

U.S. Department
of Agriculture

Forest Service

National Technology &
Development Program

5100—Fire Management
1151 1815—SDTDC
June 2012



Hydrogen Sulfide Dosimeters for Wildland Firefighters



H₂S Abstract

In certain geographic areas of the United States, wildland firefighters may encounter oil and gas extraction and refining operations during wildland and prescribed fire management activities. While working near such operations, wildland firefighters can be exposed to hydrogen sulfide (H₂S) gas. Hydrogen sulfide is an extremely hazardous, toxic compound. The gas occurs naturally in coal pits, gas wells, and sulfur springs as a product of decaying plant and animal material under low oxygen conditions. It is, therefore, commonly encountered in places such as sewage treatment plants, manure stockpiles, mines, swamps, and hot springs. Industrial sources of hydrogen sulfide include petroleum and natural gas extraction and refining, pulp and paper manufacturing, and waste disposal. Any oil or natural gas site should be considered as a potential source of H₂S.

The Forest Service National Technology and Development Program received two proposals requesting an evaluation and recommendation for a dosimeter¹ that would warn wildland firefighters of the presence of hydrogen sulfide. These proposals were in response to concerns raised by firefighters and fire managers who were often given different brands of dosimeters that were not effective or easy for firefighters to use. Additionally, firefighters have been exposed to H₂S during fire suppression activities in the past.

Through a comprehensive market search and evaluation; and field testing, a reliable and accurate H₂S dosimeter for use in wildland and prescribed fire management activities has been recommended. Firefighter safety will be greatly enhanced by providing a standardized dosimeter that has consistently performed well in the fire environment and has been accepted by firefighters.

¹ *A dosimeter is a device that contains an electrochemical sensor to detect atmospheric gases. Their purpose is to alert individuals of the presence of harmful gases. Dosimeters may also be referred to as monitors.*

H₂S Keywords

Hydrogen Sulfide, H₂S, wildland firefighting, oil and gas infrastructure, wildland firefighting in the wildland urban interface, H₂S dosimeters, H₂S monitoring

Hydrogen Sulfide Dosimeters for Wildland Firefighters



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In certain geographic areas of the United States, wildland firefighters may encounter oil and gas extraction and refining operations during wildland and prescribed fire management activities. While working near such operations, wildland firefighters can be exposed to hydrogen sulfide (H₂S) gas. Hydrogen sulfide is an extremely hazardous, toxic compound. It is a colorless, flammable gas characterized by a rotten egg odor at low concentrations. The gas occurs naturally in coal pits, gas wells, and sulfur springs as a product of decaying plant and animal material under low oxygen conditions. It is, therefore, commonly encountered in places, such as sewage treatment plants, manure stockpiles, mines, swamps, and hot springs. Industrial sources of H₂S include petroleum and natural gas extraction and refining, pulp and paper manufacturing, and waste disposal. Although oil field companies are required to provide warning signs of the presence of H₂S, firefighters cannot rely on the accuracy of these signs. Furthermore, wells that have been free of H₂S in the past may become contaminated and produce H₂S without the knowledge of oil industry employees. Any oil or natural gas site should be considered as a potential source of H₂S.

The National Technology and Development Program of the Forest Service, an agency of the U.S. Department of Agriculture, received two proposals requesting an evaluation and recommendation for a dosimeter¹ that would warn wildland firefighters of the presence of H₂S. One proposal was submitted from the U.S. Department of the Interior, Bureau of Land Management, and the Forest Service Fire Management from the Rocky Mountain Region. The second proposal was submitted by the Southern Ute Agency, U.S. Department of the Interior, Bureau of Indian Affairs. Both proposals requested an evaluation of H₂S dosimeters and a recommendation for one dosimeter that could be used by all wildland firefighters. These proposals were in response to concerns raised by firefighters and fire managers who often were given different brands of dosimeters that were neither effective nor easy for firefighters to use.

¹ A dosimeter is a device that contains an electrochemical sensor to detect atmospheric gases. Their purpose is to alert individuals of the presence of harmful gases. Dosimeters may also be referred to as monitors.

Additionally, firefighters have been exposed to H₂S during fire suppression activities in the past. As oil and gas extraction increases throughout the United States, exposure incidents may become more likely.

Hydrogen sulfide is classified as a chemical asphyxiate similar to carbon monoxide and hydrogen cyanide gases. It inhibits cellular respiration and uptake of oxygen, causing biochemical suffocation. Typical exposure symptoms include:

- Low (0–10 parts per million [ppm]): Irritation of the eyes, nose, and throat.
- Moderate (10–50 ppm): Headache, dizziness, nausea, vomiting, coughing, and difficulty breathing.
- High (50–200 ppm): Severe respiratory tract irritation, eye irritation/acute conjunctivitis, shock, convulsions, coma, and death in severe cases.

Given the clear importance of protecting the health and safety of wildland firefighters and the serious health consequences of H₂S exposure, the San Dimas Technology and Development Center (SDTDC) a National Technology and Development Center was asked to evaluate portable gas dosimeters (specifically H₂S) for use in wildland fire and resource management environments. The SDTDC Fire and Fuels Management staff conducted an evaluation of several gas dosimeters, including several that have been used in wildland fire management, as well as other commercially available dosimeters that could be mission-appropriate. Objectives of the evaluation were as follows:

- Review the dosimeters currently in use and evaluate the criteria applied in their selection.
- Develop specifications and operating parameters to serve as a benchmark for dosimeter evaluation.
- Conduct a market search of commercially available dosimeters.
- Develop a method to compare the performance of dosimeters being evaluated.
- Recommend a standard single-gas and multigas dosimeter.

