Recommended Practice for Oil and Gas Well Servicing and Workover Operations Involving Hydrogen Sulfide

API RECOMMENDED PRACTICE 68
FIRST EDITION, JANUARY 1998

STEP
Strategies for Today's
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Environmental Partnership

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- To commit to reduce overall emissions and waste generation.
- To work with others to resolve problems created by handling and disposal of hazardous substances from our operations.
- To participate with government and others in creating responsible laws, regulations and standards to safeguard the community, workplace and environment.
- To promote these principles and practices by sharing experiences and offering assistance to others who produce, handle, use, transport or dispose of similar raw materials, petroleum products and wastes.

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Exploration & Production Department

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FOREWORD

These recommended practices were prepared by the API Subcommittee on Oil and Gas Well Servicing and Workover Operations Involving Hydrogen Sulfide. This standard is under the administration of the American Petroleum Institute Exploration & Production Department's Executive Committee on Drilling & Production Practices.

It is intended that these voluntary recommended practices serve as a guide to promote and maintain integrity of oil and gas well servicing/workover facilities and operations in the interest of public safety, personnel safety, and protection of the environment. Users of this publication are reminded that constantly developing technology, specific company requirements and policy, and specialized or limited operations do not permit coverage of all possible operations, practices, or alternatives. This standard is not so comprehensive as to present all of the recommended practices for oil and gas well servicing/workover operations involving hydrogen sulfide. Alternative operating procedures and/or equipment are available and routinely used to meet or exceed recommended practices or performance levels set forth herein. Recommendations presented in this publication are based on industry experience and expertise involving a wide range of operating locations and conditions. Recommendations presented in this publication are not intended to inhibit developing technology and equipment improvements or improved operating procedures. This publication, or portions thereof, cannot be substituted for qualified technical/operations analysis and judgment to fit a specific situation.

There may be federal, state, or local statutes, rules, or regulations requiring oil and gas well servicing/workover operations to be conducted in a safe or environmentally sound manner. Organizations and individuals using this standard are cautioned that requirements of federal, state, or local laws and regulations are constantly changing. These requirements should be reviewed to determine whether the practices recommended herein and the operations being planned or conducted are consistent with current laws and regulations.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet (MSDS).

Provisions of these voluntary recommended practices include use of the verbs "shall" and "should," whichever is deemed most applicable for the specific situation. For purposes of this publication, the following definitions are applicable:

Shall: Indicates the "recommended practice(s)" have universal applicability to that specific activity.

Should: Denotes a "recommended practice(s)" 1) where a safe comparable alternative practice(s) is available; 2) that may be impractical under certain circumstances; or 3) that may be unnecessary under certain circumstances.

Suggested revisions to these recommended practices are invited and should be submitted to: Director, Exploration & Production Department, American Petroleum Institute,
1220 L St., N.W. Washington, D.C. 20005.

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Recommended Practice for Oil and Gas Well Servicing and Workover Operations Involving Hydrogen Sulfide

0 Introduction

The petroleum industry, through many years of research and operating experience, has developed guidelines and standards for safe operations under conditions involving hydrogen sulfide. Continuing industry efforts, which include planning, prudent selection and layout of equipment, prudent selection of materials, operating and emergency procedures, specialized safety equipment, and appropriate personnel training, have contributed to successful and safe operations. Effective response to emergencies requires prior planning. *Good engineering practice (engineering and administrative controls) dictates that operations systems be designed to minimize exposure of personnel and the public to hydrogen sulfide and sulfur dioxide.*

1 Scope

Recommendations set forth in this publication apply to oil and gas well servicing and workover operations involving hydrogen sulfide. These operations include well completion, servicing, workover, downhole maintenance, and plug and abandonment procedures conducted with hydrogen sulfide present in the fluids being handled. Coverage of this publication is applicable to operations confined to the original wellbore or original total depth and applies to the selection of materials for installation or use in the well and in the well servicing operation(s). The presence of hydrogen sulfide in these operations also presents the possibility of exposure to sulfur dioxide from the combustion of hydrogen sulfide. *Refer to Section 5 for applicability of this standard.*

This standard addresses personnel training, personnel protective equipment, contingency planning and emergency procedures, classification of locations, materials and equipment, operations, rig practices, special operations, offshore operations, characteristics of hydrogen sulfide and sulfur dioxide, and evaluation and selection of hydrogen sulfide monitoring equipment.

2 References

2.1 STANDARDS

The following standards contain provisions which, through reference in this text, constitute provisions of the standard. All standards are subject to revision, and users are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

API

BULL E1	*Bulletin on the Generic Hazardous Chemical Category List and Inventory for the Oil and Gas Exploration & Production Industry*
BULL E4	*Release Reporting for the Oil and Gas Exploration and Production Industry as Required by the CWA, CERCLA, and SARA Title III*
BULL 6J	*Bulletin on Testing of Oilfield Elastomers, A Tutorial*
RP7G	*Recommended Practice for Drill Stem Design and Operating Limits*
RP 14C	*Recommended Practice for Analysis, Design, Installation, and Testing of Basic Surface Safety Systems on Offshore Production Platforms*
RP 14F	*Recommended Practice for Design and Installation of Electrical Systems for Offshore Production Platforms*
RP 49	*Recommended Practices for Drilling and Drill Stem Testing Operations Involving Hydrogen Sulfide*
RP 53	*Recommended Practices for Blowout Prevention Equipment Systems for Drilling Wells*
RP 54	*Recommended Practices for Occupational Safety for Oil and Gas Well Drilling and Servicing Operations*
RP 67	*Recommended Practices for Oilfield Explosives Safety*
RP 500	*Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities*
RP 2201	*Procedures for Welding or Hot Tapping on Equipment in Service*
Spec 5 CT	*Specification for Casing and Tubing*
Spec 5 D	*Specification for Drill Pipe*
Spec 6 A	*Specification for Valves and Wellhead Equipment*
Spec 16 A	*Specification for Drill Through Equipment*
Spec 16 C	*Specification for Choke and Kill Systems*
Publ 2217A	*Guidelines for Work in Inert Confined Spaces in the Petroleum Industry*

ACGIH[1]

Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents and Biological Exposure Indices

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[1] American Conference of Governmental Industial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240.

ANSI[2]

CGA G-7.1	*Breathing Air, Grade D*
IES RP7-1990	*Practice for Industrial Lighting*
Z88-2	*Practices for Respiratory Protection*

EPA[3]

EPA/600/8-E86/026A	*Health Assessment Document for Hydrogen Sulfide*

ISA[4]

S12.15, Part I	*Performance Requirements for Hydrogen Sulfide Detection Instruments*
RP12.15, Part II	*Installation, Operation, and Maintenance of Hydrogen Sulfide Detection Instruments*

NACE[5]

MR0175-94	*Standard Material Requirements Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment*

National Response Team[6]

NRT-1	*Hazardous Materials Emergency Planning Guide* *Technical Guidance for Hazards Analysis, Emergency Planning for Extremely Hazardous Substances*

NFPA[7]

NFPA 70	*National Electrical Code*

NIOSH[8]

NIOSH 74-111	*Criteria for a Recommended Standard for Occupational Exposure to Sulfur Dioxide (*GPO No. 017-033-00029*)*
NIOSH 77-158	*Criteria for a Recommended Standard for Occupational Exposure to Hydrogen Sulfide (*GPO No. 017-033-00217-7*)*
DHHS 94-116	*NIOSH Pocket Guide to Chemical Hazards*

PACE[9]

Report 85-5	*Review of Ambient Hydrogen Sulfide Standards in Canada*

2.2 REGULATIONS

The following regulations are referenced in this standard. All regulations are subject to revision, and users should determine the latest version to ensure compliance.

Bureau of Mines (DOI)[10]

30 *CFR*	Chapter 1, Subchapter B, Part II, Subpart H, *Respiratory Protection Devices*

Coast Guard (DOT)[11]

33 *CFR*	Parts 140, 143, and 146, *Emergency Evacuation Plans for Manned OCS Facilities*
54 FR 21566,	May 18, 1989, *Emergency Evacuation Plans for Manned OCS Facilities*

DOT[12]

49 *CFR*	Part 178, Subpart C, *Shipping Container Specifications*

EPA[3]

40 *CFR*	Part 264, Subpart D, *Contingency Plans and Emergency Procedures*
40 *CFR*	Part 302, *Designation, Reportable Quantities, and Notification*
40 *CFR*	Part 355, *Emergency Planning and Notification*
40 *CFR*	Part 370, *Hazardous Chemical Reporting: Community Right-to-Know*

MMS (DOI)[13]

30 *CFR*	Parts 250 & 256, *Oil, Gas, and Sulphur Operations in the Outer Continental Shelf*
53 *FR* 10596-10777, April 1, 1988	*Oil, Gas, and Sulphur Operations in the Outer Continental Shelf*
MMS-OCS-1	*Safety Requirements for Drilling Opertions a Hydrogen Sulfide Environment, Outer Continental Shelf (February 1976)*
47 *FR* 28888, July 1, 1982	*Safety Requirements for Drilling Operations in a Hydrogen Sulfide Environment, Outer Continental Shelf*

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[2] American National Standards Institute, 1430 Broadway, New York, New York 10018.

[3] Environmental Protection Agency, available from U.S. Government Printing Office, Washington, D.C. 20402.

[4] Instrument Society of America, Box 12277, Research Triangle Park, North Carolina 27709.

[5] National Association of Corrosion Engineers, NACE International, Box 218340, Houston, Texas 77218-8340.

[6] National Response Team, National Oil and Hazardous Substances Contingency Plan GWDR/12, 2100 Second Street SW, Washington, D.C. 20593.

[7] National Fire Protection Association, 60 Batterymarch Park, Quincy, Massachusetts 02269.

[8] National Institute for Occupational Safety and Health (U.S. Department of Health, Education, and Welfare), available from U.S. Government Printing Office, Washington, D.C. 20402.

[9] Petroleum Association for Conservation of the Canadian Environment, 12002-275 Slater Street, Ottawa, Ontario, Canada LIP 5H9.

[10] Bureau of Mines, U.S. Department of Interior, available from U.S. Government Printing Office, Washington, D.C. 20402.

[11] Coast Guard, U. S. Department of Transportation, available from U.S. Government Printing Office, Washington, D.C. 20402.

[12] U. S. Department of Transportation, available from U.S. Government Printing Office, Washington, D.C. 20402.

[13] Minerals Management Service, U.S. Department of Interior, 381 Elden Street, Herndon, VA 22070-4817. Available from U.S. Government Printing Office, Washington, D.C. 20402.

OSHA[14]

29 *CFR*	Part 1910.38, *Employee Emergency Plans and Fire Prevention Plans*
29 *CFR*	Part 1910.120, *Hazardous Waste Operations and Emergency Response*
29 *CFR*	Part 1910.134, *Respiratory Protection Standard*
29 *CFR*	Part 1910.146, *Permit-Required Confined Spaces*
29 *CFR*	Part 1910.1000, 321A*ir Contaminants*
29 *CFR*	Part 1910 Subpart I, *Personal Protective Equipment*
29 *CFR*	Part 1910.1200, *Hazard Communication Standard*

2.3 OTHER REFERENCES

1. Poda, George A., "Hydrogen Sulfide Can Be Handled Safely," *Archives of Environmental Health,* Vol. 12, 795–800, June 1966.
2. Ronk, Richard and White, M. K., "Hydrogen Sulfide and the Probabilities of Inhalation Through a Tympanic Membrane Defect," *Journal of Occupational Medicine,* Vol. 25, No. 5, 337–340, May 1985.
3. Pasquill, F., *Atmospheric Diffusion*, Second Edition, John Wiley & Sons, New York, NY, 1947.
4. Slade, D. H., *Metrology and Atomic Energy* NTIS-TID 24190 (1968), National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161.
5. Wilson, D. J., "Release and Dispersion of Gas from Pipeline Ruptures," Department of Mechanical Engineering, University of Alberta, Edmonton, Canada.
6. Jann, P. R., "Evaluation of Sheltering In Place," *Journal of Loss Prevention in the Process Industry*, Vol. 2, No. 1, Jan. 1989, pp 33–38.
7. MacFarlane, D. R. and Ewing, T. F., "Acute Health Effects From Accidental Releases of High Toxic Hazard Chemicals," *Journal of Loss Prevention in the Process Industry*, Vol. 3, No. 1, January 1990, pp 167–176.
8. Wilson, D. J., "Stay Indoors or Evacuate to Avoid Exposure to Toxic Gas?," *Emergency Preparedness Digest*, Ottawa, Canada, January–March 1987, pp 19–24.
9. Davies, P. C. and Purdy, G., "Toxic Gas Risk Assessments–The Effects of Being Indoors," North Western Branch Papers 1986 No. 1, Institution of Chemical Engineers, Health and Safety Executive, Major Hazards Assessment Unit, St. Annes House, Stanley Precinct, Bootle, Merseyside, England.
10. Glickman, T.S. and Ujrhara, A. M., "Protective Action Decision Making in Toxic Vapor Cloud Emergencies," Center for Risk Management, Resources for the Future, Washington, D. C. 20036.
11. Wilson, D. J., "Variation of Indoor Shelter Effectiveness Caused by Air Leakage Variability of Houses in Canada and the USA," US EPA/FEMA Conference on Effective Use of In-Place Sheltering as a Potential Option to Evacuation During Chemical Release Emergencies, Emmitsburg, MD, November 30–December 1, 1988.

2.4 BIBLIOGRAPHY

The following publications contain information related to this subject:

1. API RP 14F, *Recommended Practice for Design and Installation of Electrical Systems for Offshore Production Platforms,* available from American Petroleum Institute, 1220 L St., NW Washington, DC 20005, 1991.
2. API RP 55, *Recommended Practices for Conducting Oil and Gas Producing and Gas Processing Plant Operations Involving Hydrogen Sulfide,* American Petroleum Institute, 1220 L St., NW Washington, DC 20005, 1995.
3. GPA 2145-85, *Physical Constants of Paraffin Hydrocarbons and Other Components of Natural Gas,* available from Gas Processors Association, 6526 E. 60th Street, Tulsa, OK 74145.
4. NIOSH, *Recommended Standard for Occupational Exposure to Hydrogen Sulfid*e, available from US Government Printing Office, Washington DC 20402.
5. Public Health Service Publication 999-AP-26, *Workbook on Atmospheric Dispersion Estimates*, D. Bruce Tanner, available from U.S. Department of Health, Education, and Welfare, Cincinnati, OH.
6. Texas Railroad Commission Rule 36, *Oil, Gas, and Geothermal Resources Operations Hydrogen Sulfide Areas,* Texas Railroad Commission, Austin, TX.

3 Acronyms and Abbreviated Definitions

The following acronyms and abbreviations are used in this publication:

3.1 ACRONYMS

ACC	Acceptable Ceiling Concentration
ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
API	American Petroleum Institute
BOP	Blowout Preventer
CAS	Chemical Abstract Service
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
CGA	Compressed Gas Association
CFR	*Code of Federal Regulations*
DC	Direct Current
DOI	U. S. Department of Interior
DOL	U. S. Department of Labor
DOT	U. S. Department of Transportation

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[14] Occupational Safety & Health Administration (U.S. Department of Labor), available from U.S. Government Printing Office, Washington, D.C. 20402.

EHS	Extremely Hazardous Substance
EMI	Electromagnetic Interference
EPA	Environmental Protection Agency
EPCRA	*Emergency Planning and Community Right-to-Know Act*
ERPG	*Emergency Response Planning Guide*
FR	*Federal Register*
HAZWOPER	Hazardous Waste Operations and Emergency Response
H_2S	Hydrogen Sulfide
IDLH	Immediately Dangerous to Life or Health
ISA	Instrument Society of America
LEL	Lower Explosive Limit
LEPC	Local Emergency Planning Committee
MMS	Minerals Management Service
MSDS	Material Safety Data Sheet
NACE	National Association of Corrosion Engineers
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NRTL	Nationally Recognized Testing Laboratory
NTIS	National Technical Information Service
OCS	Outer Continental Shelf
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PG	Pasquill-Gifford
ppm	parts per million
RCRA	*Resource Conservation & Recovery Act*
REL	Recommended Exposure Level
RFI	Radio Frequency Interference
ROE	Radius of Exposure
RP	*Recommended Practice(s)*
RQ	Reportable Quantity
SARA	*Superfund Amendments and Reauthorization Act*
SCF	Standard Cubic Feet
SERC	State Emergency Response Commission
SO_2	Sulfur Dioxide
SSC	Sulfide Stress Cracking
STEL	Short Term Exposure Level
TLV	Threshold Limit Value
TPQ	Threshold Planning Quantity
TWA	Time Weighted Average

3.2 DEFINITIONS

For the purposes of this standard, the following definitions are applicable.

3.2.1 acceptable ceiling concentration (**ACC**): The designated level of an air contaminant to which an employee may be exposed at any time during an 8-hour shift, except for a time period and up to a concentration not exceeding the "acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift." Refer to 29 *CFR* Part 1910.1000 and Table Z-2.

3.2.2 breathing zone: A hemisphere forward of the shoulders with a radius of 6 to 9 inches. Refer to OSHA Instruction CPL 2-2.20A, March 30, 1984; amended by CPL 2-20A CH-1, October 29, 1984.

3.2.3 continuous hydrogen sulfide monitoring equipment: Equipment capable of continuously measuring and displaying the concentration of hydrogen sulfide in ambient air.

