## ANSI/ISA-S12.15, Part I-1990

Approved June 19, 1991

**American National Standard** 

# Performance Requirements for Hydrogen Sulfide Detection Instruments (10-100 ppm)



ANSI/ISA-SI2.15, Part I — Performance Requirements for Hydrogen Sulfide Detection Instruments (10-100 ppm)

ISBN 1-55617-239-7

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## Preface

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This standard was approved for publication by the ISA Standards and Practices Board in February 1990.

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## **1** Purpose

**CAUTION:** Hydrogen sulfide is an extremely toxic gas, and exposure may result in loss of consciousness or death.

**1.1** ISA-S12.15, Part 1, has been prepared to provide minimum requirements for performance of electrical instruments for the detection of hydrogen sulfide gas to enhance the safety of personnel.

**1.2** Part II of this standard establishes user criteria for the installation, operation, and maintenance of hydrogen sulfide gas detection instruments.

## 2 Scope

**2.1** This standard covers the details of construction, performance, and testing of portable, mobile, and stationary electrical instruments used for continuous monitoring for the presence of hydrogen sulfide gas concentrations in air, parts of which may be installed or operated in hazardous (classified) locations.

**2.2** This standard applies to line voltage-operated instruments rated at 250 V nominal or less and to portable, mobile, and stationary-type instruments utilizing a battery(s).

**2.3** This standard applies to instruments suitable for use in an ambient temperature range of at least –10°C to 50°C (14°F to 122°F).

**2.4** This standard covers hydrogen sulfide gas detection instruments intended to provide a warning of the presence of potential hazards in the concentration ranges up to 100 ppm. Hereafter, the term "gas detection instrument" or just "instrument" refers to a hydrogen sulfide gas detection instrument.

**2.5** This standard does not cover gas detection instruments of the laboratory or scientific type used for analysis or measurement in process control and process monitoring applications, instruments intended for residential purposes, or instruments with full-scale gas concentration ranges less than 10 ppm or greater than 100 ppm.

**NOTE:** The user should specify instrumentation that will provide a higher level of accuracy than the minimum tolerances of this standard if required by the application risk.

## 3 Definitions

**Alarm** is an audible, visual, or physical presentation designed to alert the instrument user that a specific level of hydrogen sulfide concentration has been reached or exceeded.

**Alarm-only instrument** is an instrument providing an alarm(s), but which does not have an integral meter or other readout device indicating current hydrogen sulfide concentration levels.

Alarm set point is the selected gas concentration level(s) where an alarm is activated.

Ambient air is air to which the sensing element is normally exposed.

**Approved** is acceptable to the authority having jurisdiction. In this standard, the term is considered synonymous with "listed" and "certified."

**Calibration** is the procedure used to adjust the instrument for proper response (e.g., zero level, span, alarm, and range).

**Calibration gas** is the known concentration(s) of hydrogen sulfide gas used to set the instrument span or alarm level(s). Reference also Section 7.8.

**Clean air** is air that is free of any substance that will adversely affect the operation or cause a response of the instrument.

**Consumables** are those materials or components that are depleted or require periodic replacement through normal use of the instrument.

**Control unit** is the portion of a multi-part gas detection instrument that is not directly responsive to the gas but responds to the electrical signal obtained from one or more detector heads to produce an indication, alarm, or other output function.

**Detector head** is the gas-responsive portion of a gas detection instrument located in the area where sensing the presence of gas is desired. Its location may be integral with or remote from its control unit.

**NOTE:** In the same housing, the detector head may incorporate the gas-sensing element and additional circuitry such as signal processing or amplifying components or circuits.

**Diffusion** is a process by which the atmosphere being monitored is transported to the gassensing element by natural random molecular movement.

**Gas detection instrument** or **instrument** is an assembly of electrical, mechanical, and chemical components (either a single integrated unit or a system comprised of two or more physically separate but interconnected component parts) that senses and responds to the presence of gas in air mixtures.

**Gas-sensing element (sensor)** is the particular subassembly or element in the gas detection instrument that, in the presence of a gas, produces a change in its electrical, chemical, or physical characteristics.

**Hydrogen sulfide** is interchangeable within this document for: hydrogen sulfide,  $H_2S$ , dihydrogen sulfide, and hydrogen sulfide gas.

**IDLH** is the immediate danger to life or health concentration value (300 ppm for hydrogen sulfide).

**Mobile** refers to a continuous-monitoring instrument mounted on a vehicle such as, but not limited to, a mining machine or industrial truck.

**Nominal voltage** is that given by manufacturers as the recommended operating voltage of their gas detection equipment. If a range (versus a specific voltage) is given, the nominal voltage shall be considered as the midpoint of the range, unless otherwise specified.

**Portable** refers to a self-contained, battery-operated instrument that can be carried.

**NOTE:** This type instrument is intended to operate continuously for 8 hours (h) or more.

**Range** is the series of outputs corresponding to values of concentrations of hydrogen sulfide over which accuracy is ensured by calibration.

**Sample draw** refers to a method used to cause deliberate flow of the atmosphere being monitored to a gas-sensing element.

Span is the algebraic difference between the upper and lower values of a range.

**Stationary** refers to a gas detection instrument intended for permanent installation in a fixed location.

Test gas is hydrogen sulfide diluted with clean air to a known concentration.

**Trouble signal** is a signal (contact transfer and/or visible or audible signal) advising an instrument user of conditions such as input power failure, an open circuit breaker, a blown fuse, loss of continuity to the detector head, defective gas-sensing element, or significant downscale indication.

## 4 General requirements

**4.1** Gas detection instruments shall meet the applicable electrical and electronic measuring instrument requirements of ANSI/ISA-S82.01, S82.02, and S82.03. See Reference F(10) of Appendix A.

**4.2** Any portion of a stationary gas detection instrument intended for installation or use in a hazardous (classified) location and all portable instruments shall be approved for use in the location and marked accordingly. Reference NFPA 70, Article 500-3, FPN No. 2.

**4.3** All gas detection instruments shall meet the minimum construction and test requirements contained in this standard. If the manufacturer makes performance claims that exceed these requirements, all such claims shall be verified to the satisfaction of parties having jurisdiction.

## 5 Construction

#### 5.1 General

**5.1.1** Gas detection instruments, their components, or remote detector heads specifically intended for use in the presence of hydrogen sulfide or other corrosive vapors or gases, or vapors or gases that may produce corrosive byproducts as a result of oxidation or other chemical process(es), shall be constructed of materials resistant to, or protected against, such corrosion.

**NOTE:** When present, even at low parts per billion concentrations, hydrogen sulfide may rapidly attack copper, silver, aluminum, and iron alloys.

(Reference: ISA-S71.04-1985, Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants.)

**5.1.2** Instruments of the sample draw type shall include the necessary sample-pumping mechanisms.

**5.1.3** Instruments of the sample draw type shall incorporate a device to indicate adequate or inadequate flow.

#### 5.2 Meters, indicators, and outputs

**5.2.1** Instruments having an integral meter to indicate gas concentrations shall employ a meter having sufficient resolution to permit measurement with the precision required for performing the tests referenced herein.

**5.2.2** All nonlinear scales or indicators shall be prominently and clearly noted in the Instruction Manual and on the instrument.

**5.2.3** Gas detection instruments that employ digital displays shall provide a means to indicate to the user that a gas concentration in excess of the range of the instrument has been detected.

**5.2.4** When outputs (e.g., 4-20 mA) are provided, the Instruction Manual shall provide graphs or other means to indicate the relationship between input and output. When such outputs are provided, their malfunction shall not adversely affect alarm functions.