SDTDC (we) evaluated 10 commercially available dosimeters. Careful consideration was made to ensure that the firefighters would be adequately protected yet would not be burdened significantly by the equipment being recommended. As a result of the evaluation, we recommend three dosimeters from Mine Safety Appliances (MSA). The first is the ALTAIR Single-Gas (H₂S) Detector. This would be the optimum dosimeter for firefighters and requires the least amount of training. The second dosimeter is the ALTAIR Pro Single-Gas (H₂S) Detector, which could be used for management purposes if datalogging capabilities were necessary. Finally, we recommend the ALTAIR 4X Multigas Detector [H₂S, carbon monoxide (CO), Lower Explosive Limit² (LEL), and oxygen (O₂)] as a multiple gas dosimeter.

Objective

The primary objective of this project is to identify a reliable and accurate H₂S dosimeter for use in the wildland fire environment. The dosimeter must be capable of providing accurate readings of H₂S, alert firefighters of the presence of H₂S, be able to withstand the wildland fire environment, and be easy for firefighters to operate. In addition to identifying a single gas (H₂S) dosimeter, we recommend a multiple gas (H₂S, CO, O₂) and combustible gases (LEL) dosimeters.

Currently, several different dosimeters are being used in areas with the potential for H₂S exposure. This presents fire managers and firefighters with numerous challenges. Because each type of dosimeter may function differently and require different methods to assure accuracy and reliability, firefighters and fire managers may be given dosimeters that are difficult to use or are not suitable for the fire environment and, therefore, do not provide adequate firefighter safety. This issue was raised after firefighters were exposed to H₂S on the Maverick Fire on August 6, 2008 <http://wildfirelessons.net/documents/Final_Maverick_Lessons_Learned_Review.pdf>.

Although dosimeters are complex instruments, which require daily testing and periodic calibration, providing a standardized dosimeter will greatly reduce confusion and help ensure greater firefighter safety.

Procedure

Effective monitoring and measurement of gases requires that instruments operate as designed, without being adversely affected by the environmental and physical conditions encountered by wildland firefighters. All equipment—particularly if safety related—must be reliable, accurate, and capable of withstanding environmental extremes. Based on the harsh conditions of the fire environment, we developed several critical evaluation criteria for the subject dosimeters. To ensure the selected dosimeter(s) are able to provide the necessary protection (accurate measurement and notification) to firefighters, we used an evaluation matrix to compare dosimeter performance to the established standards. Dosimeters not meeting one or more of the criteria were removed from consideration. Critical operational parameters were:

- Temperature range: 5 °C–50 °C (41 °F–122 °F).
- Shock/vibration: Military Standard 810G.
- Waterproof/dust penetration: (IP Rating: 66).
- Relative humidity: 10 to 95 percent.
- Smoke exposure: Gas sensor not adversely affected by vegetative smoke.
- Radio interference: Radio frequency interference protection.
- Elevation: 0–10,000 feet.
- Minimum battery life: 24 hours.

Additional criteria, which were beneficial but not critical, also were included in the evaluation. We developed these criteria to identify additional features that would be useful to wildland firefighters and fire managers. These criteria proved to be valuable in an evaluation of CO dosimeters that we used to measure smoke exposure to wildland firefighters.

² Lower Explosive Limit is the lowest concentration (in percentage) of a gas or vapor in air capable of producing a flash fire in the presence of an ignition source.

The supplemental evaluation criteria were:

- Ease of use.
 - Field operation.
 - Calibration.
 - Bump test.³
- Alarms.
 - Multiple alarm set points.
 - User-defined alarm set points.
- Sensor range of detection (parts per million [ppm]).
- Calibration requirements.
- Exposure measurements. (Appendix C contains definitions for these terms.)
 - IDLH—Immediately Dangerous to Life and Health.
 - STEL—Short-Term Exposure Limit.
 - TWA—Time-Weighted Average.
 - Real time display.
- Sampling rate.
- Data acquisition.

The specification form used for the evaluation matrix is shown in appendix A.

We evaluated 10 dosimeters from 4 different manufacturers, including several that have been used on wildland fires in the Rocky Mountain Region*.

BW Technologies

- GasAlert MicroClip MultiGas Detector*
- GasAlertClip Extreme (Single Gas)
- GasAlert Extreme (Single Gas)

Drager

- Pac 5500
- Pac 7000

Industrial Scientific*

- M40
- GasBadge Plus

MSA

- ALTAIR Pro Single Gas Detector
- ALTAIR Single Gas Detector
- ALTAIR 4X Multigas Detector

* Evaluation results for each dosimeter are shown in appendix B.

³ A bump test is used to ensure that the electrochemical sensor in the dosimeter is functioning properly and is within the acceptable tolerance limits of detection.

Results and Discussion

Firefighters often work extended shifts and, at times, do not have access to electrical power sources. A 24-hour minimum battery life was selected to ensure that the candidate dosimeter would provide adequate monitoring coverage for firefighters. The BW Technologies GasAlert MicroClip Multi Gas Detector and the Industrial Scientific M40 have a battery life expectancy of 10 and 18 hours respectively, and were removed from further consideration.

Dosimeters used in the fire environment also must be impervious to water and dust. An Ingress Protection (IP) rating of 66⁴ ensures that the dosimeter will function properly in dusty and wet conditions, so the specification required an IP rating of 66. The Drager Pac 5500 and Pac 7000 have an IP rating of 65, the Industrial Scientific M40 has an IP rating of 64. Therefore, these dosimeters were removed from further consideration.

SDTDC staff conducted a Wildland Firefighter Smoke Exposure study from 2009 to 2011. At the outset of this project, SDTDC evaluated several single-gas dosimeters to measure CO on the fireline and in fire camps. This evaluation included a market search, laboratory testing, and field trials. The results of this evaluation led SDTDC staff to select the MSA Altair Pro Fire CO dosimeter. During the 3-year study, these dosimeters proved to be very reliable, accurate, and durable while being used on numerous fires throughout the United States.

Dosimeters must be bump-tested daily to assure that the electrochemical sensor remains within acceptable calibration limits. The Altair Pro dosimeters were calibrated at a minimum of 30 days and consistently passed the daily bump test. MSA offers a QuickCheck Station (figures 1 and 2) for daily bump testing. This unit provides a simple, quick method to run the required daily test. The QuickCheck Station is portable



Figure 1—QuickCheck Station with calibration gas.



