements							
Ease of deployment							
Portability							
Tube organization							
<b>Maintainability</b>							
Decontamination capability							
Maintenance schedule							
Replacement parts							
Warranty coverage							
Storage requirements							
<b>Usability</b>							
Ease of operation							
Easy to interpret results							
Display visibility							
Training							
Tube readiness							
Ergonomic design							
Durability							
Disposability							