**5.2.5** Devices (such as switches) that disable alarm or trouble outputs or signals are acceptable if the following criteria are met:

- 1) Alarm or trouble outputs or signals are automatically enabled when the device is returned to the operating (normal) mode.
- 2) A distinctive visual and/or audible indication and a distinctive output signal are provided with the device in the disable (bypass) mode.
- 3) Local visual alarm indications are not disabled. EXCEPTION: Indications may be disabled when the instrument is in the CALIBRATE mode.

#### 5.3 Alarm function(s)

**5.3.1** Alarm device output contacts (or equivalent), if provided as part of instruments and intended to indicate a specific minimum hydrogen sulfide gas concentration, shall be of a latching type, requiring a deliberate manual action to reset. If two or more set points or alarm positions are provided, the lower may be nonlatching, based on user preference.

**5.3.2** The latching requirement may be omitted, or a defeating option permitted, if a clear and prominent statement in the Instruction Manual recommends that the instrument be connected to an auxiliary system that accomplishes the same purpose as latching.

5.3.3 All instruments shall have at least one alarm function that cannot be adjusted above 20 ppm.

**5.3.4** All portable gas detection instruments shall be provided with a distinguishable alarm indicating low battery condition. This alarm shall operate for a minimum of 5 minutes, during which time no erratic readings or false alarms are permitted.

#### 5.4 Trouble signals

**5.4.1** All gas detection instruments shall provide for a signal transfer or contact transfer to produce a trouble signal in the event of:

- a) input power failure to the instrument,
- b) opening of circuit protection device,
- c) loss of continuity in any one or more electrical conductors or other links to any remote detector head, or
- d) downscale indication below zero equivalent to 5 ppm.

Such signal or contact transfer shall be independent of other alarms, shutdown signals, and contact transfer.

**NOTE:** It is desirable to provide a trouble signal for a defective element (or other component) if technically feasible.

**5.4.2** Stationary and mobile sample draw-type gas detection instruments shall be provided with flow-proving devices (either integral or non-integral) that shall produce a trouble signal in the form of a contact transfer or signal transfer in the event of flow below the manufacturer's stated minimum required flow rate. All portable gas detection instruments shall be provided with an audible and/ or visual trouble signal indicating when flow is below the manufacturer's stated minimum required flow rate.

## 5.5 Controls and adjustments

**5.5.1** All gas detection instruments shall be provided with means for facilitating calibration checks and adjustments as required.

**5.5.2** Calibration, zero, and alarm(s) settings shall be designed to minimize the possibility of unauthorized or accidental readjustment and shall require a key, code, or tool for adjustment.

**5.5.3** Stationary instruments shall have all controls for normal operations accessible from outside the enclosures if they are housed in explosion-proof enclosures or enclosures that are purged in accordance with NFPA No. 496. The controls/adjustments for routine calibration of such instruments may be inside the enclosure, provided *all* the following requirements are met:

- 1) The enclosure is of the type with a cover that can be readily opened and closed and does not require removal and replacement of bolts or other securing devices in order to open and close the enclosure.
- 2) All adjustments, switches, or controls that may be deliberately or accidentally operated during the calibration procedure shall involve only nonincendive circuits.
- 3) All circuits exceeding 30 V rms or 42.4 V peak to peak and all circuits 30 V rms or less that are not Class 2 power limited as defined by Article 725 of the NEC are protected from accidental contact through appropriate mechanical guards or barriers.
- 4) All circuits are either intrinsically safe or the enclosure is marked in accordance with Section 6.1.4.

## 5.6 Consumables

**5.6.1** For information relating to batteries, refer to Section 5.7.

**5.6.2** Portable and mobile instruments that require consumables shall be capable of operating a minimum of 8 hours without replacement or replenishment of such consumables under the conditions described by Section 7.17.3.

## 5.7 Batteries

Instruments powered by integral batteries shall be capable of continuous operation at a temperature of  $-10^{\circ}$ C (14°F) for a period of at least 8 hours, including 15 minutes of maximum load (continuous alarm, lights, etc.) without replacement or recharge of batteries.

## 6 Instrument markings and instruction manuals

#### 6.1 Markings on instrument

**6.1.1** The markings required in this section are in addition to the marking requirement contained in Section 4.2.

**6.1.2** The markings required by this standard shall appear in a clearly legible, visible, and permanent manner on each gas detection instrument in the following manner, as applicable:

- 1) For portable instruments, the marking shall appear both on the outside surface of the instrument and on any removable carrying case, if the latter obscures the markings required.
- For stationary instruments, the marking required shall appear in a location where it will be visible after installation and in direct sight during the routine periodic recalibration and adjustment of alarm set point(s).

**6.1.3** All gas detection instruments shall be marked "CAUTION — READ AND UNDERSTAND INSTRUCTION MANUAL BEFORE OPERATING OR SERVICING." The word "CAUTION" of the foregoing is to be in capital letters at least 3 mm high. The balance of the wording is to be in capital letters at least 2.5 mm high.

**NOTE 1:** For gas detection instruments that comprise a control unit and a remote detector head, it is sufficient that the marking appear on the control unit only, except that, if routine recalibration can be accomplished entirely by adjustments at the remote detector location(s), this marking is to appear both on the control unit and on the remote detector head.

**NOTE 2:** For modular control units that are comprised of one or more control modules in a common enclosure or mounting assembly, the marking need not be repeated on each module but may appear as a single marking on the common portion of the assembly.

**NOTE 3:** Where there is insufficient space for required markings to appear on the front panel (visible after installation), markings may be provided on permanent labels or tags to be installed by the user.

**6.1.4** Instruments of the type referred to in Section 5.5.3 and not intrinsically safe shall be marked "CAUTION — THIS AREA MUST BE KNOWN TO BE NONHAZARDOUS PRIOR TO OPENING THE ENCLOSURE" in capital letters at least 5 mm high and in a permanent manner. The location is to be conspicuously visible without having to remove the cover.

**6.1.5** Where the design of special features of the instrument requires additional markings or changes in marking requirements, the additions or revisions are allowed, but the safety and instructional intent of Section 6.1 must be met.

**6.1.6** The manufacturer's stated temperature range within which the detector heads will perform within specifications shall appear in a clearly legible, visible, and permanent manner on each detector head. If multiple or interchangeable gas-sensing elements are provided in a common housing, the most restrictive temperature range shall be used.

**6.1.7** The range of detection shall be prominently marked on the instrument.

#### 6.2 Instruction manual

**6.2.1** Each gas detection instrument shall be provided with an Instruction Manual furnished by the manufacturer that shall contain at least the following information:

1) A list of desensitizing, contaminating, or interfering substances or water vapor concentrations known to the instrument manufacturer that may adversely affect proper operation of the instrument. Warning as to effects of oxygen-enriched or oxygen-deficient atmospheres must be included.

**NOTE:** Recognizing that it is difficult to compile a complete list of all possible desensitizing or contaminating gases or substances, it is recommended that the manual also include either the generic description of the sensing element or a description of its properties so that the user can evaluate the probable effect of contaminants that are not included in the list.