3.2.4 emergency response planning guide—level 2 (**ERPG-2**): The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective actions. Refer to *Technical Guidance for Hazards Analysis; Emergency Planning for Extremely Hazardous Substances*.

3.2.5 enclosed facility: A 3-dimensional space enclosed by more than $^{2}/_{3}$ of the possible projected plane surface and of sufficient size to allow the entry of personnel. For a typical building, this would require that more than $^{2}/_{3}$ of the walls, ceiling, and floor be present. Refer to API RP 500.

3.2.6 essential personnel: Those individuals required to provide proper and prudent safe operations activities and those required to effect control of the hazardous hydrogen sulfide or sulfur dioxide conditions.

3.2.7 gas detection instrument: An assembly of electrical, mechanical, and chemical components designed to sense and respond continuously to the presence of chemical gases in atmospheric mixtures.

3.2.8 hydrogen sulfide: Chemical formula is H_2S. A flammable, toxic gas that is normally heavier than air and sometimes found in fluids encountered in oil and gas producing and gas processing operations. *CAUTION: Inhalation at certain concentrations can lead to injury or death.* Refer to Appendix A.

3.2.9 immediately dangerous to life and health (**IDLH**): An atmospheric concentration of any toxic, corrosive, or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere. API Publication 2217A specifies an oxygen content of less than 19.5% as oxygen deficient and an oxygen content of less than 16% is considered IDLH.

3.2.10 inadequately ventilated: Ventilation (natural or artificial) that is not sufficient to prevent the accumulation of significant quantities of toxic or inert gases such that a hazard is created.

3.2.11 length-of-stain detector: A specially designed pump and colorimetric indicator tube detector (length-of-stain), with a supply of detector tubes, that operates by using the pump to pull a known volume of air or gas through a detector tube. The tubes contain chemical reagents that are designed to detect the presence and display the concentration of specific gases or vapors in the sample. The length of the resultant color band in the tube indicates an instantaneous quantitative concentration of the specific chemical in the sample.

3.2.12 permissible exposure limit (**PEL**): The inhalation exposure limit specified in 29 *CFR* 1910.1000 or applicable state standards. These limits may be expressed as an 8-hour time weighted average (TWA), a Ceiling Limit, or 15-minute Short Term Exposure Limit (STEL). PELs are subject to change and users should check the latest version of 29 *CFR* Part 1910.1000, "Toxic and Hazardous Substances," for compliance.

3.2.13 shall: Indicates the "recommended practice(s)" has universal applicability to that specific activity.

3.2.14 shelter-in-place: The concept of providing the public protection from exposure to toxic gas or vapor releases to the environment by having residents stay indoors until emergency evacuators arrive or the emergency is over. Refer to Section 2.3, 7.11.

3.2.15 should: Denotes a "recommended practice(s)" 1) where a safe comparable alternative practice(s) is available; 2) that may be impractical under certain circumtances; or 3) that may be unnecessary under certain circumstances.

3.2.16 sulfur dioxide: Chemical formula is SO_2. A toxic product of combustion of hydrogen sulfide, normally heavier than air. *CAUTION: Inhalation at certain concentrations can lead to injury or death.* Refer to Appendix B.

3.2.17 temporary safe haven: Refer to "shelter-in-place" (3.2.14).

3.2.18 threshold limit value (**TLV**): Airborne concentrations of substances representing conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effects. These value may be expressed as 8-hour time weighted average (TWA), Ceiling Limits, or 15-minute Short Term Exposure Limits (STEL). Refer to American Conference of Governmental Industrial Hygienists (ACGIH), *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.* "TLV" is a trademarked term of ACGIH. TLVs are subject to change and users should check the latest edition of the forestated reference.

4 Applicability

4.1 PERSONNEL AND EQUIPMENT PROTECTION

In oil and gas well servicing/workover operations, severity of the environment shall be assessed. As a minimum, the following measures shall be implemented:

a. Personnel protection should be provided if the work area concentration of hydrogen sulfide (refer to 3.2.8) exceeds 10 ppm 8-hour time weighted average (TWA) or 15 ppm as a short term exposure level (STEL) averaged over 15 minutes (refer to Appendix A); or the work area concentration of sulfur dioxide (refer to 4.16) exceeds 2 ppm as an 8-hour TWA or 5 ppm as a STEL averaged over 15 minutes (refer to Appendix B). Personnel safety provisions of this publication do not apply when:

1. the atmospheric concentration of hydrogen sulfide could not exceed 10 ppm (by volume) in the breathing zone; or
2. the atmospheric concentration of sulfur dioxide could not exceed 2 ppm (by volume) in the breathing zone.

b. Equipment and materials shall be selected on the basis of resistance to sulfide stress cracking and corrosion. Refer to NACE Standard MR0175 for recommendations for selection of equipment and materials.

The equipment and materials provisions of this publication do not apply when the partial pressure of hydrogen sulfide in the gas could not exceed 0.05 psia or 10 psia in the gas phase of sour crude systems.

Some conditions may require extensive personnel safety measures but only the use of conventional equipment and materials; other conditions may require the use of special equipment and materials but only minimal personnel safety measures; still other conditions may require both.

Throughout this publication, "trigger levels" for various actions are used to ensure safety of employees and the public. These trigger levels have been established considering threshold limit values (TLVs—refer to 3.2.18). These TLVs are subject to change and users should check the latest edition of *Threshold Limit Values and Biological Exposure Indices* and the latest revision of 29 *CFR* Part 1910.1000 for compliance.

In 1989, the U. S. Department of Labor, Occupational Safety and Health Administration (OSHA) issued updated permissible exposure limits (PELs) for several hundred chemicals, including revised PELs for hydrogen sulfide (10 ppm as an 8-hour TWA or 15 ppm STEL averaged over 15 minutes) and sulfur dioxide [2 ppm as an 8-hour TWA or 5 ppm STEL averaged over 15 minutes (refer to 54 *FR* 2333, January 19, 1989)]. A federal court set aside the OSHA 1989 rule (refer to 58 *FR* 35338, June 30, 1993).

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a hydrogen sulfide TLV of 10 ppm (8-hour TWA) and a STEL of 15 ppm averaged over 15 minutes and recommends 2 ppm as an 8-hour TWA TLV and 5 ppm as a STEL averaged over 15 minutes for sulfur dioxide (refer to *Threshold Limit Values for Chemical Substances and Biological Exposure Indices*).

In the interest of safety and health, this standard recommends use of the ACGIH TLVs (refer to *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*) as trigger levels for employee safety (refer to Appendices A and B). Some states have adopted these levels as requirements for employee safety.

Individual employers may set their own trigger levels after review and due consideration of site specific conditions, various regulatory requirements, and material safety data sheet (MSDS) information. Users should check the current status of OSHA PELs, OSHA acceptable ceiling concentrations (ACCs), ACGIH TLVs, and applicable regulatory requirements concerning substances of interest.

4.2 LEGAL REQUIREMENTS

This publication presents recommended practices and precautions deemed pertinent to protect personnel and the public from exposure to potentially hazardous concentrations of hydrogen sulfide and sulfur dioxide. These recommended practices recognize that owners, operators, contractors, and their employees have separate responsibilities that may be contractual in nature. It is not the intent of these recommended practices to alter the contractual relationship(s) between the parties. Some of the practices recommended herein are mandatory by local, state, or federal laws, rules, and regulations. Because of the functional and geographical diversity of these requirements, no attempt has been made in these recommended practices to designate which are optional and which are required. Furthermore, even if all the practices recommended herein are followed, there still may be existing or future legally imposed laws or regulations which would not be met. *In the event of any omission or conflict between these recommended practices and legally required action(s), the requirements of laws and regulations must control.* Some of the federal regulations (standards) pertinent to safe well servicing/workover operations involving hydrogen sulfide are listed in Section 2, “References.” Users of this publication should review these regulations and other federal, state, and local laws to assure appropriate compliance in their specific operations.

4.3 HAZARD COMMUNICATION (WORKER RIGHT-TO-KNOW)

This publication contains important information that is intended as a guide but may not comply in all respects with OSHA’s Hazard Communication Standard. Appropriate counsel should be sought to assure compliance with hazard communication requirements for the specific operations. Refer to OSHA rules on hazard communication in 29 *CFR* Part 1910.1200, “Hazard Communication Standard” (52 *FR* 31877-31886, August 24, 1987).

4.4 EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT (EPCRA) AND COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA)

The Emergency Planning and Community Right-to-Know Act (EPCRA), also known as Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA III), requires facilities with a threshold planning quantity (TPQ) of an extremely hazardous substance (EHS) to participate in emergency planning at a local level. Hydrogen sulfide and sulfur dioxide are both listed as EHSs with a TPQ of 500 pounds. A facility with hydrogen sulfide or sulfur dioxide present at its TPQ must notify the State Emergency Response Commission (SERC) and designate a facility emergency coordinator to assist the Local Emergency Planning Committee (LEPC) with its response plan.

EPCRA and CERCLA both require a facility to report a release of a reportable quantity (RQ) of a listed substance. The RQs for release reporting are 100 pounds for hydrogen sulfide and one pound for sulfur dioxide. Refer to API Bulletin E4 for guidance on release reporting requirements. Both RQs (40 *CFR* Part 302) and TPQs (40 *CFR* Part 355) are subject to change and the facility operator should check for revisions.

EPCRA also requires submission of periodic and annual reports of information to state and local officials on the presence of hazardous chemicals at production facilities. These regulations are set forth in 40 *CFR* Part 370, and API has published suggested generic reporting forms (refer to API Bulletin E1) that are acceptable to the U. S. Environmental Protection Agency (EPA).

4.5 HAZARDOUS WASTE OPERATIONS AND EMERGENCY RESPONSE (HAZWOPER)

OSHA’s standard, 29 *CFR* Part 1910.120, sets requirements for safety and health protection of employees involved in cleanup operations at uncontrolled hazardous waste sites being performed under government mandate; certain hazardous waste treatment, storage, and disposal operations conducted under the *Resource Conservation and Recovery Act* (RCRA); and emergency response to incidents involving hazardous substances. Appropriate guidance should be sought to assure compliance with 29 *CFR* Part 1910.120 requirements for the specific operations (refer to 54 *FR* 9294-9336, March 6, 1989).

5 Personnel Training

5.1 INTRODUCTION

Operators of potential hydrogen sulfide producing properties shall alert all personnel (including employer, service companies, and contractors) of the possibility of hydrogen sulfide atmospheric concentrations greater than 10 ppm and sulfur dioxide atmospheric concentrations greater than 2 ppm that may be encountered in the performance of their work. All personnel working in an area where concentrations of hydrogen sulfide or sulfur dioxide may exceed the levels stipulated in 4.1.a should be provided with training prior to beginning the work assignment. All employers, whether operator, contractor, or subcontractor, shall be responsible for the training and instruction of their own employees. Personnel assigned to work in areas where they may be exposed to hydrogen sulfide or sulfur dioxide shall be trained by a hydrogen sulfide safety instructor as defined in 5.4.

5.2 MINIMUM TRAINING

The value of training and periodic drills in well servicing and workover operations cannot be over emphasized. The uniqueness or complexity of a specific operation will determine the extent of training (e.g., SARA Title III and HAZWOPER, refer to 4.4) deemed necessary for the assigned personnel. However, the following elements are considered a minimum level of training for personnel assigned to the operations:

a. The hazards, characteristics, and properties of hydrogen sulfide and sulfur dioxide (refer to Appendices A and B).

b. Sources of hydrogen sulfide and sulfur dioxide.

c. Proper use of hydrogen sulfide and sulfur dioxide detection methods used at the workplace.

d. Recognition of, and proper response to, the warning signals initiated by hydrogen sulfide and sulfur dioxide detection systems in use at the workplace.

e. Symptoms of hydrogen sulfide exposure (refer to Appendix A); symptoms of sulfur dioxide exposure (refer to Appendix B).

f. Rescue techniques and first aid to victims of hydrogen sulfide and sulfur dioxide exposure.

g. Proper use and maintenance of breathing equipment for working in hydrogen sulfide and sulfur dioxide atmospheres, as appropriate (theory and hands-on practice, with demonstrated proficiency). Refer to 29 *CFR* Part 1910.134.

h. Workplace practices and relevant maintenance procedures that have been established to protect personnel from the hazards of hydrogen sulfide and sulfur dioxide.

i. Wind direction awareness and routes of egress (refer to 6.8).

j. Confined space and enclosed facility entry procedures (if applicable).

k. Emergency response procedures that have been developed for the facility or operations. Refer to Section 7, “Contingency Planning Including Emergency Procedures.”

l. Locations and use of safety equipment.

m. Locations of emergency assembly areas, if so designated.

5.3 ADDITIONAL TRAINING FOR ONSITE SUPERVISORY PERSONNEL

Those personnel assigned supervising responsibilities at the site shall have additional training in the following elements:

a. Supervisor responsibilities of the contingency plan (refer to Section 7).

b. Effects of hydrogen sulfide on components of the hydrogen sulfide handling system (i.e., corrosion, embrittlement, etc.).

5.4 HYDROGEN SULFIDE SAFETY INSTRUCTORS

Hydrogen sulfide safety instructors are persons who have:

a. successfully completed a course in hydrogen sulfide instructor training from an institution or organization offering such courses, or

b. received equivalent instruction from a company-designated hydrogen sulfide safety instructor/trainer.

A recurring training program shall be implemented to maintain proficiency of all hydrogen sulfide safety instructors.

5.5 TRAINING VISITORS AND OTHER NON-REGULARLY ASSIGNED PERSONNEL

Prior to entering a potentially hazardous area, visitors and other non-regularly assigned personnel shall be briefed on route(s) of egress, emergency assembly area(s), applicable warning signals, and how to respond in the event of an emergency, including use of personal protective equipment, if required. These personnel may be allowed in potentially hazardous areas only in the presence of trained personnel, after being briefed on emergency action and evacuation procedures. In the event of an emergency, these personnel shall be immediately evacuated or immediately supplied with proper personal protective equipment.

5.6 SAFETY REVIEW

As site specific conditions dictate, an applicable hydrogen sulfide safety meeting should be held. Before any persons unfamiliar with the job site enter the location, they shall, as a minimum, be briefed on emergency evacuation procedures.

5.7 RECORDS

Dates, instructors, attendees, and subjects for all personnel training sessions shall be documented and appropriate records should be retained for a minimum of one year.

5.8 OTHER PERSONNEL CONSIDERATIONS

5.8.1 Enclosed Facilities and Confined Space Entry

Refer to 29 *CFR* Part 1910.146 for OSHA's confined space entry regulations.

5.8.2 Respiratory Problems

Personnel with known physiological or psychological conditions that impair normal respiration shall not be assigned to jobs involving potential exposure to a hydrogen sulfide or sulfur dioxide environment if use of the breathing equipment or exposure will complicate their respiratory problems. Refer to OSHA's Respiratory Protection Standard (29 *CFR* Part 1910.134).

Note: Personnel assigned job-related tasks requiring routine use of breathing equipment should have a periodic review to determine their physiological and psychological adequacy for use of this equipment (refer to 29 *CFR* Part 1910.134 and *ANSI Z88.2*).

5.8.3 Perforated Eardrums

Based on recent studies it is unlikely that H_2S could be inhaled through a perforated eardrum at quantities that would be harmful.[15]

6 Personnel Protective Equipment

6.1 INTRODUCTION

Section 6 discusses some personnel protective equipment that can be used in oil and gas well servicing and workover operations where the work area atmospheric concentration of hydrogen sulfide could exceed 10 ppm or sulfur dioxide atmospheric concentration could exceed 2 ppm, (refer to 4.1 and to Appendices A and B). Having personnel protective equipment available is not enough; training personnel in the selection, use, inspection, and maintenance of the equipment is essential.

6.2 FIXED (STATIONARY) HYDROGEN SULFIDE MONITORING SYSTEMS

Fixed hydrogen sulfide atmospheric monitoring systems used in oil and gas well servicing and workover operations shall include visual or and audible alarm(s), located where the alarm can be seen or heard throughout the work area. The batteries of direct current (DC) systems should be checked daily during operation unless an automatic low voltage alarm is provided. Instrument Society of America publications, ISA-S12.15, Part I, and ISA-RP12.15, Part II, contain equipment performance requirements and recommendations for installation, operation, and maintenance of hydrogen sulfide monitoring and detection instruments, respectively. Refer to Appendix E for additional details regarding evaluation and selection of hydrogen sulfide monitoring and detection equipment.

6.3 DETECTION EQUIPMENT

If the atmospheric concentration of hydrogen sulfide could exceed those levels described in 6.1, hydrogen sulfide detection instruments shall be available. Refer to Appendix E for details regarding evaluation, selection, maintenance, and use of hydrogen sulfide detection equipment. In those instances where the hydrogen sulfide atmospheric concentration may exceed the measurement range of the detection instruments in use, a pump and colorimetric indicator tube detector[16] (length-of-stain), with a supply of detector tubes, shall be available to take instantaneous "grab" samples to determine hydrogen sulfide concentrations in enclosed facilities, storage tanks, vessels, etc.

If sulfur dioxide levels could exceed those described in 6.1 (e.g., during flaring or other operations producing sulfur dioxide), either portable sulfur dioxide detection instruments or length-of-stain detectors, with a supply of detector tubes, shall be available for determining the sulfur dioxide concentration in the area and to monitor areas impacted by sulfur dioxide gas when fluids containing hydrogen sulfide are burned.

Personnel shall wear appropriate respiratory breathing equipment (refer to 6.5) unless it is established that the work area atmosphere is safe.