Figure 2—QuickCheck Station with dosimeter.

⁴An IP (Ingress Protection) rating is used to specify the environmental protection—electrical enclosure—of equipment. The first number relates to protection against solid objects; a rating of 6 means the device is totally protected against dust. The second number relates to protection against liquids; a rating of 6 means the device is protected against temporary flooding of water.

and can be used for single-gas MSA dosimeters as long as the appropriate test gas is available. The Altair Pro Fire CO dosimeter used in the Wildland Firefighter Smoke Exposure project is identical to the H₂S Altair Pro, except that it uses a different sensor to detect H₂S.

During the dosimeter evaluation for the Wildland Firefighter Smoke Exposure project, we also evaluated the Industrial Scientific GasBadge Plus. Although the GasBadge Plus meets the critical evaluation criteria, field trials in 2009 found this unit to be inadequate and problematic in wildland fire situations. While being worn by wildland firefighters, the exposed vapor/dust barrier that protects the sensor became torn on several occasions, a condition that may expose the sensor to damage or excessive amounts of dust or moisture. In addition, at times the barrier became covered with dust and ash, impeding its ability to accurately measure CO concentrations. This was confirmed by bump test failures on several occasions. Furthermore, the bump test calibration procedure for this device is more time consuming and less straightforward than the MSA Altair Pro.

Field evaluation of the MSA Altair Pro H₂S dosimeters took place at two sites in the Rocky Mountain Region during the 2011 fire season. Dosimeters, QuickCheck Stations, the Galaxy calibration unit (figure 3), and test gas were provided to Forest Service and Bureau of Land Management employees at an interagency fire station in Rifle, CO, and to firefighters on the Southern Ute Agency. This provided the firefighters and fire managers the opportunity to use and evaluate the recommended equipment. Based on personal conversations and responses to a project evaluation, the MSA dosimeters and equipment were very well received by both firefighters and managers. Users commented on the ease of use and simplicity of the dosimeters and calibration procedures. The individuals who submitted the two proposals commented that the recommended dosimeters met their original objectives and believe that the MSA Altair units will provide the protection and service they need for their firefighters.



Figure 3—MSA Galaxy calibration Unit.

SDTDC recommends the MSA Altair Single-Gas Detector (H₂S) dosimeter for firefighters working in areas that may be subject to H₂S exposure. This dosimeter, which can operate for 2 years without being turned off, is designed to be disposable; neither the sensor nor the battery can be replaced. Calibration and bump tests are the only maintenance requirements. Calibration is recommended every 30 days. Calibration is done with the MSA Galaxy. The calibration procedure requires the same test gas used for the bump test. It is a simple process that takes about 5 minutes per device. The results of the calibration are recorded in the dosimeter memory and also should be documented on a tracking form.

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Daily bump tests are recommended during regular use or prior to being used by firefighters. A bump test also should be documented on a tracking form. A designated employee (who manages the monitoring program) can apply the appropriate alarm settings, turn the units on, and transfer the units to the firefighters. Firefighters do not have to interface with the dosimeter; they only need to understand the safety information regarding H₂S and what actions to take when an alarm sounds. Upon detection of H₂S at the alarm point setting, the Altair Pro emits an audible alarm, vibrates, and illuminates a flashing red light emitting diode (LEDs) on top of the unit. The redundancy of these alarms is designed so that the user will be aware of the danger regardless of other noise or distractions. The battery and sensor in the Altair Pro have a minimum life expectancy of 2 years.

SDTDC also recommends the MSA Altair Pro Single-Gas Detector (H₂S) (figures 4 and 5). It is similar to the Altair Single-Gas Detector, but with several distinct differences. The Pro model has the ability to log exposure levels. This information can be downloaded to a personal computer (PC) for later reference and analysis. This may be useful in the event of an exposure incident, but it requires more management of the dosimeter. If the Altair Pro is used, a designated employee must have responsibility to ensure the alarm set points are correct and the device is configured correctly. The alarm and configuration settings may be password protected so that only designated personnel can access them. In addition, the dosimeter can be configured so that the user cannot turn off the device or disable the alarms. We recommend that this become part of the standard operating procedure. The sensor and battery can be replaced on the Altair Pro. The battery on the Altair Pro will last for 2 years.

If a safety officer or division supervisor is interested in monitoring CO levels as well as H₂S, SDTDC recommends the MSA Altair 4X Multigas Detector dosimeter. This dosimeter is capable of detecting the level of H₂S, CO, and O₂. In addition, the unit will warn the firefighter if the combination of gases in the atmosphere pose a flash fire potential.



Figure 4—MSA Altair Pro (CO unit shown).



Figure 5—MSA Altair Pro (CO unit shown).

Through a comprehensive market search, evaluation, and field testing, we recommended reliable and accurate H₂S dosimeters for use in wildland and prescribed fire management activities. Local fire management staff must ensure that firefighters are trained in the use and care of these safety devices. Furthermore, they must assign staff to maintain the dosimeters so the units are in good working order when needed. Firefighter safety will be greatly enhanced by providing a standardized dosimeter that has consistently performed well in the fire environment and has been accepted by firefighters.

SDTDC staff would like to thank Trevor Maynard, mechanical engineer, SDTDC for his technical review of this publication.

The National Technology and Development Center's national publications are available on the Internet at <http://www.fs.fed.us/eng/pubs/>.

Forest Service and U.S. Department of the Interior, Bureau of Land Management employees also can view videos, CDs, and National Technology and Development Center's individual project pages on their internal computer network at <http://fsweb.sdtc.wo.fs.fed.us/>.

For additional information on hydrogen sulfide dosimeters for wildland firefighters, contact George Broyles at SDTDC, gbroyles@fs.fed.us.