- Instructions and recommended frequencies for checking and calibrating: (a) on a routine basis, (b) following exposure to desensitizing or contaminating substances, and (c) following exposure to concentrations causing operation of any alarm.
- 3) Complete installation and initial start-up instructions.
- 4) A list of operating adjustments and instructions for setting them (e.g., alarm set point, zero, and span adjustments).
- 5) Details of instrument operational limitations (e.g., ambient temperature limits for all parts of the instrument, warm-up time, humidity range, voltage range, maximum loop resistance, and minimum wire size for wiring between control unit and remote detector head(s), need for shielding of wiring, grounding, battery life, accuracy, response times, maximum and minimum storage temperatures, pressure limits, and air velocity limits).
- 6) Instructions to clearly indicate the nature and significance of all alarms, trouble signals, and any provisions that may be made for silencing or resetting of such alarms, as applicable.
- 7) Instructions for the installation and operation of any accessories provided. A list of available options shall be included.
- 8) For instruments of the sample draw type, detailed instructions to ensure that sample lines are intact and proper flow is established.
- 9) For instruments of the sample draw type, instructions to indicate the minimum and/ or maximum flow rate or range of flow rates, tubing pressure rating, maximum tubing length/size, sample draw lag times, and materials suitable for proper operation.
- 10) For instruments of the sample draw type, adequate data/information to advise the user of inaccuracies caused by absorption/adsorption of hydrogen sulfide by sample lines, contaminates, etc.
- 11) An operational review to determine possible sources of malfunction and the corrective procedures, including periodic servicing of the instrument.
- 12) A listing of consumable and replacement components and the expected life/usage rate, recommendations for storage of each item, and installation instructions with an emphasis on the gas-sensing element.
- 13) Minimum and maximum operating voltages for battery-operated instruments as well as a listing by manufacturer and model number (or NEDA number) of recommended batteries for portables (not necessarily all-inclusive).

- 14) Information concerning effects of externally generated electromagnetic interference on instrument performance. Likewise, if the instrument is prone to generating emi that could be detrimental to other nearby instrumentation, this information shall also be included.
- 15) The specific type(s) of calibration gas to be used (hydrogen sulfide in nitrogen, hydrogen sulfide diluted with clean air, etc.).
- 16) Information concerning nonlinear scales, indicators, and outputs.
- 17) Relationship between any outputs and hydrogen sulfide concentrations.
- 18) A recommendation for external alarm latching when non-latching alarms are provided.

**6.2.2** The design or special nature of the instrument may require additional instructions and/or special information that are in contradiction of, or in addition to, the requirements of Section 6.2.1.

## 7 Performance tests

#### 7.1 General

- 1) The tests described in Sections 7.5 through 7.19 are in addition to the requirements referred to in Section 4.
- 2) The instrument to be tested shall be fully representative of instruments intended for commercial production, and the same instrument shall be subjected to all tests applicable to that type of instrument.
- 3) Unwarranted (false) alarms shall be considered failure of the tests.

#### 7.2 Sequence of tests

The sequence of tests shall correspond to the order of these paragraphs.

**EXCEPTION:** The tests described by Sections 7.10 through 7.15 (i.e., step change, supply voltage, temperature, humidity, air velocity, and emi) may be performed in any order following the test described by Section 7.9 but before the test described by Section 7.16.

#### 7.3 Preparation of the instrument

The instrument selected for testing shall be prepared as if for actual service, including all necessary interconnections and initial adjustments, in accordance with the manufacturer's Instruction Manual.

**NOTE:** For instruments having remote detector heads, all tests shall be performed with resistances connected in the detector circuit to simulate the maximum line resistance specified by the instrument manufacturer except where the minimum line resistance offers a more stringent test in the judgment of the parties having jurisdiction.

#### 7.4 Conditions for test and test area

**7.4.1 Voltage.** Except as otherwise indicated herein, all tests shall be performed at the nominal system voltage and frequency marked on the equipment, or with fresh or fully charged batteries, as applicable.

**7.4.2 Ambient temperature.** Except as otherwise indicated herein, tests may be performed at any conveniently available ambient temperature in the range of 18 to  $30 \degree C$  (64 to  $86 \degree F$ ).

**7.4.3 Humidity.** Except as otherwise indicated herein, tests may be performed in ambient air having a relative humidity of any convenient value in the range of 30 to 70 percent.

**7.4.4 Air circulation.** Except as otherwise indicated herein, tests are to be performed in relatively still air (velocity not more than 1 meter per second [m/s]) other than those currents that may be induced by convection due to the natural heating of the equipment under test or caused by airmoving devices that are part of the equipment under test. The output indication may differ under conditions of a stagnant sample (sample velocities of 0.1 m/s or less).

**7.4.5 Removal of parts.** For purposes of the tests in Sections 7.7 through 7.18 where reference is made to exposing the detector head to specified gas mixtures or to other specified conditions, in the case of remote detector heads, the entire detector head (including all normally attached diffusion devices or protective mechanical parts) shall be so exposed.

**7.4.6 Multiple detector heads.** For instruments intended to be used with more than one remote detector head, only one detector head will be exposed when tests call for the exposure of the remote detector head to a specified test gas or other specified set of conditions.

Dummy electrical loads (e.g., fixed resistors) may be substituted for additional detector heads, but, if additional detector heads are used, all other detector heads shall be exposed to clean air and normal conditions for tests as described in Sections 7.4.2 through 7.4.4.

**7.4.7 Recalibration or adjustment.** The instrument under test may be adjusted or recalibrated prior to the start of each of the tests described in Sections 7.7 through 7.18; however, no further adjustments or recalibration shall be carried out for the duration of that test, except where specifically permitted by the particular test procedure.

**7.4.8 Stabilization time.** For purposes of the tests in Sections 7.10, 7.12, 7.13, and 7.14, except as otherwise indicated herein, the instrument shall be allowed to stabilize under each different test condition before measurements are taken for comparison purposes.

**NOTE:** An instrument shall be considered to be stabilized when three successive observations of the indication taken at 5-minute intervals indicate no further significant change from the initial reading. A significant change is defined as a variation greater than one division for analog meters or two counts of the unit digit for digital displays.

**7.4.9 Alarm-only instruments.** For the tests described in the following paragraphs of Section 7, a tolerance of 4 ppm or 10 percent of the nominal alarm set point value, whichever is greater, shall apply. One alarm set point shall not be adjustable higher than 20 ppm.

**7.4.10** For instruments having selectable ranges, the tests of Sections 7.9 through 7.17 shall be performed with the instrument set at all ranges unless specifically stated otherwise.

## 7.5 Non-powered transportation

To evaluate instruments for typical transportation environmental ranges, prior to tests described by Sections 7.6 through 7.18, all parts of the gas detection instrument shall be exposed sequentially to the following conditions:

- 1) Temperature of  $-35 \,^{\circ}C(-31 \,^{\circ}F)$  and ambient barometric pressure for 24 hours.
- 2) Ambient temperature and humidity for at least 24 hours.
- 3) Temperature of  $+55 \,^{\circ}$ C (131  $^{\circ}$ F) and ambient barometric pressure for 24 hours.
- 4) Ambient temperature and humidity for at least 24 hours.

## 7.6 Drop test

**7.6.1** This test is applicable only to portable instruments.

**7.6.2** While in the operating mode, the instrument (less any removable case) shall be released from a height of 1 m above a concrete surface and allowed to free fall.

**7.6.3** The test required by Section 7.6.2 shall be performed three separate times — each time released with a different side (surface) of the instrument facing down at the time of release.

7.6.4 The instrument shall be considered to fail this test if it is obviously inoperative after the test.NOTE: Failures resulting from this test may not become apparent until the tests required by future sections are conducted.

**7.6.5** For the tests of Section 7.6, multi-range instruments need to be tested only on one range.

## 7.7 Vibration

**7.7.1 Apparatus.** The vibration test machine shall be capable of producing a vibration of variable frequency and variable constant excursion (or variable constant acceleration peak) with the instrument under test mounted in place, as required by the test procedure.

**7.7.2 Procedures.** While in the operating mode in clean air, all instruments shall be mounted on the vibration test machine and vibrated successively in each of three mutually perpendicular directions, respectively parallel to the edges of the instrument. The instrument shall be mounted on the vibration test machine in the same manner and position as intended for service, using any resilient mounts, carriers, or holding devices that are provided as a standard part of the instrument. The instruments shall be vibrated over a frequency range of 10 to 30 Hz at a total excursion of 1.0 mm and 31 to 100 Hz at a 2-*g* peak acceleration for a period of 1 hour in each of three mutually perpendicular directions. The rate of change of frequency shall not exceed 10 hertz per minute (Hz/minute).