An adequate number of fixed or portable, or both type detectors should be provided for the safety of personnel working near the wellhead, on the rig floor, and near any surface pits, tanks, or other equipment. Prior to commencement of operations, there should be a clear understanding as to who will provide detection equipment.

Note: For the purpose of this standard, the terms "portable" monitors and "personal" monitors are considered interchangeable. Some manufacturers may designate monitor units as either "portable" or "personal." These units may or may not have a readout displaying concentration of hydrogen sulfide but must contain audible, visual, or physical sensation alarms.

6.4 SENSOR LOCATIONS AND EQUIPMENT CALIBRATION

Hydrogen sulfide monitors (fixed or portable) should be used during all "open hole" completion, workover, and well servicing operations (refer to 6.1). Fixed hydrogen sulfide atmospheric monitoring systems should have one or more

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[15] Ronk, Richard and White, M.K., "Hydrogen Sulfide and the Probabilities of Inhalation Through Tympanic Membrane Defect," Journal of Occupational Medicine, Vol. 25 No. 5, 337-340, May 1985.

[16] A gas detection instrument is an assembly of electrical, mechanical, and chemical components designed to sense and respond continuously to the presence of chemical gases (e.g., hydrogen sulfide or sulfur dioxide) in atmospheric mixtures.

sensors located on the rig floor near the wellbore, preferably on the downwind side. Hydrogen sulfide atmospheric concentrations during well completion, workover, and servicing operations are often highest in this area. Where well fluids are flowed to a surface pit, one or more sensors should be installed in the area of the surface pit(s). Completion, workover, and well servicing operations requiring the use of circulation fluids should include sensors at the return line and above open circulation fluid tanks. It may be convenient to install the sensors of fixed systems on movable mounts. Additional sensors may be located in work areas of likely hydrogen sulfide gas accumulation.

Low areas, inadequately ventilated areas, and enclosed areas should be carefully investigated prior to personnel entry. To establish reliability, continuous monitoring equipment should be serviced, calibrated, and tested at least as often as recommended by the equipment manufacturer, and possibly more frequently under high humidity, dusty, or other adverse service conditions.

The monitoring equipment should be calibrated by qualified individuals at intervals frequent enough to enable the user to determine an acceptable calibration schedule. This schedule should be at intervals not exceeding 30 days.

The equipment alarms should be functionally tested at least once daily.

6.5 BREATHING (RESPIRATORY PROTECTION) EQUIPMENT

Respirators shall meet the requirements of OSHA's Respiratory Protection Standard (refer to 29 *CFR* Part 1910.134). All breathing air cylinders shall meet U. S. Department of Transportation (DOT) or other appropriate regulatory requirements (refer to 30 *CFR* Part 1910.134, Chapter 1, Subchapter B, Part II, Subpart H, Par. 11.80 and 40 *CFR* Part 178, Subpart C). The following types of respiratory protection equipment, with full face piece, meet these requirements and should be used where the work area atmospheric concentration exceeds 10 ppm for hydrogen sulfide or 2 ppm for sulfur dioxide:

a. Self-contained, positive-pressure/pressure-demand breathing equipment that provides respiratory protection in any atmospheric concentration of hydrogen sulfide or sulfur dioxide.

b. Positive-pressure/pressure-demand air-line breathing equipment coupled with a self-contained breathing apparatus equipped with a low pressure warning alarm and rated for 15 minutes (minimum). This equipment permits the wearer to move from one work area to another.

c. Positive-pressure/pressure-demand, air-line breathing equipment, with an auxiliary self-contained air supply (rated for a minimum of 5 minutes). This type unit can be used for entry as long as the air line is connected to a source of breathing air. ***The auxiliary self-contained air supply (rated for less than 15 minutes) is suitable only for escape or self-rescue use.***

Note: Positive-pressure/pressure-demand, air-line with egress bottle or self-contained breathing apparatus, as appropriate, with full face piece shall be worn by personnel exposed to atmospheres containing concentrations of hydrogen sulfide or sulfur dioxide above OSHA's ACCs and PELs for air contaminants (refer to 29 *CFR* Part 1910.1000) or in any atmosphere of H_2S or SO_2 of unknown concentration.

CAUTION: Respirators and demand type (negative pressure) breathing equipment shall not be used in oil and gas well servicing/workover operations when a hydrogen sulfide or sulfur dioxide environment could be encountered.

6.5.1 Storage and Maintenance

Personal breathing equipment shall be strategically located so that this equipment is quickly and easily available to essential personnel. Essential personnel are those required to provide proper and prudent safe operations activities and those required to effect control of hazardous hydrogen sulfide or sulfur dioxide conditions. Refer to 7.5. Additional breathing equipment may be required by site specific contingency plans (refer to Section 7).

Breathing equipment shall be maintained and stored in a convenient, clean, and sanitary location, in accordance with the OSHA's Respiratory Protection Standard (refer to 29 *CFR* Part 1910.134). All breathing equipment shall be checked before and after each use and inspected at least monthly to ensure that it is maintained in satisfactory condition. A record of the monthly inspection results, including dates and findings, shall be retained (refer to 29 *CFR* Part 1910.134). These records should be retained for a minimum of twelve (12) months. Equipment needing repair shall be appropriately tagged and removed from equipment stock until it is suitably repaired or replaced. Proper storage, maintenance, handling, and inspection is essential to the integrity of personal breathing equipment. Personnel with assigned breathing equipment shall be instructed in proper maintenance of this equipment, or other steps shall be taken to ensure its integrity. Applicable NIOSH, OSHA, and manufacturer's recommendations shall be followed.

6.5.2 Face Piece Restrictions

Full face piece breathing equipment meeting requirements of 6.5 should be used where the work area atmospheric concentration exceeds 10 ppm for hydrogen sulfide or 2 ppm for sulfur dioxide. Personnel shall not wear eyeglasses with temple bars that extend through the sealing edge of the face piece. Using approved adapters, corrective prescription lenses may be mounted inside the breathing apparatus face piece.

OSHA has investigated the prohibition of contact lenses used under respiratory protection equipment and has issued a field memorandum (February 8, 1989) stating their intent to modify the rule and has issued an interim enforcement policy as follows:

a. Violations of the Respiratory Protection Standard (29 *CFR* Part 1910.134) involving the use of gas permeable and soft contact lenses shall continue to be documented in the case file and recorded as de minimis; citations shall not be issued.

b. Evidence indicating any negative effect(s) associated with the use of contact lenses with respiratory protection equipment should be provided to U. S. Department of Labor, Occupational Safety and Health Administration, Directorate for Compliance Programs, Washington, D. C. 20210. Benefits associated with the use of contact lenses with respiratory protection equipment would be useful to OSHA. The issue of use of non-gas-permeable hard contact lenses will be resolved in OSHA's revision of 29 *CFR* Part 1910.134.

Note: Companies should review available information and provide employee guidance regarding the use of contact lenses under respiratory protection equipment.

Personnel shall be satisfied that a face seal can be obtained with the assigned equipment or randomly selected unassigned equipment before they use the equipment. If a face seal cannot be obtained with a specific respirator, other satisfactory equipment must be provided or the individual shall be disqualified from working in areas where hazardous conditions exist or are anticipated.

6.5.3 Air Supply

Breathing air quality shall meet requirements set forth in 29 *CFR* Part 1910.134 of OSHA's Respiratory Protection Standard and shall at least meet Grade D requirements as described in ANSI CGA G-7.1.

6.5.4 Breathing Air Compressors

All breathing air compressors used shall meet the requirements set forth in 29 *CFR* Part 1910.134 of OSHA's Respiratory Protection Standard. The air intake for such compressors must be located in a contaminant-free area that is unclassified by API RP 500, Section B. Inlet air for such compressors shall be monitored when conditions arise that permit possible contamination of the inlet by toxic, flammable, or combustible gases.

6.5.5 Breathing Equipment Use

Personnel shall use breathing equipment prior to entering an area where OSHA ACCs and PELs for either hydrogen sulfide or sulfur dioxide are exceeded or where H_2S or SO_2 concentrations are suspected but are unknown. (refer to 4.1, Appendices A and B, and 29 *CFR* Part 1910.1000 Subpart Z, Table Z.1) until either the area is made or tested safe or the personnel return to a safe area. *CAUTION: Breathing equipment shall be put on in a safe area prior to either beginning a rescue operation or entering a hazardous environment.*

6.6 STANDBY RESCUE PERSONNEL

When personnel work in atmospheres considered immediately dangerous to life or health (IDLH) (refer to Appendices A and B), a standby rescue person trained in rescue techniques and equipped with suitable rescue equipment, including appropriate breathing apparatus (refer to 6.5), shall be provided.

6.7 RESCUE EQUIPMENT

At locations with hydrogen sulfide, sulfur dioxide, or oxygen concentration considered immediately dangerous to life or health (IDLH), suitable rescue equipment [e.g., self-contained breathing equipment, lifeline(s), and harness(es)] shall be provided. Types of rescue equipment required will vary and will depend on the type of job and work being performed. A qualified person familiar with rescue equipment should be consulted to determine what equipment should be available for site-specific job and work conditions.

6.8 WIND DIRECTION INDICATORS

Consideration should be given to locating windsocks, streamers or flags, or other suitable device(s) for indicating wind direction at the well servicing/workover work site. The device shall be readily visible to personnel on or approaching the work location.

Note: Regulatory requirements for wind direction indicators shall be observed.

6.9 WARNING SIGNS

Legible warning signs, such as "HYDROGEN SULFIDE OPERATIONS—ENTER ONLY WHEN MONITORING SHOWS THE AREA TO BE SAFE" or "RESPIRATORY PROTECTION EQUIPMENT MUST BE WORN BEYOND THIS POINT," should be prominently posted at appropriate locations (e.g., entrance points) for well servicing/workover operations where hydrogen sulfide may be encountered (refer to 4.1 for applicability).

Note: Regulatory requirements for sign posting shall be observed.

7 Contingency Planning, Including Emergency Procedures

7.1 INTRODUCTION

Operators shall evaluate operations involving hydrogen sulfide and sulfur dioxide to determine if contingency plans, special emergency procedures, and/or training are required by applicable federal, state, or local regulatory agencies. The evaluation process shall identify potential emergencies and their impact on operating personnel and the general public. The contingency plan, if required, shall conform to all applicable local, state, and federal regulations regarding notifications, precautions, evacuations, and other requirements (refer to 40 *CFR* Part 264, Subpart D, and 29 *CFR* Part 1910.120, and 29 *CFR* Part 1910.38 for EPA and OSHA requirements, respectively, for contingency plans and emergency procedures).

7.2 SCOPE

The contingency plan should contain emergency response procedures that provide an organized immediate action plan for alerting and protecting operating personnel, contractor personnel, and the public. Contingency plans should consider the severity and extent of the anticipated atmospheric hydrogen sulfide and sulfur dioxide concentrations. Contingency plans should consider the dispersion characteristics of hydrogen sulfide and sulfur dioxide (refer to Appendix C or other recognized dispersion modeling techniques). Contingency plans should contain provisions for all applicable items listed in this section. Refer to *Hazardous Materials Emergency Planning Guide*, NRT-1, and *Technical Guidance for Hazards Analysis*. In addition to the contingency plan, Sections 302 and 303 of the *Superfund Amendments and Reauthorization Act of 1986* (SARA Title III) can require a facility operator to name a facility emergency coordinator to work with a local emergency planning committee (LEPC) in the development of an emergency response plan (refer to 40 *CFR* Part 355).

7.3 AVAILABILITY OF PLAN

The contingency plan shall be available to all personnel responsible for implementation, regardless of their normal location assignment.

7.4 PLAN INFORMATION

Contingency plan provisions may be contained in several plans or in a single plan. Contingency plans should contain, but not be limited to, information on the following subjects, as appropriate:

a. Emergency Procedures:
  1. Responsibilities of personnel (refer to 7.5).
  2. Immediate action plan (refer to 7.6).
  3. Telephone numbers and communication methods (refer to 7.7).
  4. Locations of nearby residences, businesses, parks, schools, churches, roads, medical facilities, athletics facilities, other facilities where population density may be unpredictable, etc.
  5. Evacuation routes and road block locations.
  6. Safety equipment and supplies available (e.g., number and location of breathing equipment).

b. Characteristics of Hydrogen Sulfide and Sulfur Dioxide
  1. Refer to Appendix A for hydrogen sulfide characteristics.
  2. Refer to Appendix B for sulfur dioxide characteristics.

c. Facility Description, Maps, and Drawings:
  1. Water injection stations.
  2. Wells, tank batteries, gas conditioning facilities, and flowlines.
  3. Compression facilities.

d. Training and Drills (refer to 3.2.8):
  1. Responsibilities and duties of essential personnel.
  2. Onsite or classroom (tabletop) drills.
  3. Informing nearby residents on protective measures in emergency situations, as appropriate.
  4. Training and attendance documentation.
  5. Briefing of public officials on issues such as evacuation or shelter-in-place plans.

7.5 RESPONSIBILITIES OF PERSONNEL

The contingency plan shall outline responsibilities and duties of all essential personnel. Visitors and other non-essential personnel should be prohibited from remaining in or entering an area contaminated by hydrogen sulfide and exceeding an atmospheric concentration of 10 ppm or a concentration of sulfur dioxide exceeding 2 ppm in the atmosphere (refer to 4.1 and Appendices A and B).

7.6 IMMEDIATE ACTION PLAN

Each contingency plan should contain a condensed "Immediate Action Plan" to be followed by designated personnel any time they receive notice of a potentially hazardous hydrogen sulfide or sulfur dioxide discharge. For the protection of personnel (including the general public) and abatement of the discharge, this "Immediate Action Plan" should include, but not be limited to, the following provisions:

a. Alert and account for facility personnel
  1. Move away from the hydrogen sulfide or sulfur dioxide source and get out of the affected area.
  2. Don proper personal breathing equipment.
  3. Alert other affected personnel.
  4. Assist personnel in distress.
  5. Proceed to the designated emergency assembly area.
  6. Account for onsite personnel.

b. Take immediate measures to control present or potential hydrogen sulfide or sulfur dioxide discharge and to eliminate possible ignition sources. Emergency shutdown procedures should be initiated as deemed necessary to correct or control the specific situation. When the required action cannot be accomplished in time to prevent exposing operating personnel or the public to hazardous concentrations of hydrogen sulfide or sulfur dioxide, proceed to the following steps, as appropriate for the site specific conditions.

c. Alert the public (directly or through appropriate government agencies) who may be subjected to an exposure exceeding 30 ppm[17] of hydrogen sulfide or 10 ppm of sulfur dioxide.

d. Initiate evacuation operations.

e. Contact the first available designated supervisor on the call list (refer to 7.4.a). Notify the supervisor of circumstances and whether or not immediate assistance is needed. The supervisor shall notify (or arrange for notification of) other supervisors and other appropriate personnel (including public officials) on the call list.

f. Make recommendations to public officials regarding blocking unauthorized access to the unsafe area and assist as appropriate.

g. Make recommendations to public officials regarding evacuating the public and assist as appropriate.

h. Notify, as required, state and local officials and the National Response Center to comply with release reporting requirements (i.e., 40 *CFR* Parts 302 and 355). Refer to 5.4.

i. Monitor the ambient air in the area of exposure (after following abatement measures) to determine when it is safe for re-entry.

Note: This sequence (7.6.a through 7.6.i) should be altered to fit the prevailing situation. Certain actions, especially those dealing with the public, should be coordinated with public officials.

7.7 EMERGENCY TELEPHONE LISTS

A list of emergency telephone numbers should be prepared and maintained as a part of the contingency plan, considering the need to contact any of the following:

a. Emergency Services.
  1. Ambulances.
  2. Hospitals.
  3. Medical personnel (e.g., doctors).
  4. Helicopter services.
  5. Veterinarians.

b. Government Agencies and Contacts.
  1. Local emergency planning committee.
  2. National response center.
  3. State emergency response commission.
  4. State and local law enforcement agencies.
  5. Civil defense.
  6. Fire departments.
  7. Other applicable government agencies.

c. Operator and Contractors.
  1. Operator personnel.
  2. Contractor personnel.
  3. Applicable service companies.

d. Public.

Telephone contacts to emergency services or law enforcement agencies should provide notification that a hydrogen sulfide or sulfur dioxide emergency condition exists.

7.8 COMMUNITY WARNING AND PROTECTION PLAN

When atmospheric exposures beyond the wellsite could exceed 30 ppm for hydrogen sulfide or 10 ppm for sulfur dioxide and could affect the general public, the contingency plans should also contain a community warning and protection plan. Appendix C or other recognized dispersion modeling techniques should be used to determine the radii of various hydrogen sulfide concentrations around the wellsite. If any residences/businesses are located inside a 100 ppm hydrogen sulfide concentration radius from the wellsite, consideration should be given to the use of the temporary safe haven or shelter-in-place concept of protection to provide additional time for safe extraction of people from the shelters. Refer to Section 2.3, 7–11, for additional information on this concept.