Example Specification Form

Make		
Model		
Gases Measured		
Detection Range:		
H ₂ S		
CO		
O ₂		
Combustible (LEL)		
Battery		
Type		
User Replaceable		
Rechargeable		
Life		
Operating Parameters		
Temperature		
Shock		
Waterproof		
IP Rating		
Humidity		
Smoke Sensitive		
Radio Frequency Interference Protection		
Dimensions		
Size		
Weight		
Calibration		
Users Can Calibrate		
Required Equipment		
Ease of Calibration		
Vender Must Calibrate		
Cost		
Turn Around		

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Bump Test		
Required Equipment		
Ease of use		
Portability		
Power Requirement		
Sensor		
Replacement		
Alarms		
User Access To Set Alarm		
# of Alarm Set Points		
Type of Alarms (Audible, Vibration, LED)		
Exposure Measured and Displayed		
IDLH		
STEL		
PEL		
TWA		
Realtime		
Other		
Cost		
Dosimeter		
Bump Test Equipment		
Calibration Equipment		
Warranty		
Datalogger Options		
Data Recorder		
Sampling Rate		
User Options		
Accessories		
Notes		

BW TECHNOLOGIES

BW Technologies GasAlert MicroClip Multi Gas Detector

Make	BW Technologies	
Model	GasAlert MicroClip Multi Gas Detector	
Gases Measured	H ₂ S, CO, O ₂ , Combustible Gases (LEL)	
Detection Range:		
H ₂ S	0–100 ppm (1/0.1 ppm increments)	
H ₂ S	0–200 ppm (1 ppm increments)	
CO	0–1,000 ppm (1 ppm increments)	
O ₂	0–30% vol (0.1% vol. increments)	
Combustible (LEL)	0–100% LEL (1% LEL increments) or 0–5.0% v/v methane	
Battery		
Type	Lithium Polymer Battery	
User Replaceable	No	
Rechargeable	Yes, <4 hrs	
Life (Run Time)	10 hrs (typical)	
Operating Parameters		
Temperature	-4 to +136 °F/-20 to +58 °C	
Shock	Concussion proof boot	
Waterproof	Water resistant	
IP Rating	66/67	
Humidity	0%– 95% RH (noncondensing)	
Elevation	N/A	
Smoke Sensitive	No (depending on the chemicals from the gas)	
Radio Frequency Interference Protection	Yes	
Dimensions		
Size	4.2 x 2.4 x 1.1 in./10.8 x 6.0 x 2.7 cm	
Weight	5.7 oz./160 g	

Hydrogen Sulfide Dosimeters for Wildland Firefighters

Calibration		
Users Can Calibrate	Yes	
<i>Required Equipment</i>	Calibration gas from BW Tech	25 ppm H ₂ S 100 ppm CO 2.5% vol. LEL 18% vol. O ₂
<i>Ease of Calibration</i>		
Vendor Must Calibrate	No	
<i>Cost</i>		
<i>Turn Around</i>		
Bump Testing		
Required Equipment	Bump Gas CG Bump 1 (aerosol)	
Ease of use		
Portability		
Power Requirement		
Sensor		
Replacement	Yes	
Alarms		
User Access To Set Alarm	Yes	
# of Alarm Set Points	5	
Type of Alarms (Audible, Vibration, Led)	Visual, vibrating, audible (95dB)	
Exposure Measured and Displayed		
IDLH		
STEL	Yes	
PEL		
TWA	Yes	
Real Time	Yes	
Other	Low, High, OL (Over Limit)	
Cost		
Dosimeter	\$545	
Bump Test Equipment	11 L cyl.-CG-Bump1 (\$65)	
Calibration Equipment	34 L cyl. - CGQ34-4 (\$150) Regulator- reg-0.5 (\$150)	
Warranty		
	Full 2 year warranty including all sensors	

Appendix B—Dosimeters Tested by Manufacturers

Datalogger Options	User-downloadable datalogger (standard)	
Data Recorder	All events and occurrences	
Sampling Rate	Factory set at 5-second intervals and user-settable from 1 to 127-second intervals	
User Options	Confidence beep	
	Set STEL interval	
	Sensor on/off	
	Latching alarms	
	Safe display mode	
	Stealth mode	
	Calibration lock	
	Auto Zero on startup	
	O ₂ auto calibration on startup	
	Set bump test interval	
	Combustible gas measurement (% LEL or % by volume methane)	
	Force bump test when overdue	
	Low alarm acknowledge	
	Language choices (5)	
	Set custom startup message	
Accessories	MicroDock II (bump test and calibration)	\$1,545
	Main Flow Regulator (reg-df-1) - Use with MicroDock II	\$325

Hydrogen Sulfide Dosimeters for Wildland Firefighters

BW Technologies GasAlertClip Extreme (Single Gas)

Make	BW Technologies	
Model	GasAlertClip Extreme (Single Gas)	
Gases Measured	H ₂ S, CO, SO ₂ , O ₂	
Detection Range:		
H ₂ S	0–100 ppm	
SO ₂	0–100 ppm	
CO	0–300 ppm	
O ₂	0–30% vol.	
Combustible (LEL)		
Battery		
Type		
User Replaceable	No	
Rechargeable	No	
Life (Run Time)	2 years (H ₂ S, CO, SO ₂ , O ₂) or 3 years (H ₂ S, CO)	
Operating Parameters		
Temperature	H ₂ S: -40 to +122 °F/-40 to +50 °C CO: -22 to +122 °F/-30 to +50 °C SO ₂ : -22 to +122 °F/-30 to +50 °C O ₂ : -4 to +122 °F/-20 to +50 °C	
Shock	Concussion proof boot	
Waterproof	Water resistant	
IP Rating	66/67	
Humidity	5%– 95% RH (noncondensing)	
Elevation	N/A	
Smoke Sensitive	No (depending on the chemicals from the gas)	
Radio Frequency Interference Protection	Yes	
Dimensions		
Size	1.1 x 2.0 x 3.2 in./2.8 x 5.0 x 8.1 cm	
Weight	2.7 oz./76 g	
Calibration		
Users Can Calibrate	No, calibration free	
<i>Required Equipment</i>		
<i>Ease of Calibration</i>		
Vendor Must Calibrate		
<i>Cost</i>		
<i>Turn Around</i>		