**7.7.3 Test Criteria.** The instruments shall not give any false alarms; there shall be no loose components or damage to the enclosure that could cause a shock hazard. The instrument shall be considered to fail this test if it is obviously inoperative after the test.

**NOTE:** Failures resulting from this test may not become apparent until the tests required by future sections are conducted.

## 7.8 Initial calibration and setup

**7.8.1** The gas used for calibration shall be hydrogen sulfide or hydrogen sulfide mixed with chemically inert gas, which may be diluted with clean air.

**7.8.2** The instrument shall be calibrated for testing in accordance with this standard by using the manufacturer's recommended calibration device and specified calibration procedures. The calibration concentration shall be determined as follows.

For instruments containing meters or other concentration indicators, the instrument shall be adjusted to display the concentration(s) of the known calibration gas(s) applied to the detector head. Unless otherwise specified by the manufacturer, at least one calibration gas shall be a minimum of 50 percent of the selected range over which the instrument is to be calibrated.

**NOTE:** The manufacturer's recommended calibration equipment shall match the results of the intended method of gas monitoring within 2 ppm or 10 percent of the calibration gases concentrating, whichever is greater.

## 7.9 Accuracy test

**7.9.1** For instruments having meters or output signals, the detector head shall be exposed to clean air and mixtures of hydrogen sulfide in clean air (hereafter referred to as test gas). Compositions of the mixtures shall be 20 to 30 percent, 40 to 60 percent, and 65 to 90 percent of calibration range and shall be known to a tolerance of 5 percent or 1 ppm, whichever is greater. In each case, the concentration indicated by the meter or output signal shall not vary from the known test gas concentration by more than 2 ppm or 10 percent of gas concentration, whichever is greater. For instruments having selectable ranges, the instrument shall be tested on all ranges.

**7.9.2** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 2 ppm or 10 percent above the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 2 ppm or 10 percent below the alarm set point concentration, whichever is greater.
- 3) The time of exposure to each gas concentration shall be 5 minutes.

**7.9.3** For instruments of the sample draw type, the accuracy test described above shall be conducted at both the minimum and the maximum sample flow rates given by the manufacturer. Unacceptable performance at either flow rate shall constitute failure of the test.

## 7.10 Step change response

**7.10.1** For instruments having meters or output signals, after initially being in clean air, the detector head shall be suddenly exposed to a prepared mixture of hydrogen sulfide-in-air at atmospheric pressure having a concentration corresponding to 95 to 100 percent of range. From the instant of exposure to this gas mixture, the instrument shall respond to provide an indication of:

- a) 20 percent of maximum indicated gas concentration within 10 seconds (s), and
- b) 50 percent of maximum indicated gas concentration within 30 s.

7.10.1.1 For sample draw-type instruments, the transportation lines should be as short as practical.

**NOTE:** The Step Change Response Test provides response times for only the instruments and does not consider transport time of sample lines.

**7.10.1.2** For sample draw-type instruments, the manufacturer's stated response times for maximum length/size sample lines (including sample draw lag times as required by Section 6.2.1(5)) shall be verified.

**7.10.2** When stabilization has occurred, the test gas shall be removed. The indicator shall decline below 50 percent of the maximum indicated gas concentration within 45 s and below 10 percent of the maximum indicated gas concentration within 90 s.

**7.10.3** For alarm-only instruments, the instrument shall initially be placed in clean air. The detector head shall then be suddenly exposed to gas concentrations of 500 percent of the values of the alarm set point concentrations. All alarms shall be tested and all shall respond within 10 s of exposure to the respective changes.

## 7.11 Supply voltage variation

**7.11.1** For gas detection instruments intended for operation on AC power supply systems, with the detector head exposed to either clean air and/or test gas as noted, the supply voltage shall first be decreased to 85 percent of nominal voltage (see Section 3) and then increased to 110 percent of nominal voltage. Adjustable alarms shall be set to operate at 20 ppm or 50 percent of selected gas concentration range, whichever is less. As a result of this test, there shall be no instrument malfunction or false actuation of the alarm(s).

**NOTE:** The method of causing these step changes in voltage shall be such as to simulate the effect of a heavy load being added to or removed from the source of supply; i.e., there shall be no actual interruption of the voltage supply during the voltage transition.

**7.11.1.1** For instruments having meters or other outputs, with the detector head exposed to a concentration of 50 percent of the selected range, the variation in the meter or other output from actual concentration shall not exceed 4 ppm or 10 percent, whichever is greater.

**7.11.1.2** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 4 ppm or 10 percent *above* the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 4 ppm or 10 percent *below* the alarm set point concentration, whichever is greater.
- 3) Alarms shall not be activated when the detector head is exposed to clean air.
- 4) The time of exposure to each gas concentration shall be 5 minutes.

**7.11.2** Gas detection instruments intended for operation from an external DC power source shall be subjected to a step change in supply voltage from nominal to 122.5 percent of nominal voltage and from nominal to 87.5 percent of nominal voltage. During this test, the sensing head shall be exposed to either clean air and/or the test gas mixture as noted.

**7.11.2.1** For instruments having meters or other outputs, with the detector head exposed to a concentration of 50 percent of the selected range, the variation in the meter or other output from actual concentration shall not exceed 4 ppm or 10 percent, whichever is greater.

**7.11.2.2** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 4 ppm or 10 percent *above* the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 4 ppm or 10 percent *below* the alarm set point concentration, whichever is greater.
- 3) Alarms shall not be activated when the detector head is exposed to clean air.
- 4) The time of exposure to each gas concentration shall be 5 minutes.

**NOTE:** The method of causing these step changes in voltage shall be such as to simulate the effect of a heavy load being added to or removed from the source of supply; i.e., there shall be no actual interruption of the voltage supply during the voltage transition.

**7.11.3** For instruments containing integral batteries, the voltage variation shall correspond to the maximum terminal voltage of a fresh or fully charged battery(s) and the voltage at which the low battery voltage alarm activates (see Section 5.3.3). This voltage must be within 5 percent of the minimum operating voltage given by the manufacturer (see Section 6.2.1.1). Instruments having provision for adjustment to compensate for battery voltage decline may be so adjusted. During this test, the sensing head shall be exposed to clean air and/or the test gas mixture as noted.

**7.11.3.1** For instruments having meters or other outputs, with the detector head exposed to a concentration of 50 percent of the selected range, the variation in the meter or other output from actual concentration shall not exceed 4 ppm or 10 percent, whichever is greater.

**7.11.3.2** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 4 ppm or 10 percent *above* the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 4 ppm or 10 percent *below* the alarm set point concentration, whichever is greater.
- 3) Alarms shall not be activated when the detector head is exposed to clean air.
- 4) The time of exposure to each gas concentration shall be 5 minutes.

**7.11.4** Gas detection instruments intended for operation from an external power source shall be subjected to five momentary power interruptions, ranging from approximately 0.1 s to 5 s, with the detector head exposed to clean air. Following each interruption, the instrument shall be allowed sufficient time (not to exceed 60 s) to return to normal operating conditions. There shall be no incorrect instrument functions when the primary power is interrupted (applied or removed), with the detector exposed to both clean air and test gas of a concentration exceeding the lowest alarm setting by a minimum of 2 ppm or 10 percent, whichever is greater.

**7.11.5** Output inhibit circuits activated upon power application are permitted provided the duration of the inhibit is visually indicated.