7.8.1 Community Warning and Protection Plan Content

The community warning and protection plan should contain information on, but not be limited to, the following subject areas.

a. A plan for the notification and evacuation of residents and occupants in the vicinity of the wellsite should the atmospheric concentration in their area reach 30 ppm for hydrogen sulfide and or 10 ppm for sulfur dioxide.

b. Quadrant maps and telephone lists showing an identification number, the location, and telephone number (if available) of all residences, schools, churches, and businesses, as well as locations of barns, pens, roads, animals, and anything else that might cause people to be present who might need to be warned or evacuated. Access and evacuation routes should be indicated on the map. Anyone requiring assistance for evacuation, such as bedridden, wheelchair bound, etc., should be noted on the list for priority evacuation assistance. If used, the shelter-in-place area can be shown as a circle around the wellsite at the radius where 100 ppm or greater may be expected.

c. Recommendations to county authorities and local emergency service organizations for the initial response to protect the public beyond the wellsite during release of hydrogen sulfide or sulfur dioxide.

d. The operating conditions under which the onsite operator representative will contact local authorities and the recommended community protection measures to be taken under those conditions.

e. Description and location of safety equipment to be provided by (1) the operator, and (2) by local authorities or

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[17] Emergency Response Planning Guide Level 2 (ERPG-2), refer to Reference 27. ERPG-2 is defined as the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.

services, to support the community warning and protection plan.

7.9 WELL-IGNITION PLAN

A plan should be prepared for ignition of the well in the event such action becomes necessary. The person, with appropriate authority to ignite the well, preferably the operator onsite representative, should be stipulated in the contingency plan.

The decision to ignite the well should be made only as a last resort, and only then in a situation where it is clear that:

a. human life and property are endangered, and
b. there is no hope of controlling the well under the prevailing conditions at the wellsite.

In any case, if time permits, an attempt should be made to notify the designated offsite operator supervisor of the plans to ignite the well. However, the onsite operator representative must not delay the decision if human life is threatened.

If the well is ignited, the combustion of hydrogen sulfide will produce sulfur dioxide, which is also highly toxic (refer to Appendix B). Sulfur dioxide atmospheric concentration should be carefully monitored. When the atmospheric concentration of sulfur dioxide in the work area exceeds 2 ppm, non-essential personnel shall proceed to a safe area and all essential working personnel should use proper personal breathing equipment (refer to 6.5).

The well contingency plan should contain procedures for monitoring the presence of sulfur dioxide on an area-wide basis and notification of all persons within the area to evacuate to a safe area if the sulfur dioxide exposure exceeds 10 ppm.

Note: In some cases, ignition may not be possible due to high concentrations of carbon dioxide or other non-combustible gases in the well fluids. Also, ignition may sometimes not be advisable due to atmospheric conditions. These eventualities should be considered during preparation of the community warning and protection plan (refer to 7.8).

7.9.1 Ignition Precautions

a. In preparation for igniting a well, all persons shall be kept in a safe briefing area or as far from the wellbore as necessary to provide safety.
b. Only qualified personnel should be used to ignite the well.

7.10 TRAINING AND DRILLS

The value of training and drills in emergency response procedures for oil and gas operations involving hydrogen sulfide or sulfur dioxide cannot be overemphasized. It is important that the training convey a full appreciation of the importance of each role and the effect that each person has on implementing an effective emergency response.

Exercises or drills that simulate an emergency in which personnel perform or demonstrate their duties are important tools that can convey the importance of contingency plans and result in their being kept current. The exercise can be a tabletop or classroom discussion; or can be a realistic drill in which equipment is deployed, communication equipment is tested, and “victims” are sent to hospital facilities with simulated injuries. Public officials should be informed of (and, preferably, involved in) these exercises. After a plan is tested, it should be revised and retested until those responsible for the plan are confident the plan is operational. Refer to NRT-1*: Hazardous Materials Emergency Planning Guide*.

7.11 UPDATING PROVISIONS

A contingency plan shall be periodically reviewed and updated any time its provisions or coverage change.

Operating personnel should be observant for changes that would make reconsiderations and possible revisions advisable in contingency plan coverage, location(s) of monitoring or detection equipment, and location(s) of lease equipment. Some changes that should be observed and considered are new residences or residential areas, churches, stores, businesses, parks, schools, or roads; changes in well operations; and changes in lease facilities.

8 Classification of Locations

8.1 GENERAL

From a hydrogen sulfide and sulfur dioxide safety standpoint, locations should be evaluated on the basis of the confinement presented by the area of the site and the specific environmental conditions. Land locations may be confined by the restriction of area, method of ingress and egress, terrain, surrounding population distribution, location proximity to municipalities or public facilities, etc. Locations with unconfined boundaries make it possible to obtain maximum safety benefits from rig configurations that take advantage of terrain and prevailing winds. Rig components should be arranged on location such that prevailing winds blow across the rig in a direction that will disperse any vented gas from the areas of the wellhead, choke manifold, flare stack or line, mud/gas separator, workover fluid tanks, reserve pits, and degasser away from any potential ignition sources e.g., engines, generators, compressors, and crew quarters) and areas used for personnel assembly. Vehicles not involved in the immediate operations should be a minimum of 100 feet from the wellbore or a distance equal to the height of the derrick or mast, whichever is greater, and in all cases should be outside the derrick or mast guyline perimeter. Comparable safety measures should be taken when terrain, location, or other conditions do not permit this spacing.

8.2 LOCATIONS WITH UNCONFINED BOUNDARIES

8.2.1 Introduction

Locations with unconfined boundaries are often possible on land. Such locations should be planned to obtain maximum safety benefits consistent with rig configurations, terrain, and prevailing winds. The rig layout will depend on the type of well (pumping, flowing, high pressure, etc.) being serviced.

8.2.2 Access to Location

All means of access to the location should be designed so that they can be barricaded at a predetermined location if hydrogen sulfide or sulfur dioxide emergency conditions arise. An auxiliary access should be available so that a shift in wind direction would not preclude escape from the location.

Appropriate caution signs (black on yellow, or equivalent) shall be displayed at all location entrances when the atmospheric concentration of hydrogen sulfide could exceed 10 ppm, so as to indicate a potential danger might be encountered.

Note: Regulatory requirements for sign posting shall be observed.

If warning flags or flashing lights are utilized, colors should be displayed in accordance with the following conditions:

CONDITION I:

Potential Danger To Life and Health: Well Operations Under Control

Warning Device: Green (hydrogen sulfide concentration <10 ppm).

Characterized By: Routine well operations in zones containing hydrogen sulfide. Hydrogen sulfide may be present at concentrations below trigger levels.

General Action:

a. Check safety equipment for proper functioning. Keep it available.
b. Be alert for a condition change.
c. Follow instructions of onsite operator representative.

CONDITION II:

Moderate Danger To Life and Health: Critical Well Control Operations

Warning Device: Yellow (hydrogen sulfide concentration ≥ 10 ppm and < 30 ppm). 3

Characterized By: Hydrogen sulfide is or potentially may be present up to 30 ppm on the well location.

General Action:

a. Stay in the “SAFE BRIEFING AREA” if not working to correct the situation.
b. Follow instructions of the onsite operator representative.
c. The onsite operator representative will follow community warning and protection plan procedures (refer to 7.8).

CONDITION III:

Extreme Danger To Life and Health: Loss Of Well Control

Warning Device: Red (Hydrogen sulfide concentration ≥ 30 ppm).

Characterized By: Hydrogen sulfide concentration is above or potentially may be above 30 ppm.

General Action:

a. Stay in the “SAFE BRIEFING AREA” if not working to correct the situation.
b. Follow instructions of the onsite operator representative.
c. The onsite operator representative will make appropriate notifications, activate the audible alarm and initiate the community warning and protection plan (refer to 7.8).
d. If the well is ignited, the burning hydrogen sulfide will be converted to sulfur dioxide, which is also dangerous to life and health. Therefore, DO NOT assume that the area is safe after the gas is ignited. Continue to observe applicable emergency and safety procedures and follow the instructions of the onsite operator representative.

8.2.3 Briefing Areas

Prevailing wind data shall be considered in locating briefing areas on either side of the location at a safe distance considering prevailing winds, or at a 90 degree angle for wind direction shifts in this area. When wind is from the prevailing direction, all briefing areas should be accessible. If the wind is quartering, one briefing area shall always be accessible.

8.2.4 Wind Direction Indicators

Windsocks, wind streamers, flags, or other suitable device(s) shall be placed at points around the wellsite location. A wind direction device should be readily visible to personnel on or approaching the work location and from any briefing area. Possible locations for installations are guylines, vertical poles around the workover site, the briefing areas, and the road entrances. Where practical and necessary, wind direction devices should be placed in illuminated areas.

Personnel should develop wind direction consciousness.

8.2.5 Electrical Equipment

All areas should be classified in accordance with API RP 500. Electric power plant(s) should be located as far from the wellbore as practical. All electrical equipment installations should conform to NFPA 70, except for offshore locations on the Outer Continental Shelf, which should conform to API RP14 F.

8.2.6 Electrical Design Considerations

In addition to being toxic, hydrogen sulfide is flammable at concentrations of 4.3 to 46% (by volume) in air. Electrical equipment installed in areas subject to exposure to methane-hydrogen sulfide mixtures composed of 25% or more (by volume) of hydrogen sulfide should be suitable for Class I, Group C classified areas (refer to Par. 3.5, “National Electrical Code Grouping of Atmospheric Mixtures,” in API RP 500).

8.2.7 Mechanical Ventilation

Mechanical ventilation (e.g., blowers or fans) may be desirable to help reduce hydrogen sulfide concentrations in the work area. Use of such ventilation equipment should be considered on the rig floor, around the derrick substructure, at the fluid tanks, and at any other low areas where hydrogen sulfide or sulfur dioxide might accumulate.

8.2.8 Burn Pits, Flare Line(s), and Flare Stack(s)

All burn pits, flare lines, and flare stacks should be located considering the prevailing wind direction. Additionally, flare lines and vents should not be pointed into the prevailing wind. Space around flares and burn pits should be cleared of brush and grass. Flare stacks should permit dispersion of sulfur dioxide, which may be generated by combustion of fluid(s) containing hydrogen sulfide. Regulatory requirements for vents, flare stacks, and ignition equipment shall be observed.

Note: Sulfur dioxide is a toxic product generated from combustion of hydrogen sulfide bearing fluids (refer to Appendix B).

8.3 LOCATIONS WITH CONFINED BOUNDARIES

8.3.1 Introduction

Space is often very restricted in mountainous or urban areas and in arctic, marsh, and water locations where operational requirements may dictate the use of special equipment such as barges, jack-up units, or similar support components. In addition to those recommendations made for unconfined locations (refer to 8.2.1 through 8.2.8), consideration should be given to confined locations considering limitations imposed by confinement of personnel and restricted distribution of equipment. Refer to Section 13, “Offshore Operations.”

9 Well Materials and Equipment

9.1 MATERIALS CONSIDERATIONS

9.1.1 Introduction

When exposed to an environment containing hydrogen sulfide, many materials may suddenly fail in a brittle manner. Failure occurs by a form of embrittlement known as sulfide stress cracking (SSC). Susceptibility of a given material to SSC increases as strength and tensile stress (residual or applied) increase. Material hardness frequently is used as an indirect measure of strength and sometimes is referenced as a limiting parameter. The failure of certain well servicing/workover and production equipment used in the SSC regime could result in the uncontrolled release of hydrogen sulfide to the atmosphere. Such components should be made from SSC resistant materials (refer to 9.1.2).

9.1.2 Materials Selection

Metallic materials satisfactory for use in hydrogen sulfide environments and the conditions under which they should be used are described in NACE Standard MR0175. The latest revision of this standard should be consulted when selecting materials for use in hydrogen sulfide environments. The provisions of NACE Standard MR0175 should be considered minimum standards, with the equipment user free to apply more stringent specifications. The material requirements of NACE Standard MR0175 offer resistance to SSC; however, other forms of corrosion and modes of failure (such as pitting, hydrogen-induced cracking, and chloride cracking) should be considered in the design and operation of equipment. Control of failures by mechanisms other than SSC should be mitigated by chemical inhibition, material selection, and environmental controls (refer to NACE Standard MR0175, Par. 1.1). Appendix D includes excerpts from NACE Standard MR0175-94, providing the definition of a sour environment and graphs that may be used to determine when SSC resistant materials should be used. Users of this publication should check the latest edition of NACE Standard MR0175 for revisions to the defining criteria for a sour environment.

9.1.2.1 Compliance with NACE Standard MR0175 for equipment intended for hydrogen sulfide service may be required by the user, depending on severity of the service. Adequate quality assurance procedures should be followed to verify compliance by the manufacturer for the original equipment and for any subsequent equipment modifications.

9.1.2.2 Materials not covered in NACE Standard MR0175 that have been qualified for hydrogen sulfide environment service by the user or manufacturer, using recognized and acceptable testing procedures, may be used. A written agreement between the manufacturer and user may be appropriate. Recognized and acceptable testing procedures are those that demonstrate that the material(s) performs as well as or superior to similar material(s) set forth in NACE Standard MR0175, using laboratory procedures or procedures for which testing has been completed under actual or simulated environmental conditions. The suitability of materials must be supported by appropriate documentation, that should include a complete description of the materials, processing, and testing procedure. Laboratory, field, or other environmental testing results or service performance should be recorded in writing. Full documentation supporting the suitability of material(s) for the selected service should be maintained by the user, manufacturer, or both. Materials use is subject to compliance with applicable regulations.

9.1.2.3 Non-metallic, resilient, rubber-like materials used in the sealing mechanisms of the various components of equipment shall be capable of sustaining the designated operating pressure, temperature, and hydrogen sulfide environment exposure for that particular component or assembly. Careful consideration should be given to effects of chemical elements or other conditions of the well fluids that may have detrimental effects on the seal materials. The equipment manufacturer should be consulted in selecting elastomeric seals for use in hydrogen sulfide environments (refer to API Bulletin 6 J).

9.1.3 Control of Sulfide Stress Cracking (SSC)

SSC of rig, special services, and well equipment may be controlled by:

a. Using materials, processes, and procedures specified in NACE Standard MR0175.

b. Using recognized testing and certification procedures specified in 9.1.2.

c. Isolating susceptible materials from exposure to the hydrogen sulfide environment.

d. Controlling the workover environment by maintaining the workover hydrostatic head or fluid density to minimize formation fluid influx. The following measures will also aid control of the workover environment:

1. Use of chemical scavengers.
2. Maintenance of pH 9 or higher to neutralize hydrogen sulfide in the wellbore.

Note: Care should be exercised to maintain proper pH to prevent reversible action that can release hydrogen sulfide from the workover fluid.

Note: The susceptibility to SSC increases as the pH decreases. This tendency can be drastically reduced if the pH is maintained above 9.

Note: Use of sulfide scavengers and alkalinity to control hydrogen sulfide in water based workover fluids should be closely monitored with appropriate field instruments that can measure scavenger residual or pH, respectively.

3. Use of a workover fluid with oil as the continuous phase.

Note: This is particularly important in high pressure, high concentration hydrogen sulfide wells.

9.1.4 Equipment Selection and Installation

Rig, special services, and well equipment components should be made from materials complying with 9.1.2, or designed to isolate susceptible material from the hydrogen sulfide environment and/or prevent the uncontrolled release of hydrogen sulfide to the atmosphere. Rig, special services, and well equipment shall not be operated at pressures that exceed the rated working pressure of the lowest rated component that is exposed.

9.1.4.1 Blowout Prevention Equipment

Blowout prevention equipment, as modified for hydrogen sulfide service, is described in API RP 53. API Spec 16A, First Edition, November 1, 1986, contains product purchase specifications for annular and ram-type blowout preventers and related equipment, as well as recommended operations characteristics tests for blowout preventer equipment.

9.1.4.1.1 Choke Manifolds

Recommendations for selection, installation, and testing of choke manifold assemblies for use in hydrogen sulfide service can be found in API RP 53 and API Spec 16C.

9.1.4.1.2 Testing

Recommended blowout preventer equipment field acceptance inspection and testing procedures are shown in API RP 53. Suggested blowout prevention equipment tests for hydrogen sulfide locations are contained in API RP 53. Refer to 30 *CFR* Part 250.57 for BOP testing requirements in OCS operations.

9.1.4.2 Wellhead Equipment

Wellhead equipment, as modified for hydrogen sulfide service, is described in API Spec 6A.

9.1.4.3 Tubular Goods

9.1.4.3.1 Casing and Tubing

Casing and tubing should be manufactured using materials specified in NACE Standard MR0175 and/or *API* Spec 5CT, and should be used under conditions consistent with the temperature limitations shown in Table 4 of NACE Standard MR0175. Materials not covered in NACE Standard MR0175, which have been qualified for hydrogen sulfide service by the user or manufacturer following recognized and acceptable procedures as shown in 9.1.2, may be used.

9.1.4.3.2 Drill Pipe

Drill pipe used as work string should be manufactured using materials specified in NACE Standard MR0175 and

API Spec 5D and should be used under conditions consistent with the temperature limitations shown in Table 4 of NACE Standard MR0175. Materials not covered in NACE Standard MR0175, which have been qualified for hydrogen sulfide service by the user or manufacturer following recognized and acceptable procedures as shown in 9.1.2, may be used.

9.1.4.4 Work String Tubulars

For improved SSC resistance, work string tubular products having actual (not the specified minimum) yield strengths higher than 95,000 psi should be properly quenched and tempered. However, normalized and tempered lower strength tubulars (e.g., J-55 or L-80 tubing and Grades E and X drill pipe) used as work strings and normalized and tempered kellys are acceptable. Refer to 9.1.4.3.1 for recommendations for tubing used as a work string The suitability of materials for hydrogen sulfide environment service can be assessed by evaluation of hardness testing results or tensile test data, if available. As pipe yield strength and service stresses increase, consideration should be given to controlling SSC (refer to 9.1.3). High-strength tubulars (e.g., Grades P110 tubing and S135 drill pipe) should not be used for a work string in potential hydrogen sulfide environments (refer to Appendix D) unless a properly maintained workover fluid is used in which oil is the continuous phase. Applicable recommendations for minimizing sulfide stress cracking of drill stem (used as a work string) are given in Section 10 of API RP 7G.