Appendix B—Dosimeters Tested by Manufacturers

Bump Testing		
Required Equipment	Bump test gas or calibration gas	
Ease of use		
Portability	Yes	
Power Requirement	No	
Sensor		
Replacement	No	
Alarms		
User Access To Set Alarm	No	
# of Alarm Set Points	2	
Type of Alarms (Audible, Vibration, LED)	Visual, vibrating, audible (95dB)	
Exposure Measured and Displayed		
IDLH		
STEL		
PEL		
TWA		
Real Time		
Other	Low, high	
Cost		
Dosimeter	\$189	
Bump Test Equipment		
Calibration Equipment		
Warranty	2 years	
Datalogger Options		
Data Recorder		
Sampling Rate		
User Options		
Accessories	MicroDock II (bump test and calibration)	\$1,545
	Main flow regulator (reg-df-1)—Use with MicroDock II	\$325

Hydrogen Sulfide Dosimeters for Wildland Firefighters

BW Technologies GasAlert Extreme (Single Gas)

Make	BW Technologies	
Model	GasAlert Extreme (Single Gas)	
Gases Measured	H ₂ S, CO, SO ₂ , O ₂ , others	
Detection Range:		
H ₂ S	0–500 ppm	
SO ₂	0–100 ppm	
CO	0–1,000 ppm	
O ₂	0–30% vol.	
Combustible (LEL)		
Battery		
Type	3V	
User Replaceable	Yes	
Rechargeable	No	
Life (Run Time)	2 year life (typical)	
Operating Parameters		
Temperature	H ₂ S: -40 to +122 °F/-40 to +50 °C CO: -22 to +122 °F/-30 to +50 °C SO ₂ : -40 to +122 °F/-40 to +50 °C O ₂ : -4 to +122 °F/-20 to +50 °C	
Shock	Concussion proof boot	
Waterproof	Water resistant	
IP Rating	66/67	
Humidity	15%– 90% RH (noncondensing)	
Elevation	N/A	
Smoke Sensitive	No (depending on the chemicals from the gas)	
Radio Frequency Interference Protection	Yes	
Dimensions		
Size	1.1 x 2.0 x 3.75 in./2.8 x 5.0 x 9.5 cm	
Weight	2.9 oz./82 g	
Calibration		
Users Can Calibrate	No, calibration free	
<i>Required Equipment</i>		
<i>Ease of Calibration</i>		
Vendor Must Calibrate		
<i>Cost</i>		
<i>Turn Around</i>		

Appendix B—Dosimeters Tested by Manufacturers

Bump Testing		
Required Equipment	Bump test gas or calibration gas	
Ease of use		
Portability	Yes	
Power Requirement	No	
Sensor		
Replacement	No	
Alarms		
User Access To Set Alarm	Yes	
# of Alarm Set Points	4	
Type of Alarms (Audible, Vibration, Led)	Visual, vibrating, audible (95dB)	
Exposure Measured and Displayed		
IDLH		
STEL	Yes	
PEL		
TWA	Yes	
Real Time		
Other	Low, high	
Cost		
Dosimeter		
Bump Test Equipment		
Calibration Equipment		
Warranty	2 years	
Datalogger Options		
Data Recorder		
Sampling Rate		
User Options		
	Confidence beep	
	Latching alarms	
	Stealth mode	
	Passcode protection	
	Automatic O ₂ calibration	
	Automatic backlight	
	User-settable calibration gas level	
	Calibration past due lockout	
	Language choices (five)	
Accessories		
	MicroDock II (bump test and calibration)	\$1,545
	Main Flow Regulator (reg-df-1)—Use with MicroDock II	\$325

Hydrogen Sulfide Dosimeters for Wildland Firefighters

DRAGER

Drager Pac 5500

Make	Drager	
Model	Pac 5500	
Gases Measured	CO, H ₂ S, O ₂	
Detection Range:		
H ₂ S	0–100 ppm	
CO	0–500 ppm	
O ₂	0–25% vol	
Combustible (LEL)		
Battery		
Type	Lithium battery	
User Replaceable	Yes	
Rechargeable		
Life (Run Time)	2 years	
Operating Parameters		
Temperature	-20 to +120 °F/-30 to +50 °C	
Shock	Impact resistant rubber coating	
Waterproof		
IP Rating	65	
Humidity	10– 90% RH	
Elevation		
Smoke Sensitive	No	
Radio Frequency Interference Protection	Yes	
Dimensions		
Size	3.3 x 2.5 x 1.0 in./8.4 x 6.4 x 2.5 cm	
Weight	3.8 oz./120 g	
Calibration		
Users Can Calibrate	Yes	
<i>Required Equipment</i>	Calibration cup, cylinder, regulator	
<i>Ease of Calibration</i>		
Vendor Must Calibrate		
<i>Cost</i>		
<i>Turn Around</i>		

Appendix B—Dosimeters Tested by Manufacturers

Bump Testing		
Required Equipment	Same as calibration	
Ease of Use		
Portability		
Power Requirement		
Sensor		
Replacement	Yes	
Alarms		
User Access To Set Alarm	Yes	
# of Alarm Set Points	2	
Type of Alarms (Audible, Vibration, LED)	Visual, vibrating, audible (90dB)	
Exposure Measured and Displayed		
IDLH		
STEL		
PEL		
TWA		
Real Time	Yes	
Other	Low or high	
Cost		
Dosimeter	\$299	
Bump Test Equipment	Cylinder: \$160 Regulator: \$160 Cup: \$39.50	
Calibration Equipment	Same as calibration	
Warranty		
2 years		
Datalogger Options		
Storage of up to 60 events		
Data Recorder		
Sampling Rate		
Accessories		
Bump test station: \$559 (regulator not required)		