## 7.12 Temperature variation

All gas detection instruments shall first be calibrated in accordance with Section 7.8, with all parts of the instrument at ambient temperature (see Section 7.4.2). The temperature of the test chamber shall be adjusted first to  $50 \,^{\circ}$ C ( $122 \,^{\circ}$ F), then ambient, and then  $-10 \,^{\circ}$ C ( $14 \,^{\circ}$ F). Stabilization time shall be as stated by the manufacturer but not less than 2 hours. Then the

sensor shall be exposed to a test gas concentration of 50 percent of the selected range and tested at each temperature as follows.

**7.12.1** For instruments with meters or other output signals and having the detector head integral with or directly attached to the control unit, the entire instrument shall be placed in the test chamber. At the two temperature extremes, the indication shall not vary from the initial stabilized ambient temperature reading by more than 4 ppm or 10 percent, whichever is greater.

**7.12.2** For instruments with meters or other output signals and a separate (non-integral) detector head,

- a) the control unit shall be placed in the test chamber at both 50°C (122°F) and -10°C (14°F) until the instrument temperature is stabilized, and then the detector head shall be exposed to a test gas concentration of 50 percent of the selected range ±5 percent or 1 ppm, whichever is greater, at ambient temperature; and
- b) with the control unit at ambient temperature, the detector head shall be placed in a test chamber at both 50°C (122°F) and –10°C (14°F), and a test gas concentration of 50 percent of the selected range ±5 percent or 1 ppm, whichever is greater, shall be applied. During these tests, the indication shall not vary from the ambient temperature indication by more than 4 ppm or 10 percent, whichever is greater, after stabilization time as stated by the manufacturer, but not less than 2 hours.

**NOTE:** The above temperature ranges are expected to accommodate most indoor environmentally controlled areas. Outdoor and special applications may require lower and/or higher temperature excursions. Detector heads suitable for such applications must be tested in accordance with Section 4.3 and so labeled.

**7.12.3** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 4 ppm or 10 percent *above* the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 4 ppm or 10 percent *below* the alarm set point concentration, whichever is greater.
- 3) The time of exposure to each gas concentration shall be 5 minutes.

#### 7.13 Humidity variation

- 1) The detector head shall be exposed to 15 percent or less relative humidity (r/h) at ambient temperature for 2 hours. The detector head shall then be exposed to ambient temperature test gas of a concentration of 50 percent of the selected range and a relative humidity of 15 percent or less.
- 2) The detector head shall then be exposed to 50 percent relative humidity (r/h) at ambient temperature for 2 hours. The detector head shall then be exposed to ambient temperature test gas of a concentration of 50 percent of the selected range and 50 percent r/h.
- 3) The detector head shall then be exposed to 90 percent relative humidity at ambient temperature for 2 hours. The detector head shall then be exposed to ambient temperature test gas of a concentration of 50 percent of the selected range and 90 percent r/h.

**7.13.1** For instruments having meters or other output signals, the meter and output indications at each humidity extreme shall not vary from the 50 percent relative humidity exposure indication by more than 4 ppm or 10 percent, whichever is greater.

**7.13.2** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 4 ppm or 10 percent *above* the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 4 ppm or 10 percent *below* the alarm set point concentration, whichever is greater.
- 3) The time of exposure to each gas concentration shall be 5 minutes.

**NOTE:** Relative humidity values are to be accurate within 5 relative humidity percentage points.

#### 7.14 Air velocity variation

**7.14.1** The instrument shall be calibrated with the detector head exposed to a static mixture of calibration gas. Next, it shall be exposed to a flowing test gas that impinges on the detector head with a velocity of  $5 \pm 0.5$  m/s. During this test, the direction of the air velocity or the orientation of the detector head shall be varied to determine the direction or orientation that causes the greatest deviation.

**7.14.1.1** For instruments having meters or other output signals, the meter or other output signal (during exposure to the mixture in motion) shall not vary from that observed during exposure to the static gas mixture by more than 4 ppm or 10 percent, whichever is greater.

**7.14.1.2** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 4 ppm or 10 percent *above* the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 4 ppm or 10 percent *below* the alarm set point concentration, whichever is greater.
- 3) The time of exposure to each gas concentration shall be 5 minutes.

## 7.15 Radio frequency interference (rfi)

The instruments (including detector head, electronics, and interconnecting wiring) shall be subjected, while in all energized modes (e.g., operating and calibrating), to electromagnetic energy in the frequency ranges of 150 to 170 MHz and 450 to 470 MHz. This test shall be conducted using frequency modulated portable radio transmitters (5 W maximum output from the final amplifier) at a distance of 1 meter from the instrument (i.e., the gas-sensing element, electronics, and any interconnecting wiring). Tests shall be conducted using any convenient frequency within each of the two frequency ranges.

**NOTE:** Except for portables, covers shall be removed when tests are conducted if the covers must be removed for calibration.

**7.15.1** For instruments incorporating meters or other output signals, the radio signals shall not cause a variation in the meter or other output from actual concentration of more than 2 ppm or 10 percent, whichever is greater, with test gas of a concentration of 50 percent of the selected range

applied, and/or shall not result in an incorrect instrument function. With clean air applied, there shall be no false alarms.

**7.15.2** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point (10 ppm maximum for adjustable set points) of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 4 ppm or 10 percent *above* the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 4 ppm or 10 percent *below* the alarm set point concentration, whichever is greater.

**7.15.3** Tests should be conducted after following the manufacturer's recommendations concerning wiring, shielding, and installation techniques as they pertain to electromagnetic interference.

**7.15.4** The equipment may be tested in accordance with SAMA PMC 33.1, Class 2, Bands "b" and "c" in lieu of the above test. See Appendix A, Reference M(2).

#### 7.16 Long-term stability

#### 7.16.1 Instruments incorporating meters or output signals

**7.16.1.1** Calibrate the instrument as per Section 7.8 and keep the power ON for the duration of this test.

**7.16.1.2** Subject the detector head to clean air at ambient temperature and humidity for a period of 21 days.

7.16.1.3 Apply test gas of a concentration of 50 percent of the selected range to the detector head.

- 1) The indicated concentration shall be at least 80 percent of the actual applied concentration within 5 minutes.
- 2) The indicated concentration shall not deviate from the actual applied concentration by more than 4 ppm or 10 percent, whichever is greater, after stabilization.

**7.16.1.4** Subject the detector head to a continuous hydrogen sulfide-in-clean air concentration of  $5 \pm 2$  ppm for a period of 14 days.

**NOTE:** A precise concentration is unnecessary. This test is provided only to test the instruments after exposure to a low background level of hydrogen sulfide.

**7.16.1.5** Remove the test gas for 5 minutes and repeat Section 7.16.1.3.

**7.16.1.6** Subject the detector head to clean air at ambient temperature and humidity for a period of 7 days.

**7.16.1.7** Apply test gas of 50 percent selected range concentration to the detector head. The indicated concentration shall be noted and shall not deviate from the actual applied concentration by more than 4 ppm or 10 percent, whichever is greater. The reading shall be taken after instrument stabilization.

7.16.1.8 Calibrate the instrument as per Section 7.8.

**7.16.1.9** Repeat the accuracy test as per Section 7.9.

#### 7.16.2 Alarm-only instruments

**7.16.2.1** Adjust the instrument as per Section 7.8.

**7.16.2.2** Subject the detector head to clean air at ambient temperature and humidity for a period of 21 days.

**7.16.2.3** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 4 ppm or 10 percent *above* the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 4 ppm or 10 percent *below* the alarm set point concentration, whichever is greater.
- 3) The time of exposure to each gas concentration shall be 5 minutes.

**7.16.2.4** Subject the detector head to a continuous hydrogen sulfide-in-air concentration of  $5 \pm 4$  ppm for a period of 14 days.