10 Operations

10.1 WELL COMPLETIONS

10.1.1 Introduction

Well completions should be conducted in a manner to take advantage of appropriate technology and materials and these operations should be effected in a prudent manner to promote safety of the public and workers and protection of the environment.

10.1.2 Completion Design

The completion design should comply with recommendations set forth in Section 9, “Well Materials and Equipment,” when the well equipment is exposed to hydrogen sulfide and may be subject to failure. The pieces of equipment where failure would result in uncontrolled release of hydrogen sulfide should be made from sulfide stress cracking resistant material (refer to 9.1.2).

10.2 WELL SERVICING OPERATIONS

10.2.1 Introduction

During well servicing operations, hazardous concentrations of hydrogen sulfide may occur unexpectedly. Precautions should be taken during well servicing work so that hazards due to the release of trapped hydrogen sulfide can be avoided. Well servicing consists of, but is not limited to, the following: blowing the well down, dismantling wellhead equipment and flowlines, circulating the well, pulling the pumps and packers, and swabbing after acidizing operations (reaction between the acid and iron sulfide can create hydrogen sulfide).

10.2.2 General Operations

10.2.2.1 Safety

The intent of this subsection is to promote personnel safety, protection of the environment, and integrity of the facilities through use of prudent practices and methods in well completion, servicing, and workover operations. *All operations should be conducted in accordance with applicable rules, regulations, and practices.* Due to the toxic nature of hydrogen sulfide and sulfur dioxide gas, precautions must be taken to ensure personnel safety during general and special rig operations (refer to Appendices A and B and 4.1). Personnel working in a location where the atmospheric concentration of hydrogen sulfide is greater than 10 ppm or the sulfur dioxide atmospheric concentration is greater than 2 ppm should wear proper breathing equipment (refer to 6.5).

10.2.2.2 Planning and Meetings

An operations work plan should be established to ensure compliance with all applicable regulations and accepted operating practices and policies. Appropriate operating company, contracting company, service company, and other job-related representatives should discuss pertinent well data and information pertaining to the job(s) to be done prior to beginning work covered in this publication. This discussion should include but not be limited to: move-on, move-off, job guidelines, and action(s) required of all parties. Where no guidelines or regulations exist, prudent operating practices should be used. Emergency response plans, precautions, and equipment installation should be effected prior to starting work.

10.2.2.3 Drills

A blowout prevention drill should be conducted at least once each week for each well servicing crew to ensure that well control equipment is operational and that crew members are informed of and properly trained to execute their assigned emergency duties.

10.2.2.4 Records

Daily operations records should be prepared to accurately document the work and drills as performed.

10.2.2.5 Blowout Prevention Equipment

Well control conditions fall into two general classifications, namely, pressure and non-pressure operations. The use of blowout preventer equipment components, as addressed herein, is directed toward use on wells where the control of surface pressure is required or may be needed. The blowout preventer equipment shall be capable of closing on each pipe size in the work string. The use of blowout preventers on non-pressure applications is encouraged in a high risk environment or where use of the equipment will facilitate workover activities and operations. Use of blowout preventer equipment in a routine, non-pressure environment is at the option and judgement of the operator. Installation and testing procedures for blowout preventer equipment in pressure service applications may be applied to non-pressure service applications. Refer to API RP 53 for blowout prevention equipment installations and tests. Refer to 30 *CFR* Part 250.57 for blowout preventer requirements in Outer Continental Shelf operations.

10.2.2.6 Other Equipment

A full-opening safety valve in the open position, complete with operating handle and with proper end connections to fit the work string in use, should be maintained in a readily accessible location on the working level of the rig. This equipment should be tested at regular intervals. When running two or more strings simultaneously, a safety valve should be available for each string being handled.

10.2.2.7 Personnel Safety Precautions During Well Testing and Evaluation

In addition to recommendations set forth in Sections 5 and 6, the following personnel safety precautions should be considered:

a. Operations should be performed with the minimum number of essential personnel required and utilizing the necessary equipment to safely perform the operation(s) and maintain related equipment and services. Protective breathing equipment shall be located so that it is quickly and easily available to essential personnel. Atmospheric conditions should be monitored with appropriate hydrogen sulfide detection equipment.

b. Prior to initiation of such operations, special safety meetings shall be conducted for all personnel who will be on the rig facility, with particular emphasis on the use of proper protective breathing equipment, first aid procedures, and emergency response procedures. Only personnel having received training as shown in Section 5, shall be used.

c. All produced gases shall be vented and/or flared in such a manner as to ensure personnel safety. Gases from stored test fluids should also be safely vented.

d. “No Smoking” rules shall be vigorously enforced.

e. Personnel handling fluid samples from known or suspected hydrogen sulfide zones should exercise caution until such operations are completed. Appropriate precautions should be employed for the handling and transportation of samples containing hydrogen sulfide. Sample containers should be made of hydrogen sulfide resistant materials and appropriate caution labels should be affixed thereto (refer to 49 *CFR* Part 178, Part C).

10.2.3 Gas-Cut Completion/Workover Fluid

When hydrogen sulfide gas is breaking out of the completion/workover fluid at the surface during circulating operations, returns should be routed through a separation system until the level of hydrogen sulfide is determined to be safe. It may be necessary to treat the fluid in order to remove hydrogen sulfide.

10.2.4 Fluid Storage

Extreme caution should be exercised when fluid, which has been exposed to hydrogen sulfide, is stored in “workover” pits or other tanks. Hydrogen sulfide gas breaking out of stored fluid can be hazardous to personnel, especially if located in an enclosed space. Contaminated fluid should be disposed of in a safe manner or properly treated. Hydrogen sulfide can be formed in stored fluid, which has not been previously exposed to hydrogen sulfide as a result of decomposition of some materials used for fluid treatment. Hydrogen sulfide may be generated by chemical reaction between stored fluids and other materials (residual or added). Personnel should take appropriate safety precautions when entering any enclosed or restricted ventilation area which contains or has contained stored fluid.

10.2.5 Circulation of Well Kicks

The decision to circulate a kick should be reviewed prior to the start of operations and should be incorporated in the completion/workover plan, the rig and well equipment selection, and the crew training.

10.2.6 Wireline Operations

Refer to Section 12, “Special Operations,” for recommendations regarding wireline operations.

10.2.7 Plugging and Abandonment Operations

These operations should be conducted in accordance with the applicable recommended practices set forth in this publication *and shall comply with federal, state, and local regulations covering well plugging and abandonment operations.* These regulations should be consulted for specific methods, qualities, quantities, and/or height of cement to be used for cement plugs.

11 Rig Practices and Operations

11.1 INTRODUCTION

Due to the toxic nature of hydrogen sulfide and sulfur dioxide, precautions must be taken to ensure personnel safety during any operation (refer to 4.1 and Appendices A and B). When protective breathing equipment must be worn by all working personnel, all nonessential personnel shall proceed to a safe briefing area. *All operations shall be conducted in accordance with applicable laws, rules, and regulations.*

11.2 HYDROGEN SULFIDE FROM PRESSURE MAINTENANCE AND/OR WATERFLOODING OPERATIONS

Pressure maintenance and/or waterflooding operations may result in the introduction of bacteria that can cause water soluble hydrogen sulfide to develop over time within the producing formation and be present in produced fluids. Operators of such producing properties should be alert to this possibility and should warn well servicing and workover personnel that hydrogen sulfide may be encountered in the performance of their normal work.

11.3 SPECIAL PRECAUTIONS

Special precautions should be taken during well servicing work, such as blowing the well down, dismantling wellhead equipment and flow lines, circulating the well, pulling pumps and packers, and swabbing after acidizing operations so that hazards due to the release of trapped hydrogen sulfide can be avoided. All servicing personnel should be trained in the potential dangers of hydrogen sulfide and precautions to be taken when it is encountered. Continuous hydrogen sulfide monitors/detectors should be available in accordance with recommendations set forth in Section 6 when working over or servicing a well with a potentially hazardous concentration of hydrogen sulfide. Protective breathing equipment shall be located so that it is quickly and easily available (refer to 6.5.1). Mechanical ventilation equipment may be used to direct vapors in the desired direction as protection against calm or light winds. Particular emphasis should be placed on low-lying work areas, such as cellars, where hazardous concentrations may develop because of the heavier hydrogen sulfide or sulfur dioxide settling in these areas.

11.4 GENERAL PRACTICES

11.4.1 Review of Contingency Plan

The operator or his representative should provide and review the hydrogen sulfide contingency plan with the servicing company representative prior to rig up of equipment. The operator should also review the service company's immediate action plan to ensure coordinated response in the event of a hydrogen sulfide emergency.

11.4.2 Availability of Personnel Protective Equipment

The operator or his representative and the servicing company representative should determine the type and quantity and verify onsite availability of personnel protective equipment required (refer to Section 6, "Personnel Protective Equipment"), in accordance with the operations to be performed. This determination should include any other servicing company personnel, operating company personnel, or other outside personnel who may be required to accomplish the operation.

11.4.3 Review of the Wellsite

The service company and operator representatives should review the wellsite arrangements prior to rig up. Considerations during the review should include prevailing wind direction, wind obstructions, sub-grade areas, location of pits, tanks, flare stack or lines, site access (entrance and exits), power lines, etc. Arrangements of rig, auxiliary equipment, and support vehicles should be planned and agreed upon in order to meet the recommendations of Section 8, "Classification of Locations."

11.4.4 Rig or Unit Selection

Special considerations should be given to rig components, handling tools, wirelines, and any auxiliary equipment exposed to a hydrogen sulfide environment (refer to Appendix D) and required for the servicing operations.

11.4.5 Operational Practices

The following operational practices should be considered on applicable locations (refer to 4.1).

11.4.5.1 Prior to rigging up on a well, the work site should be observed for unusual conditions. If unusual conditions are observed, the site should be checked for the presence of hydrogen sulfide. Special consideration should be given to sub-grade or low areas such as cellars.

11.4.5.2 Placement of rig, auxiliary equipment, and support vehicles should follow the prearranged plan to take advantage of prevailing wind. Safe briefing areas should be designated and a safety meeting should be held to familiarize all personnel with the emergency plan, the location of safe briefing areas, available personnel protective equipment, and any special precautions or procedures that may be required.

11.4.5.3 During normal rig up procedures, wind direction indicators shall be installed (refer to 6.8). The hydrogen sulfide monitoring system shall be placed in operation and functionally tested in accordance with recommendations set forth in Section 6, "Personnel Protective Equipment."

11.4.5.4 No employee shall be allowed in the derrick without proper equipment (e.g., self-contained air supply for escape or emergency use or a derrick escape device) being immediately available for use.

11.4.5.5 If the hydrogen sulfide monitoring system alarm sounds at any time during operations, the applicable emergency procedures shall be implemented (refer to Section 7, “Contingency Planning Including Emergency Procedures”).

11.4.5.6 No personnel shall be allowed to re-enter the work area without proper personal protective breathing equipment (refer to 6.5) until the hydrogen sulfide atmospheric concentration has fallen to 10 ppm or below or until the sulfur dioxide atmospheric concentration has fallen to 2 ppm or below. If personnel rescue is required, the person or persons effecting the rescue shall use proper personal breathing equipment until a safe area is achieved.

11.4.5.7 If conditions require operations to continue where concentrations of hydrogen sulfide in the atmosphere remain above 10 ppm or sulfur dioxide in the atmosphere exceed 2 ppm, all personnel remaining in the work area should wear appropriate personal protective breathing equipment (refer to 6.5). Refer to 6.6 for information regarding requirements for working in an IDLH atmosphere.

11.4.5.8 Daily checks should be performed by the designated wellsite supervisor prior to beginning work each day. The following items should be checked:

a. The work site for the presence of hydrogen sulfide.
b. Wind direction indicators. The results of this check may require redesignating the safe briefing areas.
c. Hydrogen sulfide monitoring or detection equipment and alarm (function test).
d. Placement of personal protective breathing equipment.
e. Placement of fire protection equipment.
f. Appropriate first aid equipment.

11.5 HYDROGEN SULFIDE AND SULFUR DIOXIDE DRILLS

In addition to hydrogen sulfide and sulfur dioxide training for personnel, periodic emergency drills shall should be held. These drills should include those steps necessary to implement the emergency procedures. Records of personnel training and emergency drills shall be documented and should be retained for a minimum of one year.

11.6 HYDROGEN SULFIDE IGNITION SOURCES

When mixed with air, hydrogen sulfide can be explosive (refer to Appendix A for some physical properties of hydrogen sulfide). To minimize potential sources of ignition, the following items should be considered.

a. Enforce “No Smoking” rules.
b. Exclude non-essential personnel from the location.
c. Adequately ventilate the rig substructure (natural or forced ventilation).
d. Locate portable generator units, dog houses, and change rooms as far from the wellbore as practical, or take appropriate safety measures.
e. Prohibit operation of vehicles equipped with catalytic converters in the immediate vicinity of the wellbore unless measures have been taken to ensure that the area is safe from the potential of ignition. Vehicles not involved in the immediate operations should be a minimum of 100 feet (30.5 m) from the wellbore or a distance equal to the height of the derrick or mast, whichever is greater, but in all cases should be outside the derrick or mast guyline perimeter. Comparable safety measures should be taken when terrain, location, or other conditions do not permit this spacing.
f. Spark arrestors or equivalent equipment should be provided on all internal combustion engine exhausts located within 100 feet of the wellbore.
g. Restrict open flame stoves, open fires, welding operations, or other possible sources of ignition (electrical power tools, two-way radios, etc.) to designated areas.
h. Locate shutdown controls for engines near the unit operator’s console for immediate emergency use.
i. Emergency shutdown devices that will close off the combustion air should be installed on all diesel engines.

12 Special Operations

12.1 INTRODUCTION

“Special Operations” are defined as any service performed on or in a well other than the normal service operations that are accomplished in their entirety by a workover or drilling rig. All applicable recommended practices of other sections of this publication, in addition to the recommendations under Section 12, apply to special operations. Although some special operations may require or be enhanced by the use of a workover or drilling rig, most special operations can be accomplished with or without a rig on location.

Operators of potential hydrogen sulfide producing properties shall alert employees and special operations service contractors of the possibility of hydrogen sulfide atmospheric concentrations greater than 10 ppm and sulfur dioxide atmospheric concentrations greater than 2 ppm that may be encountered in the performance of their work.

Special operations include, but are not limited to, the following service operations:

a. Wireline operations, which include all types of wireline such as multi-strand conductor (electrical) line, multi-strand non-conductor line, and single-strand (slick) line.
b. Perforating operations.
c. Pumping operations such as acidizing, fracturing, cementing, and hot oil operations.
d. Snubbing operations.
e. Continuous reeled (coiled) tubing operations.
f. Freezing (plug).
g. Valve drilling and hot tapping operations.

Note: Adequate lighting (refer to ANSI/IES RP7-1990) should be provided in the work area(s) when special operations are required to be performed during the hours of darkness.

12.2 PERSONNEL AND SAFETY

12.2.1 Personnel Safety Training

Refer to Section 5, "Personnel Training."

12.2.2 Personnel Protective Equipment

Refer to Section 6, "Personnel Protective Equipment."

12.2.3 Tools and Equipment

By means of previous training and experience, personnel performing special services operations should be aware of the capabilities and limitations of their service equipment, tools, and operating procedures.

12.2.4 Review of Operations

Upon arrival at the wellsite, the service personnel supervisor should meet with the operator's representative to discuss the operations to be performed and applicable safety and emergency procedures.

12.2.5 Responsibilities of Personnel

Prior to beginning the operation, the special service personnel supervisor should thoroughly review and define the specific responsibilities of each individual crew member for the ensuing special service operations, the safety procedures to be followed, and any emergency actions that affect the operations. Additionally, the special service personnel supervisor shall inform other affected personnel on the location regarding special services to be performed.

12.2.6 Restriction of Personnel to Work Site

If hydrogen sulfide is involved, discretion should be used in admitting personnel to the wellsite who are not essential to the performance or supervision of the operation in progress.

12.2.7 Venting Operation

When opening or bleeding a tool, lubricator, or any other device which has the potential to release hydrogen sulfide, appropriate piping should be installed to vent to a remote location. Otherwise, proper personal protective breathing equipment shall be worn by all personnel involved in the operation with a potential to be exposed to hydrogen sulfide.

12.3 WIRELINE OPERATIONS

12.3.1 Wireline Lubricator Equipment

If the well is capable of flowing, the minimum lubricator equipment should conform to 9.1.2 and consist of:

a. Wireline valve (blowout preventer).
b. Lubricator (riser) section(s).
c. Pressure bleed valve.
d. Stuffing box or control head.

When opening or bleeding a tool, lubricator, or any other device that has the potential to release hydrogen sulfide, appropriate piping should be installed to vent to a remote location. Otherwise, proper personal protective breathing equipment shall be worn by all personnel involved in the operation and with a potential to be exposed to hydrogen sulfide.