Hydrogen Sulfide Dosimeters for Wildland Firefighters

Drager Pac 7000

Make	Drager	
Model	Pac 7000	
Gases Measured	CO, H ₂ S, O ₂ , others	
Detection Range:		
<i>H₂S</i>	0–100 ppm	
CO	0–1,999 ppm	
O ₂	0–25% vol	
<i>Combustible (LEL)</i>		
Battery		
Type	Lithium battery	
User Replaceable	Yes	
Rechargeable		
Life (Run Time)	5,500 hours (O ₂ : 2,700 hrs)	
Operating Parameters		
Temperature	-20 to +120 °F/-30 to +50 °C	
Shock	Impact resistant rubber coating	
Waterproof		
IP Rating	65	
Humidity	10– 90% RH	
Elevation		
Smoke Sensitive	No	
Radio Frequency Interference Protection	Yes	
Dimensions		
Size	3.3 x 2.5 x 1.0 in./8.4 x 6.4 x 2.5 cm	
Weight	3.8 oz./120 g	
Calibration		
Users Can Calibrate	Yes	
<i>Required Equipment</i>	Calibration cup, cylinder, regulator	
<i>Ease of Calibration</i>		
Vendor Must Calibrate		
<i>Cost</i>		
<i>Turn Around</i>		

Appendix B—Dosimeters Tested by Manufacturers

Bump Testing		
Required Equipment	Same as calibration	
Ease of use		
Portability		
Power Requirement		
Sensor		
Replacement	Yes	
Alarms		
User Access To Set Alarm	Yes	
# of Alarm Set Points	2	
Type of Alarms (Audible, Vibration, LED)	Visual, vibrating, audible (90dB)	
Exposure Measured and Displayed		
IDLH		
STEL	Yes	
PEL		
TWA	Yes	
Real Time	Yes	
Other		
Cost		
Dosimeter	\$399 (H2S)	
Bump Test Equipment	Cylinder: \$160 Regulator: \$160 Cup: \$39.50	
Calibration Equipment		
Warranty		
	5 year	
Datalogger Options		
	Yes	
Data Recorder		
Sampling Rate	120 hrs @1 data set per min.	
Accessories		
	Bump test station: \$559 (don't need regulator)	

Hydrogen Sulfide Dosimeters for Wildland Firefighters

INDUSTRIAL SCIENTIFIC

Industrial Scientific M40

Make	Industrial Scientific	
Model	M40	
Gases Measured	H ₂ S, CO, O ₂ , combustible gases (LEL)	
Detection Range:		
H ₂ S	0–500 ppm (1 ppm increments)	
CO	0–999 ppm (1 ppm increments)	
O ₂	0–30% vol (0.1% vol. increments)	
Combustible (LEL)	0–100% LEL (1% LEL increments)	
Battery		
Type	Lithium-ion Integral battery	
User Replaceable	No	
Rechargeable	Yes	
Life (Run Time)	18 hr - Instrument (nonalarm)	
Operating Parameters		
Temperature	-20 to +58 °C (-4 to +122 °F)	
Shock	Impact resistant case	
Waterproof	Water resistant	
IP Rating	64	
Humidity	15 to 95% RH (typical) 0 to 99% RH intermittent (noncondensing)	
Elevation	Zero at elevation	
Smoke Sensitive	No	
Radio Frequency Interference Protection	Yes	
Dimensions		
Size	4.30 x 2.45 x 1.37 in./10.9 x 6.22 x 3.48 cm	
Weight w/Pump	8.6 oz/244 g	
Calibration		
Users Can Calibrate	Yes	
<i>Required Equipment</i>	Gas cylinder and regulator	25 ppm H ₂ S 100 ppm CO 25% vol. LEL Pentane 19% vol. O ₂
<i>Ease of Calibration</i>	Calibrates all sensors at once	
Vendor Must Calibrate		
Cost		
Turn Around		

Appendix B—Dosimeters Tested by Manufacturers

Bump Testing		
Required Equipment	Same as calibration	
Ease of use		
Portability		
Power Requirement		
Sensor		
Replacement	Yes, recommended send in to IS	
Alarms		
User Access To Set Alarm	Yes	
# of Alarm Set Points	5	
Type of Alarms (Audible, Vibration, LED)	Vibrating, 90 dB audible, and ultra-bright LED visual alarms	
Exposure Measured and Displayed		
IDLH		
STEL	Yes	
PEL		
TWA	Yes	
Real Time	Yes	
Other	High, Low	
Cost		
Dosimeter	\$553.90 (M40)	
Bump Test Equipment	Same as calibration	
Calibration Equipment	\$186.19 cylinder \$139.64 regulator	
Warranty		
2 years		
Datalogger Options		
Up to 75 hrs of datalogging		\$139.64
Data Recorder		
Sampling Rate		
Accessories		
M Cal 401 calibration station (6 unit)		\$1,485
M Cal 401 calibration station (single unit)		\$740

Hydrogen Sulfide Dosimeters for Wildland Firefighters

GASBADGE

GasBadge Plus

Make	GasBadge Plus	
Model	181000050-2 (H2S)	
Gases Measured	Is available to detect either O ₂ , CO, H ₂ S, NO ₂ , or SO ₂ .	
Detection Range:		
<i>H₂S</i>	0–500 ppm /0.1 ppm	
<i>NO₂</i>	0–150 ppm /0.1 ppm	
<i>CO</i>	0–1,500/1 ppm	
<i>SO₂</i>	0–150 ppm/0.1 ppm	
<i>O₂</i>	0–30% of volume/0.1%	
<i>Combustible (LEL)</i>		
Battery		
Type	3V Lithium, nonreplaceable	
User Replaceable	No	
Rechargeable	No	
Life	Continuously monitors and displays the amount of instrument life remaining until the unit is no longer operational. (2 years/2,600 hrs)	
Operating Parameters		
Temperature	40 °C to 60 °C (-40 °F to 140 °F),	
Shock	Protective concussion-proof overmold protects the unit from extreme abuse	
Waterproof	Third party certified (water resistant)	
IP Rating	66/67	
Humidity	0-99% RH (noncondensing), typical	
Smoke Sensitive		
Radio Frequency Interference Protection	Resistant to radio frequency interference	
Dimensions		
Size	3.2 x 1.9 x 1.1 in.	
Weight	2.5 oz	