**NOTE:** A precise concentration is unnecessary. This test is provided only to test the instruments after exposure to a low background level of hydrogen sulfide.

**7.16.2.5** Remove the test gas for 5 minutes and repeat the tests of Section 7.16.2.3.

**7.16.2.6** Subject the detector head to clean air at ambient temperature and humidity for a period of 7 days.

7.16.2.7 Repeat the tests of Section 7.16.2.3.

**NOTE 1:** For battery-operated instruments, a suitable DC power supply or fresh batteries may be used for the test of Section 7.16, but the actual batteries specified for the instrument shall be used for the first 8 hours.

**NOTE 2:** Portable instruments shall be ON for 8 hours minimum and OFF for 16 hours maximum, according to the manufacturer's intended usage. The instruments shall be exposed to the clean air or hydrogen sulfide mixture, as specified above, continuously (except when batteries are being exchanged or when adjustments are being made). Calibration shall be performed as recommended by the manufacturer.

**NOTE 3:** For multi-range instruments, the test of Section 7.16 need be performed only on their highest range.

#### 7.17 Battery and low-battery voltage alarm

**7.17.1** This section is applicable only to instruments powered by integral batteries (excluding batteries used for memory retention and the like). This test is intended to verify that portable instruments will operate for specified time periods without exchanging or recharging internal batteries.

7.17.2 Calibrate or adjust the instrument per Section 7.8.

**7.17.3** Subject the instrument to clean air at a nominal temperature of -10 °C (14 °F) for 8 hours. The 8-hour period shall include a continuous 15-minute period of maximum load conditions (alarms, lights, etc., activated). Instruments having provisions for adjustment to compensate for battery voltage decline may be adjusted.

**7.17.4** For instruments having meters or output signals, at the end of the 8 hours specified in Section 7.17.3, the detector head shall be exposed to test gas of a concentration of 50 percent of the selected range. The indicated concentration shall not deviate from the actual applied concentration by more than 4 ppm or 10 percent, whichever is greater.

**7.17.5** For alarm-only instruments, all alarm set points shall be tested, with the lowest alarm set point of multiple alarm set point units tested first.

- 1) Alarms shall be activated by a test gas concentration of 4 ppm or 10 percent *above* the alarm set point concentration, whichever is greater.
- 2) Alarms shall NOT be activated by a test gas concentration of 4 ppm or 10 percent *below* the alarm set point concentration, whichever is greater.
- 3) The time of exposure to each gas concentration shall be 5 minutes.

#### 7.17.6 Low battery voltage alarm test

**7.17.6.1** Remove test gas and continue to operate the instrument until the low battery voltage alarm activates.

**7.17.6.2** The alarm must operate for a minimum of 5 minutes.

#### 7.18 Exposure to high concentration gas

**CAUTION:** HYDROGEN SULFIDE IS AN EXTREMELY TOXIC GAS, AND EXPOSURE MAY RESULT IN A LOSS OF CONSCIOUSNESS OR DEATH.

**7.18.1** The detector head of instruments other than the sample draw type shall be subjected to a step change in gas concentration from clean air to 1000-ppm gas for five (5) minutes. The instrument shall produce an alarm output within 10 seconds of exposure.

**7.18.1.1** Following removal of the 1000-ppm test gas, the detector head shall be exposed to clean air.

**7.18.1.2** For instruments incorporating meters or output signals, the meter indication or outputs shall drop to an indication of less than 20 ppm within 10 minutes.

**7.18.1.3** Alarm-only instruments with alarm set point(s) adjusted to 20 ppm or 50 percent of selected range, whichever is less, shall not indicate an alarm condition at 10 minutes.

**7.18.1.4** The accuracy test (Section 7.9) shall be performed thirty (30) minutes after the removal of the 1000-ppm test gas and exposure to clean air.

**NOTE:** If recommended by the manufacturer, the unit shall be calibrated prior to performing the accuracy test.

**7.18.2** Sample draw-type instruments shall be subjected to a test whereby, using the shortest possible sample tubing and operating at the flow rate recommended by the manufacturer with the sample inlet connected to a source of 1000-ppm gas, the instrument shall produce an alarm output within 10 seconds of exposure.

7.18.2.1 Following removal of the test gas, the detector head shall be exposed to clean air.

**7.18.2.2** For instruments incorporating meters or output signals, the meter indication or outputs shall drop to an indication of less than 20 ppm within 10 minutes.

**7.18.2.3** Alarm-only instruments with alarm set point(s) adjusted to 20 ppm or 50 percent of selected range, whichever is less, shall not indicate an alarm condition at 10 minutes.

**7.18.2.4** The accuracy test (Section 7.9) shall be performed thirty (30) minutes after the removal of the 1000-ppm test gas and exposure to clean air.

**NOTE:** If recommended by the manufacturer, the unit shall be calibrated prior to performing the accuracy test.

## 7.19 Electrical safety requirements

Following completion of all applicable tests of the preceding sections, the equipment shall be subjected to dielectric strength tests as specified by ANSI/ISA-S82.01, S82.02, and S82.03. See Reference F(10), Appendix A.

## Appendix A — Reference publications

This appendix is included for informational purposes and is not part of this standard.

- A. American Petroleum Institute (API)
  - 1) API RP 14C-1984, Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms.
  - 2) API RP 14F-1985, Recommended Practice for Design and Installation of Electrical Systems for Offshore Production Platforms.
  - 3) API RP 49-1987, Recommended Practices for Safe Drilling of Wells Containing Hydrogen Sulfide.
  - 4) API RP 55-1983, Conducting Oil and Gas Production Operations Involving Hydrogen Sulfide.
  - 5) API RP 500A-1982, Recommended Practice for Classification of Locations for Electrical Installations in Petroleum Refineries.
  - 6) API RP 500B-1987, Recommended Practice for Classification of Locations for Electrical Installations at Drilling Rigs and Production Facilities on Land and on Marine Fixed and Mobile Platforms.
  - 7) API RP 500C-1984, Recommended Practice for Classification of Locations for Electrical Installations at Pipeline Transportation Facilities.
- B. British Standards Institute
  - 1) BS.5345, Code of Practice in Selection, Installation, and Maintenance of Electrical Apparatus for Use in Potentially Explosive Atmospheres (Other Than Mining Applications for Explosive Processing and Manufacture). Parts 1-9.
- C. Canadian Standards Association (CSA)
  - 1) CSA Standard C22.2, No. 0.4, Bonding and Grounding of Electrical Equipment (Protective Grounding).
  - 2) CSA Standard C22.2, No. 152, Combustible Gas Detection Instruments.
- D. Factory Mutual Research Corporation
  - 1) Approval Standard Class Number 3610, October 1988, Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1 Hazardous (Classified) Locations.
  - 2) Approval Standard Class Number 3611, April 1986, Electrical Equipment for Use in Class I and II, Division 2, and Class III, Divisions 1 and 2 Hazardous Locations.
  - 3) Approval Standard Class Number 3615, March 1989, Explosionproof Electrical Equipment General Requirements.
  - 4) Approval Standard Class Number 3810, March 1989, Electrical and Electronic Test, Measuring, and Process Control Equipment.

- 5) Approval Standard Class Number 3600, March 1989, Electrical Equipment for Use in Hazardous (Classified) Locations General Requirements.
- 6) Approval Standard Class Number 6310, 6320, December 1989, Combustible Gas Detectors.
- E. Institute of Electrical and Electronics Engineers (IEEE)
  - 1) IEEE Std. 142-82, Recommended Practice for Grounding of Industrial and Commercial Power Systems.
  - 2) IEEE Std. 315-75, Graphic Symbols for Electrical and Electronics Diagrams.