12.3.2 Wireline Materials

Wireline materials should be suitable for the environment to which they will be subjected. Where hydrogen sulfide is the single chemical factor involved, several wire materials are available that are highly resistant to SSC. Consideration should be given to pretreating wirelines and slicklines with corrosion inhibitor(s) prior to running them in the well. In addition, consideration should be given to onsite inspection and field ductility testing of the wireline to detect pitting, surface damage, or embrittlement of the material that may have been incurred during operations. Some wire materials that are resistant to the effects of a hydrogen sulfide environment may not be adequate if other chemical elements, such as halides, are present. Halides include a class of chemical compounds commonly occurring in oil and gas wells. Examples of halide compounds that may be present in well fluids are hydrochloric acid, salt water, calcium chloride, and zinc bromide. Halides at elevated temperatures, such as are commonly present in the lower regions of the tubing string, can embrittle stainless steel wirelines. Metallurgical consultation may be required prior to running stainless steel wireline into well fluids containing halides.

12.3.3 Well Swabbing Operations

The swabbing unit should be placed upwind from the wellbore, swabbing tanks, and pits. On a still day, the prevailing wind direction should be considered in positioning the swabbing unit.

12.4 PERFORATING OPERATIONS

Refer to API RP 67 and RP 54 for information regarding safety in perforating operations.

12.5 CEMENTING, ACIDIZING, FRACTURING, AND HOT OIL PUMPING OPERATIONS

Refer to 5.1 for general information regarding personnel involved in cementing, acidizing, fracturing, and hot oil pumping operations. Refer to 9.1.2 and 9.1.4 for information regarding selection and use of materials and equipment for such operations when hydrogen sulfide is present. Refer to API RP 54 for general safety information applicable to these operations.

12.6 SNUBBING OPERATIONS

Snubbing operations should be restricted to daylight hours, excepting where existing emergency or environmental conditions dictate that such operations be performed in hours of darkness.

When working atop snubbing equipment, an escape device shall be provided for each employee at the work level. No employee shall be allowed in the snubbing work basket without proper equipment (e.g., self-contained air supply for escape or emergency use or an escape device being immediately available for use).

12.7 CONTINUOUS REELED (COILED) TUBING OPERATIONS

Refer to Section 9, “Well Materials and Equipment,” for information regarding selection and use of equipment used in continuous reeled tubing operations. Cold working of continuous reeled tubing can affect material hardness. A quality control program should be implemented to monitor tubing condition.

12.7.1 Placement of the Reel Unit

The continuous reeled tubing unit should be placed upwind of the well, considering the prevailing wind direction and specific wellsite conditions. The reel unit and its conveyance should be adequately secured so as to prevent any unwanted movement.

12.7.2 Special Equipment

When possible, a flanged type connection should be used on the bottom connection of the coiled tubing blowout preventer.

In pressured operations, consideration should be given to a dedicated pump cross and a second set of tubing ram preventers located below the pump cross.

Wellbore fluids should not be routed to the coiled tubing operation enclosure for the purpose of instrumentation or other uses.

12.8 FREEZING OPERATIONS (PLUG)

Some materials may become brittle at low temperature. Prior to plug freezing operations, steel specifications should be determined to prevent low temperature damage to the material.

12.9 VALVE DRILLING AND HOT TAPPING OPERATIONS

Equipment used in valve drilling and hot tapping operations shall be suitable for hydrogen sulfide service. The rated working pressure of all equipment used in these operations should exceed the anticipated pressure inside equipment being drilled or tapped. Refer to API RP 2201 for additional general information regarding hot tapping operations on equipment in service.

The bleed-off ports on the lubricator and lubricator assembly should be equipped with two (2) valves in series on each port. These valves should be suitable for hydrogen sulfide service and shall have a rated working pressure that equals or exceeds the rated working pressure of the lubricator assembly. The outer valve should be used as the operational valve in order to conserve the innermost valve for emergency use.

13 Offshore Operations

13.1 INTRODUCTION

Section 13 presents some additional recommendations for offshore operations due to the uniqueness of these operations. Many recommendations in other sections of this publication are also applicable to offshore operations. Refer to Appendix F, “Toxic Gases,” API RP 14 C.

13.2 UNIQUENESS OF OFFSHORE OPERATIONS

Conditions that might be considered minor in onshore operations can be more critical in offshore operations. This is due to the remoteness of offshore operations, compactness of facilities, limited escape and evacuation routes, and sophisticated escape and evacuation equipment.

13.3 FEDERAL REGULATORY REQUIREMENTS

Refer to 30 *CFR* Parts 250 and 256 for Minerals Management Service (MMS), U. S. Department of Interior (DOI) requirements for Outer Continental Shelf (OCS) oil and gas drilling, producing, and well servicing operations involving hydrogen sulfide. These regulations include requirements for training personnel involved in OCS oil and gas well servicing operations and for contingency plans for OCS oil and gas producing operations.

13.4 CONTINGENCY PLANNING

Where potentially hazardous atmospheric concentrations of hydrogen sulfide could occur offshore, contingency planning is particularly essential due to the uniqueness of facilities and operations, as discussed in 13.2. Although the recommendations for contingency planning presented in Section 8 are applicable to offshore operations, there are additional items that should be addressed. These items include, but are not limited to, the following:

13.4.1 Training

All personnel shall be familiar with the location and use of emergency escape routes and equipment. Personnel regularly assigned to offshore facilities shall be trained in the requirements of 5.2, as well as be proficient in the use of oxygen resuscitation equipment.

13.4.2 Evacuation Procedures

The U. S. Coast Guard's (DOT) requirements for emergency evacuation plans for manned OCS facilities are contained in 33 *CFR* Parts 140, 143, and 146 (refer to 54 *FR* 21566, May 18, 1989). Surface and/or air transportation to the site should be available since it may be necessary to evacuate visitors and other non-essential personnel and to bring in specialists or equipment if a hazardous hydrogen sulfide condition is suspected or does occur. Monitoring for combustible gases (primarily methane) and hydrogen sulfide should be provided to avoid unnecessarily exposing personnel and equipment to the dangers of a fire, explosion, or hazardous concentration during transport or transfer operations. If a hazardous hydrogen sulfide condition is known or suspected to be imminent, boats and helicopters should approach the site from an upwind direction, when possible.

Proper respiratory protective equipment must be provided for all personnel who are on the platform, including helicopter and boat crew members and all passengers. Evacuation routes and deboarding procedures shall be well planned and posted. Evacuation drills shall be regularly performed.

13.5 SIMULTANEOUS OPERATIONS

Particular emphasis must be given to coordination between drilling, well servicing, well workover, producing, and construction operations when 2 or more of these activities are conducted simultaneously. An individual shall be designated to be the person-in-charge for simultaneous operations, and the chain of command shall be communicated to all applicable personnel.

APPENDIX A—PHYSICAL PROPERTIES AND PHYSIOLOGICAL EFFECTS OF HYDROGEN SULFIDE

A.1 Physical Data

Table A-1—Hydrogen Sulfide

Chemical Name:	Hydrogen Sulfide
CAS Number:	7783-06-4
Synonyms:	Sulfureted hydrogen, hydrosulfuric acid, dihydrogen sulfide.
Chemical Family:	Inorganic sulfide
Chemical Formula:	H_2S.
Normal Physical State:	Colorless gas, slightly heavier than air. Vapor density (specific gravity) at 59°F (15°C) and 1 atmosphere = 1.189.
Autoignition Temperature:	500°F (260°C)
Boiling Point:	-76.4°F (-60.2°C)
Melting Point:	-117.2°F (-82.9°C)
Flammable Limits:	4.3 - 46 percent vapor by volume in air.
Solubility:	Soluble in water and oil; solubility decreases as the fluid temperature increases.
Combustibility:	Burns with a blue flame to produce sulfur dioxide (SO_2). Refer to Appendix B.
Odor and Warning Properties:	Hydrogen sulfide has an extremely unpleasant odor, characteristic of rotten eggs, and is easily detected at low concentrations. However, due to rapid onset of olfactory fatigue and paralysis (inability to smell), ODOR *SHALL NOT* BE USED AS A WARNING MEASURE.

A.2 Exposure Limits

The Occupational Safety and Health Administration (OSHA) has established 20 ppm by volume as an acceptable ceiling concentration (ACC) and 50 ppm (10-min. max. peak) by volume as an acceptable maximum peak above the ACC for an 8-hour shift for hydrogen sulfide (refer to 29 *CFR* Part 1910.1000, Subpart Z, Table Z-2). The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a Threshold Limit Value (TLV)®[18] of 10 ppm (8-hour TWA) and a short term exposure limit (STEL) of 15 ppm averaged over 15 minutes. Exposure at the STEL should not be repeated more than 4 times per day with at least 60 minutes between successive exposures in this range. For Outer Continental Shelf (OCS) oil and gas operations, exposure levels exceeding 20 ppm instantaneous exposure require use of personal protective breathing equipment pursuant to U.S. Department of Interior Minerals Management Service Final Rule, 30 *CFR* Part 250.67. The *NIOSH Recommended Standard for Occupational Exposure to Hydrogen Sulfide* should be consulted for additional detailed information. Refer to Table A-2 for additional information on exposure values. CHECK WITH THE EMPLOYER CONCERNING EXPOSURE LIMITS FOR PARTICULAR CIRCUMSTANCES.

A.3 Physiological Effects

CAUTION: Inhalation at certain concentrations can lead to injury or death (refer to Table A-1).

Hydrogen sulfide is an extremely toxic, flammable gas that may be encountered in the production of gas well gas, high-sulfur-content crude oil, crude oil fractions, associated gas, and waters. Since hydrogen sulfide is heavier than air, it can collect in low places. It is colorless and has a foul, rotten-egg odor. In low concentrations, it is detectable by its characteristic odor. However, smell cannot be relied on to forewarn of dangerous concentrations because exposure to high concentrations (greater than 100 ppm) of the gas rapidly paralyzes the sense of smell due to paralysis of the olfactory nerve. A longer exposure to lower concentrations has a similar desensitizing effect on the sense of smell.

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[18] "TLV" is a trademarked term of the American Conference of Governmental Industrial Hygienists (ACGIH). Refer to *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices* and companion documents available from ACGIH, 1330 Kemper Meadow Drive, Cincinnati, OH 45240 (check latest edition).

CAUTION: It should be well understood that the sense of smell will be rendered ineffective by hydrogen sulfide, which can result in an individual failing to recognize the presence of dangerously high concentrations.

Excess exposure to hydrogen sulfide causes death by poisoning the respiratory system *at the cellular level*. There is some indication that the presence of alcohol in the blood aggravates the effects of hydrogen sulfide in acute poisoning cases. Even at low concentrations (10-50 ppm) hydrogen sulfide is irritating to the eyes and respiratory tract. Closely repeated short-term exposures at low concentrations may lead to irritation of the eyes, nose, and throat. Symptoms from repeated exposures to low concentrations usually disappear after not being exposed for a period of time. Repeated exposures to low concentrations that do not produce effects initially may eventually lead to irritation if the exposures are frequent.

A.4 Respiratory Protection

The National Institute for Occupational Safety and Health (NIOSH) has examined the criteria for respirator tests and sources of respirator leakage and recommends that positive pressure, either supplied-air or self-contained personal breathing apparatus, as appropriate, with a full face piece be worn by anyone exposed to atmosphere containing hydrogen sulfide concentrations above OSHA's Acceptable Ceiling Concentrations. Refer to 6.5 for proper breathing equipment recommendations for oil and gas well servicing and workover

APPENDIX B—PHYSICAL PROPERTIES AND PHYSIOLOGICAL EFFECTS OF SULFUR DIOXIDE

B.1 Physical Data

Table B-1—Sulfur Dioxide

Chemical Name:	Sulfur Dioxide.
CAS Number:	7446-09-05.
Synonyms:	Sulfurous acid anhydride, sulfurous oxide, sulfuroxide
Chemical Family:	Inorganic
Chemical Formula:	SO_2.
Normal Physical State:	Colorless gas normally heavier than air
Boiling Point:	14° F (-10.0° C).
Flammable Limits:	Non-flammable (produced from burning hydrogen sulfide).
Solubility:	Readily soluble in water and oil; solubility decreases as the fluid temperature increases.
Odor and Warning Properties:	Sulfur dioxide has a pungent odor associated with burning sulfur. It produces a suffocating effect and produces sulfurous acid on membranes of the nose and throat.

B.2 Exposure Limits

The Occupational Safety and Health Administration (OSHA) has established a permissible exposure limit (PEL) of 5 ppm as an 8-hour TWA for sulfur dioxide. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends 2 ppm as an eight-hour TWA Threshold Limit Value (TLV)®[19] and 5 ppm as a STEL averaged over 15 minutes for sulfur dioxide. CHECK WITH THE EMPLOYER CONCERNING EXPOSURE LIMITS FOR PARTICULAR CIRCUMSTANCES.

B.3 Physiological Effects

B.3.1 ACUTE TOXICITY

INHALATION AT CERTAIN CONCENTRATIONS CAN LEAD TO INJURY OR DEATH. Exposure to concentrations below 20 ppm can cause eye irritation, throat irritation, respiratory tract irritation, chest constriction, and some nausea. Exposure to concentrations above 20 ppm can result in marked coughing, sneezing, eye irritation, and chest constriction. Exposure to 50 ppm causes irritation to the nose and throat, running nose, coughing, reflex broncho-constriction with possible increase in bronchial mucous secretion, and increased pulmonary resistance to air flow (breathing congestion) occurs promptly. This atmosphere (50 ppm or more) will not be tolerated by most persons for more than 15 minutes. Some reported acute reactions of exposure to high concentrations include, but are not limited to, inflammation of the eyes, nausea, vomiting, abdominal pain, and sore throat. These symptoms are sometimes followed by bronchitis, pneumonia, and/or complaints of weakness for a period of weeks.

B.3.2 CHRONIC TOXICITY

It has been reported that prolonged exposures to sulfur dioxide may lead to increased risk of chronic nasopharyngitis, alteration in sense of smell and taste, shortness of breath on exertion, and a higher frequency of respiratory tract infections compared to unexposed persons. It has also been postulated that sulfur dioxide in the work environment "possibly enhances" the suspected carcinogenic (cancer) effect of arsenic or other cancer agents[20]. No definite evidence is available regarding co-carcinogenesis or promotion of cancer by sulfur dioxide exposure. A few persons apparently have or develop a hypersusceptibility to sulfur dioxide. Decrements in pulmonary function tests have been noted after both acute and chronic exposures.

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[19] "TLV" is a trademarked term of the American Conference of Governmental Industrial Hygienists (ACGIH). Refer to *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices* and companion documents available from ACGIH, 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240 (check latest edition).

[20] *Criteria for a Recommended Standard for Occupational Exposure to Sulfur Dioxide*, NIOSH, 1974, p. 26. Refer also to the 1977 edition.

B.3.3 EXPOSURE RISKS

It is not yet clear what concentrations of low level exposure or lengths of exposure increase the risks, nor by how much the risks are increased. Sulfur dioxide exposures should be minimized. Smoking by persons exposed to sulfur dioxide should be strongly discouraged.

Note: Any preexisting chronic respiratory impairment must be considered in regard to job placement since these conditions can be aggravated by exposure to sulfur dioxide.

B.4 Respiratory Protection

The National Institute for Occupational Safety and Health (NIOSH) has examined the criteria for respirator tests and sources of respirator leakage and recommends that positive pressure, either supplied air or self-contained personal breathing apparatus, as appropriate, with a full face piece be worn by anyone exposed to atmosphere containing sulfur dioxide concentrations above OSHA's permissible exposure limit (PEL). Refer to 6.5 for proper breathing equipment recommendations for oil and gas well servicing and workover operations involving sulfur dioxide.

APPENDIX C—A SCREENING APPROACH TO DISPERSION OF HYDROGEN SULFIDE

Note: The exposure radii shown in Figures C-1 through C-4 represent estimates developed by API's Air Modeling Task Force (AQ7) using simple screening models and modeling techniques. These models should be reasonably accurate for low velocity releases of neutrally-buoyant mixtures of hydrogen sulfide and carrier gas. Figures C-1 through C-4 are useful as a conservative screening tool for high velocity releases and for light hydrogen sulfide carrier gas mixtures. Figures C-1 through C-4 are not recommended for low velocity releases of heavier-than-air hydrogen sulfide/carrier gas mixtures or of potential aerosol-generating mixtures, since these illustrations sometimes will underpredict exposure radii for these mixtures. Site specific conditions should be assessed to determine the need for additional, more rigorous modeling techniques. Users should evaluate their operations and select proper modeling applications for their specific emergency planning purposes.

C.1 Introduction

The material presented in Appendix C is generic in nature and is intended for emergency response planning purposes to arrive at conservative hydrogen sulfide dispersion estimates. Figures C-1 through C-4 present the screening-level, model-predicted radius of exposure (ROE) for atmospheric concentrations of hydrogen sulfide at 10, 30, 100, 300, and 500 ppm for both continuous and puff (instantaneous) releases of pure hydrogen sulfide. The ROE represents the distance from the emission source to the concentration of interest measured along the plume's centerline at ground level. Equations were developed for predicting the ROE as a function of the quantity/rate of hydrogen sulfide released for each of the hydrogen sulfide concentrations modeled and the type of release (continuous and puff). The equations and corresponding coefficients are presented in Par. C.8 and Table C-1. Meteorological conditions typical of worst-case daytime and nighttime conditions were modeled.

Various regulations dealing with hydrogen sulfide operations prescribe a method(s) or technique(s) for ROE predictions. Such methods must be taken into account because specific compliance actions may require use of a method(s) specified by the regulation, unless use of other methods is allowed.