Appendix B—Dosimeters Tested by Manufacturers

Calibration		
Users Can Calibrate	Yes	
<i>Required Equipment</i>	Calibration gas cylinder, calibration cup	
<i>Ease of Calibration</i>	Seems easy	
Vendor Must Calibrate	No	
<i>Cost</i>		
<i>Turn Around</i>		
Bump Testing		
Required Equipment	Calibration gas cylinder, calibration cup	
Ease of use		
Portability	Yes	
Power Requirement	No	
Sensor		
Replacement	Part numbers provided in manual to order more	
Alarms		
User Access To Set Alarm	The low and high alarm setpoints are completely adjustable by the end user. This allows customers to set the instrument alarms according to company standards.	
# of Alarm Set Points		
Type of Alarms (Audible, Vibration, LED)	Powerful audible alarm (95 dB) complemented by vibrating and visual alarms, standard	
Exposure Measured and Displayed		
IDLH		
STEL		
PEL		
TWA		
Real Time	Yes	
Other	The instrument will continuously keep track and make viewable in the field, the highest gas reading the sensor has been exposed to since the last time the peak was cleared. The instrument will display “OR” to alert the user of an over-range condition.	

Hydrogen Sulfide Dosimeters for Wildland Firefighters

Cost		
Dosimeter	\$195	
Bump Test Equipment		
Calibration Equipment		
Warranty	2 years from the date of activation or 1,000 minutes of total alarm time. Must be activated by the date on the package.	
Datalogger Options		
Data Recorder	Continually on. Logs last 15 alarm events, stamping how long ago the event occurred, the duration of the event, and the peak reading seen during the event. Event-logger can be viewed on PC or printed directly from the instrument to an infrared printer.	
Sampling Rate		
User Options	Can be password-protected for added security	
	Online training available	
	Can configure operating system to users' needs	
	Rent device on a weekly or monthly basis	
Accessories	Cal-Plus calibration station (optional)	\$874.50
	Datalink (optional)	\$165.00
	Nylon carrying case	\$11.00
	Docking station	\$1,974.50
	Neck lanyard with safety release	
Notes	At 7 days of battery life remaining, the empty outline of the battery icon will blink to warn the user that the unit is nearing the end of its life. At 4 hours of life remaining, the user is alerted by a short burst of alarms every 15 seconds accompanied by the empty blinking icon. Both warnings are designed to give an advanced indication that it is time to get a new instrument.	
	Two buttons (mode and entry)	
	Large display screen with many icons	
	Sensor over-range protection	

MSA ALTAIR

MSA ALTAIR Pro Single Gas Detector

Make	MSA	
Model	ALTAIR Pro Single Gas Detector	
Gases Measured	O ₂ , CO, H ₂ S, HCN, Cl ₂ , ClO ₂ , SO ₂ , NO ₂ , NH ₃ , PH ₃ , O ₂ -R	
Detection Range:		
<i>H₂S</i>	0–200 ppm (1 ppm increments)	
CO	0–1,500 ppm (1 ppm increments)	
O ₂	0– 25% vol (0.1% vol. increments)	
<i>Combustible (LEL)</i>		
Battery		
Type	CR ₂ lithium camera battery	
User Replaceable	Yes	
Rechargeable	No	
Life (Run Time)	9,000 hrs	
Operating Parameters		
Temperature	-20 to +58 °C (-4 to +122 °F)	
Shock		
Waterproof		
IP Rating	67	
Humidity	10%– 95% RH (noncondensing)	
Elevation	O ₂ sensor may be affected	
Smoke Sensitive	No	
Radio Frequency Interference Protection	Yes	
Dimensions		
Size	3.4 x 2.0 x 1.0 in	
Weight	4.0 oz.	
Calibration		
Users Can Calibrate	Yes	
<i>Required Equipment</i>	Regulator and cylinder	
<i>Ease of Calibration</i>		
Vendor Must Calibrate		
<i>Cost</i>		
<i>Turn Around</i>		

Hydrogen Sulfide Dosimeters for Wildland Firefighters

Bump Testing		
Required Equipment	Same as calibration	
Ease of use		
Portability		
Power Requirement		
Sensor		
Replacement	Yes, user can replace	
Alarms		
User Access To Set Alarm	Yes with software	
# of Alarm Set Points	4	
Type of Alarms (Audible, Vibration, LED)	Visual, vibrating, audible (95dB)	
Exposure Measured and Displayed		
IDLH		
STEL	Yes	
PEL		
TWA	Yes	
Real Time	Yes	
Other	Low, high, min, max, FAS time, Cal/Span time	
Cost		
Dosimeter	H ₂ S \$332.00	
Bump Test Equipment	Same as calibration	
Calibration Equipment	Calibration gas –\$159.00 Regulator– \$193.00	
Warranty		
Datalogger Options		
Data Recorder		
Sampling Rate	50 latest events in session log. Peak value every 3 min in periodic log	
Accessories		
	Galaxy	
	Quick check	

MSA ALTAIR Single Gas Detector

Make	MSA	
Model	ALTAIR Single Gas Detector	
Gases Measured	O ₂ , CO, H ₂ S	
Detection Range:		
<i>H₂S</i>	0–100 ppm (1 ppm increments)	
<i>CO</i>	0–500 ppm (1 ppm increments)	
<i>O₂</i>	0–25% vol (0.1% vol. increments)	
<i>Combustible (LEL)</i>		
Battery		
Type	Lithium	
User Replaceable	No	
Rechargeable	No	
Life (Run Time)	Stays on for 24 months	
Operating Parameters		
Temperature	-20 to +58 °C (-4 to +122 °F)	
Shock		
Waterproof		
IP Rating	67	
Humidity	10%– 95% RH (noncondensing)	
Elevation	O ₂ sensor may be affected	
Smoke Sensitive	No	
Radio Frequency Interference Protection	Yes	
Dimensions		
Size	3.4 x 2.0 x 1.0 in	
Weight	4.0 oz.	
Calibration		
Users Can Calibrate	Yes	
<i>Required Equipment</i>	Regulator and cylinder	
<i>Ease of Calibration</i>		
Vendor Must Calibrate		
<i>Cost</i>		
<i>Turn Around</i>		