F.

ISA

- 1) ANSI/ISA-S5.5-1984, Instrumentation Symbols and Identification.
- 2) ISA-S12.1-1960, Electrical Instruments in Hazardous Atmospheres.
- 3) ISA-S12.4-1970, Instrument Purging for Reduction of Hazardous Area Classification.
- 4) ANSI/ISA-RP12.6-1987, Installation of Intrinsically Safe Instrument Systems for Class 1 Hazardous Locations.
- 5) ANSI/ISA-S12.13, Part I, Performance Requirements, Combustible Gas Detectors.
- 6) ANSI/ISA-RP12.13, Part II, Installation, Operation, and Maintenance of Combustible Gas Detection Instruments.
- 7) ISA-RP-12.15, Part II, Installation, Operation, and Maintenance of Hydrogen Sulfide Detection Instruments.
- 8) ANSI/ISA-S51.1-1979, Process Instrumentation Terminology.
- 9) ANSI/ISA-S71.04-1985, Environmental Conditions for Process Measurement and Control Systems; Airborne Contaminants.
- 10) ANSI/ISA-S82.01, S82.02, and S82.03, Safety Standard for Electrical and Electronic Test, Measuring, Controlling, and Related Equipment.
- 11) Schaeffer, M. J., "The Use of Combustible Detectors in Protecting Facilities from Flammable Hazards," *ISA Transactions*, Vol. 20, No. 2., Research Triangle Park, N.C.
- 12) Bossert, John A., "Performance Certification of Combustible Gas Detectors," presented at ISA International Symposium, 1976.
- G. International Electrotechnical Commission (IEC)
  - 1) IEC Pub. 654-1 (1979), Operating Conditions for Industrial-Process Measurement and Control Equipment, Part I: Temperature, Humidity and Barometric Pressure.
- H. National Association of Corrosion Engineers (NACE)
  - 1) Corrosion Data Survey, Metals Section.
  - MR-01-75, Sulfide Stress Cracking Resistant Metallic Materials for Oil Field Equipment.

- I. National Fire Protection Association (NFPA)
  - 1) NFPA No. 70-1987, National Electrical Code.
  - 2) NFPA No. 493-1978, Intrinsically Safe Apparatus for Use in Division 1 Hazardous Locations.
  - 3) NFPA No. 496-1986, Standard for Purged and Pressurized Enclosures for Electrical Equipment.
- J. Underwriters Laboratories, Inc. (UL)
  - 1) UL 913-1979, Intrinsically Safe Apparatus and Associated Apparatus for Use In Class I, II, and III, Division 1, Hazardous Locations.
- K. United States Coast Guard (USCG)
  - 1) 46 CFR 154.1345 and 1350, U.S. Coast Guard Regulations for Gas Detection and Gas Detection Systems on Self-Propelled Vessels Carrying Bulk Liquefied Gases.
- L. United States Code of Federal Regulations
  - 1) Title 29, Part 1910, Occupational Safety and Health Standards, Subpart S, Electrical.
  - 2) Title 30, Parts 250 and 256 (April 1, 1988), Oil and Gas and Sulphur Operations in the Outer Continental Shelf.
- M. *Miscellaneous* 
  - 1) Threshold Limit Values for Chemical Substances in the Work Environment Adopted by ACGIH for 1984-1985.
  - 2) SAMA PMC 33.1-1978, Electromagnetic Susceptibility of Process Control Instrumentation. (Under revision as potential ISA Standards; currently designated as ISA-dS71.05, ISA-dS71.06, and ISA-dS71.07.)
  - 3) Criteria Documents on Hydrogen Sulfide and Sulfur Dioxide, National Institute for Occupational Safety and Health (NIOSH).
  - "Occupational Health Guideline for Hydrogen Sulfide," DHHS (NIOSH) Publication No. 81-123, Occupational Health Guidelines for Chemical Hazards, Jan., 1981, pp. 1-5.

## **B.1 Introduction**

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

## **B.2 Substance identification**

- Formula: H<sub>2</sub>S
- Synonyms: Sulfuretted hydrogen; hydrosulfuric acid; hepatic gas
- Appearance and odor: Colorless gas with a strong odor of rotten eggs. The odor of this gas should not be used as a warning, since its presence may deaden the sense of smell. Hydrogen

sulfide can also exist as a liquid at low temperature and high pressure.

## **B.3 Permissible Exposure Limit (PEL)**

The current OSHA standard for hydrogen sulfide is a ceiling level of 20 parts of hydrogen sulfide per million parts of air (ppm) or a maximum allowable peak of 50 ppm for 10 minutes once, if no other measurable exposure occurs. NIOSH has recommended that the permissible exposure limit be reduced to 15 mg/m (10 ppm) averaged over a 10 minute period, and that work areas in which the concentration of hydrogen sulfide exceeds 70 mg/m be evacuated. The NIOSH Criteria Document for Hydrogen Sulfide should be consulted for more detailed information.

These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.\*

## B.4 Health hazard information

Routes of exposure

Hydrogen sulfide can affect the body if it is inhaled or if it comes in contact with the eyes, skin, nose, or throat. It can also affect the body if it is swallowed.

- Effects of overexposure
  - 1. Short-term exposure: Inhalation of high concentrations of hydrogen sulfide vapor may cause loss of consciousness and death. Inhalation of lower concentrations may cause headache, dizziness, and upset stomach. Exposure to hydrogen sulfide can cause temporary loss of the sense of smell, and irritation of the eyes, nose, or throat
  - 2. Long-term exposure: Not known.

<sup>\*</sup>Reprinted from NIOSH-OSHA, *Occupational Health Guidelines for Chemical Hazards*, DHHS (NIOSH) Publication No. 81-123,1978.

- 3. Reporting signs and symptoms: A physician should be contacted if anyone develops any sign or symptoms and suspects that they are caused by exposure to hydrogen sulfide.
- Recommended medical surveillance

The following medical procedures should be made available to each employee who is exposed to hydrogen sulfide at potentially hazardous levels:

- 1. Initial medical examination:
- A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the eyes and lungs should be stressed.
- Eye disease: Hydrogen sulfide is a severe eye irritant and may cause tissue damage. Those with pre-existing eye problems may be at increased risk from exposure.
- 14" x 17" chest roentgenogram: Hydrogen sulfide may cause human lung damage. Surveillance of lungs is indicated.
- FVC and FEV (1 sec): Hydrogen sulfide is a respiratory irritant. Persons with impaired pulmonary function may be at increased risk from exposure. Periodic surveillance is indicated.
  - Periodic medical examination: The aforementioned medical examinations should be repeated on an annual basis, except that an x-ray is considered necessary only when indicated by the results of pulmonary function testing, or by signs and symptoms of respiratory disease.
- Summary of toxology

Hydrogen sulfide gas is a rapidly acting systematic poison which causes respiratory paralysis with consequent asphyxia at high concentrations. It irritates the eyes and respiratory tract at low concentrations. Inhalation of high concentrations of hydrogen sulfide, 1000 to 2000 ppm, may cause coma after a single breath and may be rapidly fatal; convulsions may also occur.

Exposure to concentrations of hydrogen sulfide above 50 ppm for one hour may produce acute conjunctivitis with pain, lacrimation, and photophobia; in severe form this may progress to keratoconjunctivitis and vesiculation of the corneal epithelium. In low concentrations, hydrogen sulfide may cause headache, fatigue, irritability, insomnia, and gastrointestinal disturbances; in somewhat higher concentrations it affects the central nervous system, causing excitement and dizziness. Prolonged exposure to 250 ppm of hydrogen sulfide may cause pulmonary edema. Prolonged exposure to concentrations of hydrogen sulfide as low as 50 ppm may cause rhinitis, pharyngitis, bronchitis, and pneumonitis. Repeated exposure to hydrogen sulfide results in increased susceptibility, so that eye irritation, cough, and systemic effects may result from concentrations previously tolerated without any effect. Rapid olfactory fatigue can occur at high concentrations.