C.2 Methodology

The ROEs shown in Figures C-1, C-2, C-3, and C-4 were predicted using standard EPA-approved modeling procedures based on Gaussian dispersion theory. The ROEs shown in Figures C-1 and C-2 were predicted by modeling a continuous, steady-state point source release of 100 percent hydrogen sulfide. The ROEs shown in Figures C-3 and C-4 were predicted by modeling an instantaneous hydrogen sulfide release. Both hydrogen sulfide release types were modeled as releases of a neutrally buoyant material under steady-state meteorological conditions. An effective plume height (release height plus plume rise) of 10 feet was used in all the modeling work. It was assumed that the predicted ROEs do not vary significantly with effective plume height in the range of 0-50 feet.

Table C-1—Linear Regression Coefficients for Mathematical Predictions of ROE as a Function of Downwind Hydrogen Sulfide Concentration and Release Quantity/Rate

Time	Type of Release	Concentration, ppm	Coefficients	
			A	B
Day	Continuous	10	0.61	0.84
Day	Continuous	30	0.62	0.59
Day	Continuous	100	0.58	0.45
Day	Continuous	300	0.64	-0.08
Day	Continuous	500	0.64	-0.23
Night	Continuous	10	0.68	1.22
Night	Continuous	30	0.67	1.02
Night	Continuous	100	0.66	0.69
Night	Continuous	300	0.65	0.46
Night	Continuous	500	0.64	032
Day	Puff	10	039	2.23
Day	Puff	30	039	2.10
Day	Puff	100	039	1.91
Day	Puff	300	039	1.70
Day	Puff	500	0.40	1.61

Table C-1—Linear Regression Coefficients for Mathematical Predictions of ROE as a Function of Downwind Hydrogen Sulfide Concentration and Release Quantity/Rate (Continued)

Time	Type of Release	Concentration, ppm	Coefficients A	Coefficients B
Night	Puff	10	039	2.77
Night	Puff	30	039	2.60
Night	Puff	100	0.40	2.40
Night	Puff	300	0.40	2.20
Night	Puff	500	0.41	2.09

Notes:
1. Day Meteorological Conditions: Stability Class PG D (Neutm 1) 1 mph Wind Speed.
2. Night Meteorological Conditions: Stability Class PG F (Stable) 2.2 mph Wind Speed.

For the purposes of dispersion modeling, the amount of turbulence in the ambient air is categorized into defined increments or stability classes. The most widely used categories are the Pasquill-Gifford (PG) Stability Classes A, B, C, D, E, and F (Pasquill, F., *Atmospheric Diffusion*, Second Edition, John Wiley & Sons, New York, New York, 1974). PG Stability Class A denotes the most unstable (most turbulent) air conditions and PG Stability Class F denotes the most stable (least turbulent) air conditions. PG Stability Class D denotes neutral atmospheric conditions where the ambient temperature gradient is essentially the same as the adiabatic lapse rate. Under neutral conditions, rising or sinking air parcels cool or heat at the same rate as the ambient air, resulting in no enhancement or suppression of vertical air motion.

Standard Pasquill-Gifford (PG) dispersion coefficients for flat, open grassland were used in the continuous hydrogen sulfide release model. The Slade (refer to NTIS-TID 24190: Slade, D.H., *Meteorology and Atomic Energy*, 1968) dispersion coefficients for flat, open grassland were used in the puff (instantaneous) release model. When modeling instantaneous hydrogen sulfide releases it was assumed that the downwind (x) and the crosswind (y) dispersion coefficients were equivalent. This assumption results in conservative (worst case) estimates of the ROEs. The following meteorological conditions were assumed to be representative of worst case daytime and nighttime conditions. For continuous daytime releases a neutral Stability Class (PG D) and 5 mile per hour wind speed were chosen. For continuous nighttime releases, a stable Stability Class (PG F) and a 2.2 mile per hour wind speed were chosen. For instantaneous (puff) daytime releases, a slightly unstable Stability Class (Slade A) and a 5 mile per hour wind speed were chosen. For instantaneous nighttime releases, a neutral-to-stable Stability Class (Slade B) and a 2.2 mile per hour wind speed were chosen.

The ROEs for continuous hydrogen sulfide releases at 30, 100, 300, and 500 ppm are valid for averaging times of 10 minutes to 1 hour. The ROEs shown for 10 ppm (continuous hydrogen sulfide release) are based on an 8-hour average concentration, since 10 ppm represents the 8-hour time weighted average (TWA) for hydrogen sulfide. To obtain the 8-hour 10 ppm average concentration a factor of 0.7 was used to convert the 1-hour concentrations (refer to EPA-450/4-88-009): *A Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants*). The ROEs for the puff (instantaneous) hydrogen sulfide releases at 30, 100, 300, and 500 ppm are valid for averaging times of 1 to 10 minutes. EPA's 0.7 conversion factor was used to obtain the 10 minute 0 ppm time averaged concentrations from instantaneous peak concentrations predicted by the model. For continuous releases, the EPA considers 10-minute and 1-hour averaging times to be equivalent. The modeling reported herein assumed that an instantaneous release would be of a very short duration (10 to 15 minutes maximum).

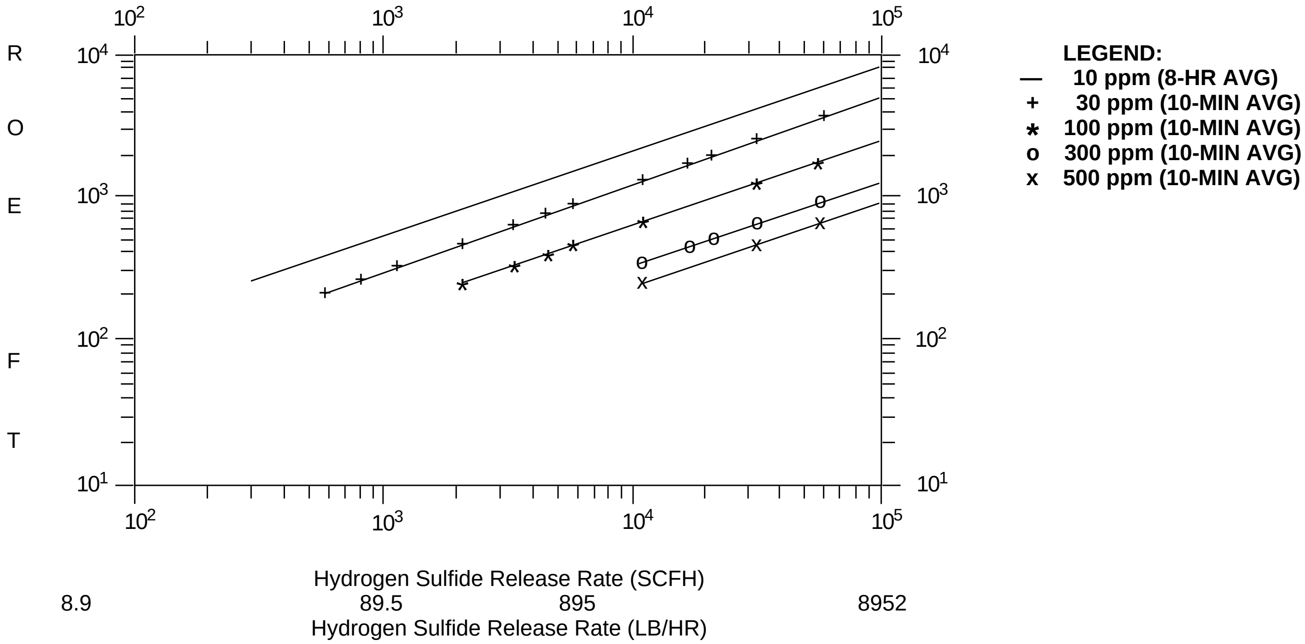


Figure C-1—Radius of Hydrogen Sulfide Exposure, Continuous Daytime Hydrogen Sulfide Releases [PG D (Neutral)—5 MPH Wind Speed]

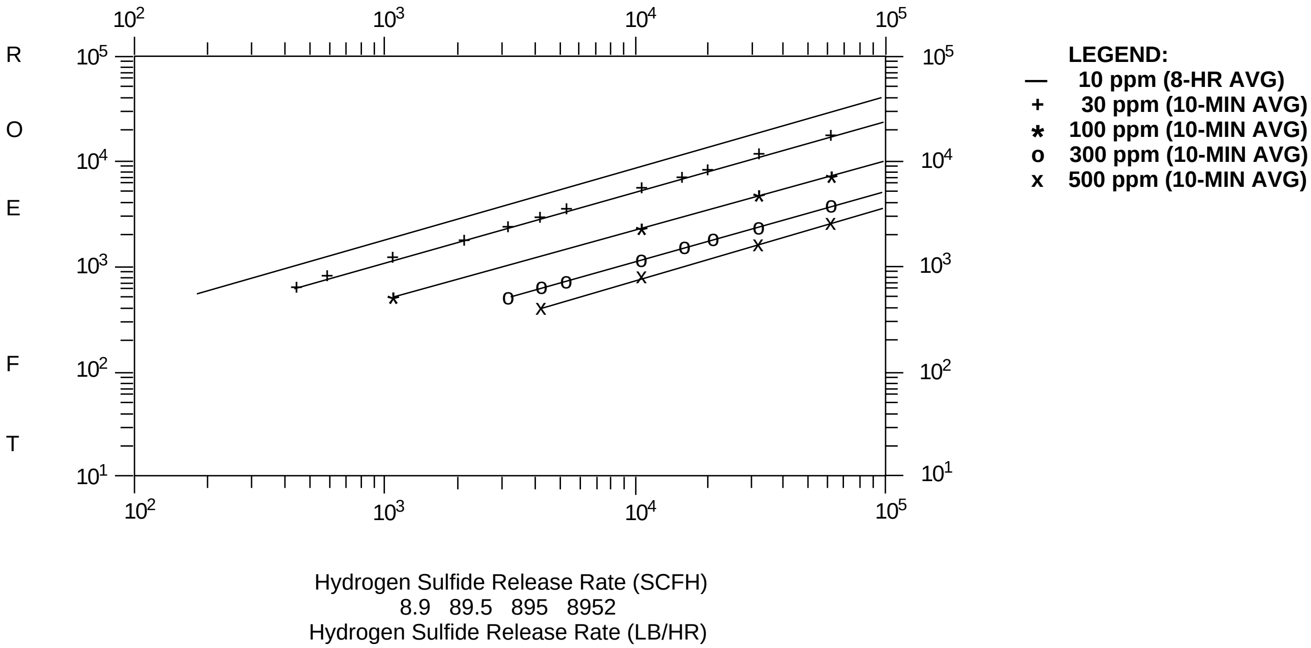


Figure C-2—Radius of Hydrogen Sulfide Exposure, Continuous Nighttime Hydrogen Sulfide Releases [PG F (Stable)—2.2 MPH Wind Speed]

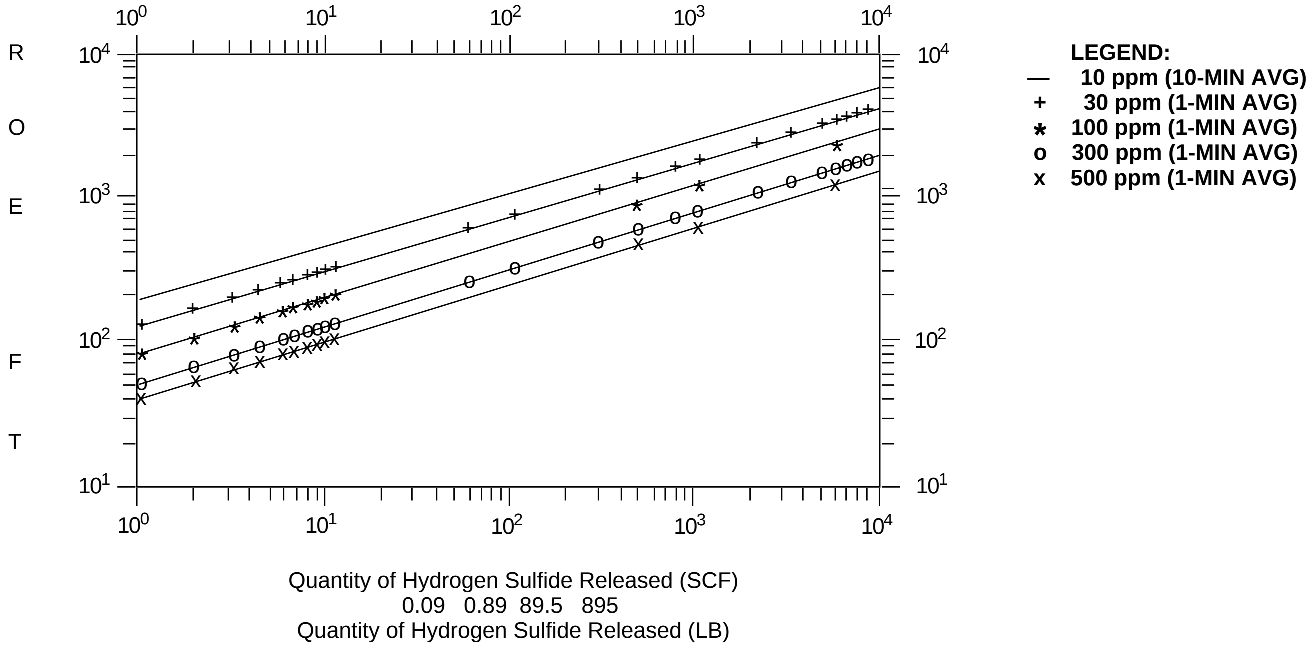


Figure C-3—Radius of Hydrogen Sulfide Exposure,
Instantaneous Daytime Hydrogen Sulfide Releases [Slade A (Slightly Unstable)—5 MPH Wind Speed]

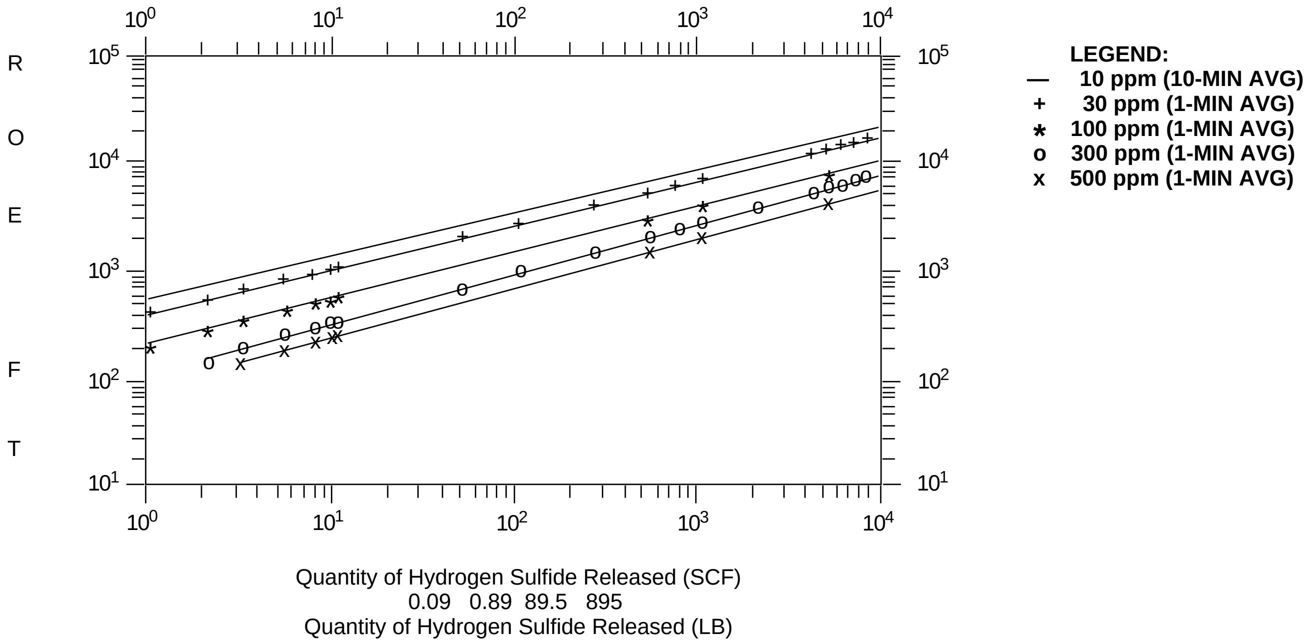


Figure C-4—Radius of Hydrogen Sulfide Exposure,
Instantaneous Nighttime Hydrogen Sulfide Releases [Slade B (Neutral)—2.2 MPH Wind Speed]

Brief descriptions of the models used to predict the ROEs for both continuous and puff (instantaneous) hydrogen sulfide releases are presented in Par. C.13.

C.3 Results

ROEs for atmospheric plume-centerline, ground-level concentrations of hydrogen sulfide resulting from instantaneous and continuous hydrogen sulfide releases were predicted and are presented in Figures C-1 through C-4. Figures C-1 and C-2 present the predicted ROEs for continuous hydrogen sulfide releases during worst case daytime and nighttime meteorological conditions, respectively. Figures C-3 and C-4 present the predicted ROEs for instantaneous hydrogen sulfide releases during worst case daytime and nighttime meteorological conditions, respectively. The ROEs for concentrations of 10, 30, 100, 300, and 500 ppm were modeled for both release types. The 10 ppm concentration ROEs represent an 8-hour averaging time for the continuous hydrogen sulfide release and a 1-minute averaging time for the instantaneous release. The 30, 100, 300, and 500 ppm concentration ROEs represent a 10-minute averaging time for the continuous hydrogen sulfide release and a 1-minute averaging time for the instantaneous release. A hydrogen sulfide release rate range of 10 to 10,000 lb/hr (111.8 to 111,768 SCFH) was modeled for the continuous type release. For the puff (instantaneous) type hydrogen sulfide release, a release quantity range of 0.1 to 1,000 pounds (1.1 to 11,177 SCF) was modeled. If the hydrogen sulfide release is based on pounds, standard cubic feet (SCF) can be obtained by multiplying pounds by a factor of 11.2.