Hydrogen Sulfide Dosimeters for Wildland Firefighters

Bump Testing		
Required Equipment	Same as calibration	
Ease of use		
Portability		
Power Requirement		
Sensor		
Replacement	Yes, user can replace	
Alarms		
User Access To Set Alarm	Yes with software	
# of Alarm Set Points	2	
Type of Alarms (Audible, Vibration, Led)	Visual, vibrating, audible (95dB)	
Exposure Measured and Displayed		
IDLH		
STEL		
PEL		
TWA		
Real Time	Yes	
Other	Low, high	
Cost		
Dosimeter	\$198	
Bump Test Equipment	Same as calibration	
Calibration Equipment	Calibration Gas-\$159.00 Regulator-\$193.00	
Warranty		
Datalogger Options		
Data Recorder	None	
Sampling Rate		
Accessories		
	Galaxy	
	Quick Check	

MSA ALTAIR 4X Multigas Detector

Make	MSA	
Model	ALTAIR 4X Multigas Detector	
Gases Measured	LEL, O ₂ , two-toxic H ₂ S/CO, or individual H ₂ S and CO sensors	
Detection Range:		
H ₂ S	1–200 ppm	
NO ₂		
CO	0–1,999 ppm	
SO ₂		
O ₂	0–30% vol	
CH ₄	0–5.00%	
Combustible (LEL)	0–100% LEL	
Battery		
Type	Lithium polymer battery	
User Replaceable	Yes	
Rechargeable	Yes; charges in < 4 hours	
Life	The nominal run-time of the instrument at room temperature is 24hrs	
Operating Parameters		
Temperature	14 to 104 °F (-10 to 40 °C) normal operating range -4 to 122 °F (-20 to 50 °C) extended operating range 50 to 95°F (10 to 35°C) while charging battery -40 to +140 °F (-40 to 60 °C) intrinsic safety ambient temperature range	
Shock	Withstands 20-foot drop	
Waterproof		
IP Rating	67	
Humidity	15– 90% relative humidity, noncondensing; 5–95% RH intermittent	
Smoke Sensitive		
Radio Frequency Interference Protection	The digital output of the sensors makes them much less susceptible to RF interference	
Dimensions		
Size	4.4 x 3.00 x 1.37 in.—without fastening clip	
Weight	7.9 oz. (instrument with battery and clip)	

Hydrogen Sulfide Dosimeters for Wildland Firefighters

Calibration		
Users Can Calibrate	Yes-manually or using the Galaxy test stand	
<i>Required Equipment</i>	Calibration check gas cylinder 0.25 L/min. flow regulator 1/8 in. ID Superthane ester tubing ALTAIR 4X calibration cap.	
<i>Ease of Calibration</i>	Directions and flowchart provided in manual	
Vendor Must Calibrate	No	
Cost		
Turn Around	Less than 60-second calibration time	
Bump Testing		
Required Equipment	Calibration check gas cylinder 0.25 L/min. Flow regulator 1/8 in. ID Superthane ester tubing ALTAIR 4X calibration cap	
Ease of use	Directions and flowchart provided in manual	
Portability		
Power Requirement	Yes	
Sensor		
Replacement	Can replace and install new sensors manually	
Alarms		
User Access To Set Alarm	Yes	
# of Alarm Set Points		
Type of Alarms (Audible, Vibration, LED)	4 gas alarm LEDs, a charge status LED, an audible alarm, and a vibrating alarm	
Exposure Measured and Displayed		
IDLH		
STEL	The STEL icon appears on the display to show the average exposure over a 15-min period.	
PEL		
TWA	The TWA icon appears on the display to show the average exposure since the instrument was turned ON or since the TWA reading was reset.	
Real Time	Yes	
Other		

Appendix B—Dosimeters Tested by Manufacturers

Cost		
Dosimeter	Dosimeter with calibration cap and tubing	\$760.00
Bump Test Equipment	Same as calibration	
Calibration Equipment	34 L calibration gas	\$200.60
	Fixed flow 0.25 L/min regulator	\$165.00
Warranty	Full 3-year warranty	
Datalogger Options		
Data Recorder	Data log (adjustable) 50 hour minimum Event log Standard 500 events	
Sampling Rate		
User Options	MSA exclusive MotionAlert™ and InstantAlert™ Features (allows user to manually alert others)	
Accessories	Battery charger provided must be used, otherwise damage may occur	
	Manual has a list of optional items to purchase	
	Glow-in-the-Dark housing for mining and confined spaces	
	Universal pump probe	
Notes	Compatible with the ALTAIR 4 QuickCheck® Station and the ALTAIR 4 Galaxy® Test Stand	
	End of sensor life advanced warning	

1. IDLH – Immediately Dangerous to Life or Health

The National Institute for Occupational Safety and Health (NIOSH) establishes an IDLH level for toxins. The IDLH refers to acute respiratory exposures that pose an immediate threat of loss of life. These exposures may result in irreversible or severe health effects, eye damage, irritation, or other conditions that could impair an employee's escape from the hazardous environment. This is the "IDLH" value (Immediately Dangerous to Life and Health). The NIOSH IDLH for H₂S is 100 ppm.

2. STEL Short-term exposure limit

The National Institute for Occupational Safety & Health (NIOSH) has established a short term exposure limit of 10 ppm for 10 minutes to prevent development of adverse health effects from brief but intense exposures.

3. TWA 8-hour permissible exposure limit

The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), has established an 8-hour work shift, time-weighted average (TWA) permissible exposure limit (PEL) for H₂S of 50 parts per million with a maximum exposure duration of 10 minutes. This limit should protect most workers at normal workplaces with little hard physical labor.