#### **B.5** Chemical and physical properties

- Physical data
  - 1. Molecular weight: 34.08
  - 2. Boiling point (760 mm Hg): -60°C (-76°F)
  - 3. Specific gravity (water = 1): Liquid = 1.54
  - 4. Vapor density (air = 1 at 15°C (59 °F): 1.189

- 5. Melting point: -82.4°C (-116°F)
- 6. Vapor pressure 25°C (77°F): 20 atm
- 7. Solubility in water, g/100 g water at 20°C (68°F): 2.9 (slight)
- 8. Evaporation rate (butyl acetate = 1): Not applicable
- Reactivity
  - 1. Conditions contributing to instability: Elevated temperatures may cause containers to burst.
  - 2. Incompatibilities: Contact with strong oxidizers and oxidizing materials may cause fire explosions. Hydrogen sulfide attacks many metals, which results in the formation of sulfides.
  - 3. Hazardous decomposition products. Toxic gases and vapors (such as sulfur oxides) may be released in a fire involving hydrogen sulfide.
  - 4. Special precautions: Liquid hydrogen sulfide will attack some forms of plastics, rubber, and coatings.
- Flammability
  - 1. Hydrogen sulfide is a flammable gas
  - 2. Autoignition temperature: 260°C (500°F)
  - 3. Flammable limits in air, % by volume: Lower 4.3; Upper 46
  - 4. Extinguishant: Alcohol foam, carbon dioxide
- Warning properties
  - Odor threshold: According to the AIHA Hygienic Guide, hydrogen sulfide can be recognized by the "sense of smell at low concentrations. Odor not reliable at high concentrations, and olfactory fatigue occurs quickly .... Threshold is 0.13 ppm. Faint but readily perceptible at 0.77 ppm. Easily noticeable at 4.6 ppm. Strong, unpleasant, but not intolerable at 27 ppm. The Hygienic Guide also states that "olfactory fatigue can occur with(in) 2 to 15 minutes at 100 ppm."
  - 2. Eye Irritation level: Grant states that "effects of hydrogen sulfide on the eyes are notable only at sublethal concentrations, so low that they have no discernible systemic effect .... Typically, workmen exposed to low concentrations of hydrogen sulfide gas... have no sensation of irritation or discomfort for at least several hours, or sometimes for several days while working in the presence of low concentrations. Ocular symptoms generally start after several hours of exposure and may not appear until the patient has finished his work for the day. There is then gradual onset of a scratchy, irritated sensation in the eyes with tearing and burning....Experimentally it is demonstrable that at a concentration of 100 ppm in air an immediate irritation of the eyes and respiratory tract is produced, but conditions responsible for the vast majority of cases of hydrogen sulfide keratoconjunctivitis are those in which the concentration is too low to cause immediate irritation and has toxic effect only after several hours or days of exposure. However, in industries where the concentration is regularly kept below 10 ppm in air, it is rare to have any irritation of the eyes."

The Hygienic Guide states that "50 to 100 ppm causes slight conjunctivitis and respiratory tract irritation after 1 hour."

3. Evaluation of warning properties: Since olfactory fatigue occurs at high concentrations, and since the irritant effects are delayed, hydrogen sulfide is treated as a material with poor warning properties.

## **B.6 Monitoring and measurement procedures**

• Eight-hour exposure evaluation

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

Ceiling evaluation

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of hydrogen sulfide. Each measurement should consist of a fifteen (15) minute sample or series of consecutive samples totaling fifteen (15) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• Peak above ceiling evaluation

Measurements to determine employee peak exposure should be taken during periods of maximum expected airborne concentration of hydrogen sulfide. Each measurement should consist of a 10-minute sample or a series of consecutive samples totaling 10 minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

Method

Sampling and analyses may be performed by collection of hydrogen sulfide in an impinger containing an alkaline suspension of cadmium hydroxide, followed by chemical treatment and spectrophotometric analysis. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure hydrogen sulfide may be used. An analytical method for hydrogen sulfide is in the NIOSH Manual of Analytical Methods, 2nd Ed., Vol. 6, 1980 available from the Government Printing Office, Washington, D.C. 20402 (G.P.) No. 017-00369-6.

#### **B.7 Respirators**

- Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.
- In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

#### **B.8 Personal protective equipment**

- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent the skin from becoming frozen from contact with liquid hydrogen sulfide or from contact with vessels containing liquid hydrogen sulfide.
- Any clothing which becomes wet with liquid hydrogen sulfide should be removed immediately and not reworn until the hydrogen sulfide has evaporated.
- Employees should be provided and required to use splash-proof safety goggles where liquid hydrogen sulfide may contact the eyes.

## **B.9 Common operations and controls**

The following list includes some common operations in which exposure to hydrogen sulfide may occur and control methods which may be effective in each case:

Operation	Controls
Liberation from pockets during underground- mining operations near sulfide ores	Local exhaust ventilation; respiratory protec- tive devices
Liberation during refining of high-sulfur petro- leum	Concentration and recovery of $H_2SO_4$
Liberation from accumulations of decaying organic matter in sewers and waste waters and tanneries, glue factories, fat-rendering plants, and fertilizer plants	Provide continuous water discharge to sewer and cover and vent waste drains
Liberation as a by-product of dehairing and tan- ning process	Provide separate sewage lines and cover and vent waste drains; add neutralizing agents $(CaCl_2)$ as appropriate; local exhaust ventilation
Liberation during manufacture of vicose rayon	Local exhaust ventilation
Liberation during production of sulfur dyes, car- bon disulfide, sulfur, oleum, and thioprene	Local exhaust ventilation or process enclosure
Liberation during vulcanization of rubber, dur- ing manufacture of coke from coal having high gypsum content	Local exhaust ventilation or process enclosure
Liberation during excavation projects	Respiratory protective equipment
Liberation in closed containers containing organic matter	Respiratory protective equipment

## **B.10 Emergency first aid procedure**

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

Eye exposure

If liquid hydrogen sulfide gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.

• Skin exposure

If liquid hydrogen sulfide gets on the skin, immediately flush the contaminated skin with water. If liquid hydrogen sulfide penetrates through the clothing, remove the clothing immediately and flush the skin with water.

If irritation is present after washing, get medical attention.

Breathing

If a person breathes in large amounts of hydrogen sulfide, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

Rescue

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

#### **B.11 Spill and leak procedures**

- Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.
- If hydrogen sulfide is spilled or leaked, the following steps should be taken:
  - 1. Remove all ignition sources
  - 2. Ventilate area of spill or leak to disperse gas.
  - 3. If in the gaseous form, stop flow of gas. If source of leak is a cylinder and the leak cannot be stopped in place, remove the leaking cylinder to a safe place in the open air, and repair the leak or allow the cylinder to empty.
  - 4. If in the liquid form, allow to vaporize.

## B.12 Respiratory protection for hydrogen sulfide

Condition	Minimum Respiratory Protection* Required Above 10 ppm
Gas Concentration	
300 ppm or less	Any supplied-air respirator with a full facepiece, helmet, or hood.
	Any self-contained breathing apparatus with a full facepiece
Greater than 300 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pres- sure-demand or other positive pressure mode.
	A combination respirator which includes a Type C supplied-air respirator with a full faceplate operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing appara- tus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pres- sure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against acid gases or hydrogen sulfide. Any escape self-contained breathing apparatus.

\*Only NIOSH-approved or MSHA-approved equipment should be used.

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