Note: The ROEs presented in Figures C-1 through C-4 are plotted against the amount of hydrogen sulfide released. For the release of a multi-component gas stream, the actual amount of hydrogen sulfide released should be used to determine the ROE.

Equation coefficients based on linear regression for predicting the ROE as a function of the release type (continuous/puff) and quantity/rate of hydrogen sulfide released for both daytime and nighttime meteorological conditions are presented in Table C-1. The equation is given in Par. C.8. The coefficients are applicable only over the ranges presented in Figures C-1 through C-4, and extrapolation could result in overly conservative estimates of the ROEs. Any release lasting significantly longer than 15 minutes should be interpreted as a continuous release. The modeling work presented in Appendix C assumes steady-state meteorological conditions. ROEs predicted for a long averaging time (8-hour) and long downwind distances are conservative because it is unlikely that the same meteorological conditions will persist during that time period.

C.4 Additional Considerations

The modeling work presented in Appendix C assumes a neutrally buoyant, gaseous hydrogen sulfide release in flat, rural terrain under steady-state meteorological conditions. Also, the ROEs shown in Figures C-1 through C-4 are for a generic class of hydrogen sulfide releases covering a wide range of site and release conditions. Actual ROEs will be dependent on the specifics of the type of release, release conditions, and release site. For instance, the ROEs for a release in a more urban setting where structures, buildings, etc., are present will be reduced significantly due to structure-induced turbulence. Some other conditions that could significantly affect the actual ROE include: a liquid/aerosol release, dense cloud behavior, a buoyant cloud (plume liftoff, jet release), time-dependent release (well blowout, pipeline ruptures, etc.), and complex terrain. If any of these phenomena are present, then more rigorous modeling may be necessary.

The ROE curves of Figures C-1 through C-4 should not be used when the mixture of hydrogen sulfide and carrier gas being dispersed is significantly heavier than air and the mixture is released at a low velocity. If the hydrogen sulfide/carrier gas mixture specific gravity exceeds approximately 1.2, Figures C-1 through C-4 may not give conservative ROEs for all release rates and meteorological conditions. Hydrogen sulfide, as encountered in the petroleum industry, is usually a minor constituent of carrier gas, such as natural gas or carbon dioxide. Carbon dioxide has a specific gravity of 1.52. Dispersion predictions for hydrogen sulfide/carbon dioxide mixtures, using a dense gas model sometimes underpredict hydrogen sulfide ROEs for low velocity gas releases. Low velocity gas releases would include those with initial velocities less than 200 feet/second and releases greater than 200 feet/second involve impact of the gas jet from the leak with a nearby surface, thereby breaking the jet's momentum. Likewise, Figures C-1 through C-4 should not be used with any hydrogen sulfide/carrier gas release that potentially could form an aerosol.

Figures C-1 through C-4 can also substantially overpredict ROEs. In the case of hydrogen sulfide/carrier gas mixtures significantly lighter than air (i.e., specific gravity less than 0.8) released at low velocity, use of these illustrations may overpredict ROEs by a factor of 2 to 3. Use of these illustrations can result in overestimation of ROEs for high velocity hydrogen sulfide/carrier gas releases (i.e., gas release velocities greater than 200 feet/second) regardless of the orientation of the release. However, this overprediction is particularly significant in the case of vertical, high-velocity releases. In such situations, the overprediction can be two orders of magnitude. The user should consult more rigorous atmospheric dispersion models.

When calculating the ROE for dilute concentrations of hazardous gases, a significant overestimation can result. For example, it would not be practical to expect higher downwind atmospheric concentrations than are present in the released gas stream. The user should consult more rigorous atmospheric dispersion models.

In summary, the composition of the hydrogen sulfide/carrier gas and the velocity and orientation of the release are critical variables, dramatically affecting predicted hydrogen sulfide ROEs. Also, other variables, such as released gas temperature and flashing or aerosol formation involving liquid containing dissolved hydrogen sulfide, can have significant impacts on ROE predictions. Accurate atmospheric dispersion techniques are, of necessity, complex. Under some circumstances, such as those mentioned above, more rigorous modeling may be required.

References and models are available to address special release scenarios. A partial list of models that may be used in such cases is shown in Pars. C.5 and C.6. API does not endorse any one particular model. Further guidance on appropriate model selection and application can be obtained from the model developers as well as other individuals experienced in this field. A specific reference to address well blowout and pipeline ruptures is “Release and Dispersion of Gas from Pipe Line Ruptures,” Wilson, D.J., Department of Mechanical Engineering, University of Alberta, Edmonton, Canada.

In the event that hydrogen sulfide release quantities calculated by the user are below the ranges shown in Figures C-1 through C-4, extensions of the ROE curves are allowed to a minimum ROE of 50 feet. In some cases, ROEs of less than 50 feet may be inferred from extrapolation of the curves. Figures C-1 through C-4 were developed using an assumed release height plus plume rise of 10 feet. Actual release heights of other than 10 feet will result in different ROEs.

C.5 Proprietary Dispersion Models

Note: Users should carefully evaluate applicability of these models to prevailing conditions.

A list of some proprietary models that can be used to address special site-specific scenarios follows:

CHARM (Radian Corporation): CHARM is a Gaussian puff model for continuous and instantaneous releases of gases or liquids. The model is configured to handle chemicals that are buoyant, neutrally buoyant, and heavier than air. Heavy gas dispersion is estimated using the Eidsvik model. Source components in the model include a modified version of Shell Oil Company’s SPILLS model. (Radian Corp., 850 MOPAC Blvd., Austin, TX 78759.)

FOCUS (Quest Consultants, Inc.): FOCUS is a modeling package that includes both emission rate models (two-phase discharges, pool evaporation, jet vapor releases, etc.) and dispersion models for both neutrally-buoyant and dense-gas plumes. The models can be run separately or in a linked mode. (Quest Consultants, Inc., 908 26th Avenue, NW, Suite 103, Norman, OK 73069-6216.)

TRACE (Dupont): TRACE uses a multiple Lagrangian Wall dispersion model to handle both puff and continuous releases. Wind channeling can be incorporated. Liquid evaporation and buoyancy effects are considered also. (E.I. Dupont de Nemours & Company, 5700 Corea Avenue, Westlake Village, CA 91362.)

WHAZAN (Technica International): WHAZAN is a package of dispersion models for both neutrally buoyant and dense-gas plumes. Submodels are included to handle two-phase discharges, evaporation, and vapor dispersion as a free jet. The model can be run both individually and in a linked mode. (Technica International Associates, Inc., Box 187, Woodstock, GA 30128-4420.)

C.6 Publicly Available Models

Note: Users should carefully evaluate applicability of these models to prevailing conditions.

A list of some publicly available models that can be used to address special site-specific scenarios follows:

DEGADIS (U.S. Coast Guard): DEGADIS, the Dense Gas Dispersion Model, is designed to simulate dispersion of heavier-than-air gas releases. It can handle both evaporative emissions from liquid spills and jet emissions. It is basically steady-state but simulates transient conditions by a series of steady-state calculations. Vapor generation rate, spill area, and meteorological parameters are important inputs to the model. Information available through National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161.

HEGADAS (Shell Research B.V.): HEGADAS is a dispersion model for neutrally-buoyant and dense gases. The basic model components are solutions to the advection/diffusion equations and are in the standard form of Gaussian dispersion models. The model can handle a wide variety of source types, including transient horizontal jets. Information available through National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161.

SLAB (Lawrence Livermore National Laboratory): SLAB is designed for application to dense gases that are emitted from liquid spills. The model considers the concentration integrated over a cross-section perpendicular to the plume centerline. The downwind variation of the integrated concentration is calculated. The size and emission rate of the liquid spill are required inputs to the model. Information available through Lawrence Livermore National Laboratory, Box 808, Livermore, CA 94550, or contact American Petroleum Institute, Health & Environmental Sciences Department, 1220 L Street, NW, Washington, DC 20005.

C.7 Sample Calculations for Figures C-1 through C-4

The following calculations may be used to estimate volume and mass of hydrogen sulfide when total gas volume and its hydrogen sulfide content are known:

Continuous Release.

Assume: Release 5,000,000 SCFD of natural gas containing 8,000 ppm (by volume) of hydrogen sulfide.

Note: The user must know both the volume (or flow rate) of natural gas and its hydrogen sulfide concentration so that Figures C-1 through C-4 can be effectively used.

To determine standard cubic feet per hour (SCFH) of hydrogen sulfide released, the following calculations should be performed using appropriate values for the conditions being evaluated:

$$\frac{\text{5,000,000 SCFD x 8,000 ppm } H_2S}{\text{24,000,000}}$$

$$\text{– 1,667 SCFH of } H_2S \text{ released}$$

To determine the pounds of hydrogen sulfide released per hour, the following calculations should be performed using appropriate values for the conditions being evaluated:

$$\frac{\text{5,000,000 SCFD x 8,000 ppm } H_2S}{\text{267,605,634}}$$

$$\text{– 150 lb/hr of } H_2S \text{ released}$$

Instantaneous Release.

Assume: Release of 100,000 SCF of natural gas containing 8,000 ppm (by volume) of hydrogen sulfide. Also, assume this example is a daytime release, 5 miles per hour wind speed (refer to Figure C-3).

To determine the volume (SCF) of hydrogen sulfide released the following calculations should be performed using appropriate values for the conditions being evaluated:

$$\frac{\text{100,000 SCF x 8,000 ppm } H_2S}{\text{1,000,000}}$$

$$\text{– 800 SCF of } H_2S \text{ released}$$

After applying the appropriate calculations and using known factors to arrive at either hydrogen sulfide release rate or quantity of hydrogen sulfide released, refer to the appropriate chart (Figures C-1 through C-4) or the equation in Par. C.8 (example calculations in Pars. C.9 through C.12) for obtaining radius of exposure (ROE) information.

The following equation can be used to convert percent hydrogen sulfide to parts per million on a volume basis:

$$\text{Percent } H_2S \text{ x 10,000 = ppm } H_2S$$

Table C-1, the coefficients applicable to this scenarios are: A = 0.40; B = 2.40. Using the equation in Par. C.8:

C.8 Radius of Exposure (ROE) Calculation

Using the values of coefficients “A” and “B” in Table C-1, the radius of exposure (ROE) for various hydrogen sulfide release rates (H_2S) can be mathematically predicted using the following equation:

$$\text{ROE = Antilog [A x log } (H_2S) \text{ + B]}$$

For a continuous release, enter the hydrogen sulfide release rate (H_2S) in standard cubic feet per hour (SCFH). For a puff (instantaneous) release, enter the quantity of hydrogen sulfide (H_2S) released in standard cubic feet (SCF).

C.9 Sample Calculation—Continuous Release (Daylight)

Determine the ROE_{100ppm} for a continuous release of 100 percent hydrogen sulfide gas at a rate of 11,170 SCFH in daylight (RG D stability) conditions and 5 mph wind speed. Using Table C-1, the coefficients applicable to this scenario are: A = 0.58; B = 0.45. Using the equation in Par. C.8:

$$\text{ROE}_{100ppm} \text{ = Antilog [0.58 x log (11,170) + 0.45] = 628 feet}$$

C.10 Sample Calculation—Continuous Release (Nighttime)

Determine the ROE for a continuous release of 100 percent hydrogen sulfide gas at a rate of 11,170 SCFH in nighttime (PG F stability) conditions and 2.2 mph wind speed. Using Table C-1, the coefficients applicable to this scenarios are: A = 0.66; B = 0.69. Using the equation in Par. C.8:

$$\text{ROE}_{100ppm} \text{ = Antilog [0.66 x log (11,170) + 0.69]}$$

$$\text{= 2,300 feet}$$

C.11 Sample Calculation—Instantaneous Release (Daylight)

Determine the ROE_{100ppm} for an instantaneous release of 100 percent hydrogen sulfide gas of 1,117 SCF in daylight (Slade A stability) conditions and 5 mph wind speed. Using Table C-1, the coefficients applicable to this scenarios are: A = 0.39; B = 1.91. Using the equation in Par. C.8:

$$\text{ROE}_{100ppm} \text{ = Antilog [0.39 x log (1,117) + 1.91]}$$

$$\text{= 1,255 feet}$$

C.12 Sample Calculation—Instantaneous Release (Nighttime)

Determine the ROE_{100ppm} for an instantaneous release of 100 percent hydrogen sulfide gas of 1,117 SCF in nighttime (Slade B stability) conditions and 2.2 mph wind speed. From

$$\text{ROE}_{100ppm} \text{ = Antilog [0.40 x log (1,117) + 2.40]}$$

$$\text{= 4,161 feet}$$

C.13 Descriptions of Gaussian and Puff Dispersion Models

C.13.1 INTRODUCTION

The emergency response Gaussian and Puff screening models are designed to predict the downwind dispersion (plume-centerline, ground-level concentration and maximum ground-level plume width as a function of downwind distance) of a neutrally buoyant, steady-state point source gaseous release under steady-state meteorological conditions. Classical EPA-approved Gaussian dispersion theory is applied in the models. The programs are in BASIC and are designed for use on personal computers. The models are described below. The program listings and runs should use the IDLH, ERPG-2, and TLV and STEL levels as the concentrations of interest because they usually are the concentration values of concern. Both models can be run for other concentrations by substituting the values of interest in place of the values for IDLH, ERPG-2, and TLV and STEL in the computer programs. Copies of the example program listings and computer runs are available on request from American Petroleum Institute, Exploration & Production Department, 1220 L St., NW, Washington, DC 20005.

C.13.2 GAUSSIAN MODEL

This model calculates the plume-centerline, ground-level concentration, and maximum ground-level plume width for a single, steady-state, continuous-point release at user-specified steady-state meteorological conditions and downwind distances. The model uses standard Gaussian dispersion modeling with Pasquill-Gifford dispersion coefficients. The user inputs the release rate, effective release height (release height plus plume rise), nominal wind speed, incremental downwind distance for which calculations are to be made, type of material released, and the stability class. A total of eight compounds are currently accepted by this model. Additional compounds can be entered by replacing compounds presently in the model. The model uses a default D Stability Class, but can be run with any of the standard Pasquill-Gifford Stability Classes (A, B, C, D, E, or F - with A being the most unstable and F being the most stable).

C.13.3 PUFF MODEL

This model calculates the plume-centerline, ground-level concentration, and maximum ground-level plume width for a single, instantaneous-point release at user-specified steady-state meteorological conditions and downwind distances. The modes uses standard Gaussian dispersion theory for an instantaneous (puff) release with Slade dispersion coefficients. User inputs to the model are the same as those used in the Gaussian model except that the total amount of material released is entered rather than the rate of release. Three values are accepted for the Stability Class (A, B, or C—with A being unstable, B being neutral, and C being stable).

APPENDIX D—DEFINITION OF A SOUR ENVIRONMENT

D.1 Sour Environments

Sour environments [21] are defined as fluids containing water as a liquid and hydrogen sulfide exceeding the limits defined in Pars. D.1.1.1 and D. 1.1.2; these environments may cause sulfide stress cracking (SSC) of susceptible materials.

CAUTION: It should be noted that highly susceptible materials may fail in less severe environments. The SSC phenomenon is affected by complex interactions of parameters including:

a. chemical composition, strength, heat treatment, and microstructure of the material;
b. hydrogen ion concentration (pH) of the environment;
c. hydrogen sulfide concentration and total pressure;
d. total tensile stress (applied plus residual);
e. temperature; and
f. time.

The user shall determine whether the environmental conditions fall within the scope of this standard. (*Editorial Comment:* The critical hydrogen levels in D.1.1.1 and D.1.1.2 and Figures D-1 and D-2 were developed from data derived from low alloy steel.)

D.1.0.1 Sour Gas

Materials shall be selected to be resistant to SSC or the environment should be controlled if the gas being handled is at a total pressure of 0.4 MPa (65 psia) or greater and if the partial pressure of hydrogen sulfide in the gas is greater than 0.0003 MPa (0.05 psia). Systems operating below 0.4 MPa (65 psia) total pressure or below 0.0003 MPa (0.05 psia) hydrogen sulfide partial pressure are outside the scope of this standard. Partial pressure is determined by multiplying the mole fraction (mol % + 100) of hydrogen sulfide in the gas by the system pressure. Figure D-1 provides a convenient method for determining whether the partial pressure of hydrogen sulfide in a sour environment exceeds 0.0003 MPa (0.05 psia). A few examples are provided:

a. partial pressure of hydrogen sulfide in a system containing 0.01 mol % hydrogen sulfide (100 ppm or 6.7 grains per 100 standard cubic feet [SCF]) at a total pressure of 7 MPa (1,000 psia) exceeds 0.0003 MPa (0.05 psia) (Point A on Figure D-1).
b. partial pressure of hydrogen sulfide in a system containing 0.005 mol % hydrogen sulfide (50 ppm or 3.3 grains per 100 SCF) at a total pressure of 1.4 MPa (200 psia) does not exceed 0.0003 MPa (0.05 psia) (Point B on Figure D-1).

D.1.0.2 Sour Oil and Multiphases

Sour crude oil systems that have operated satisfactorily using standard equipment are outside the scope of this standard when the fluids being handled are either crude oil, or two- or three-phase crude, water, and gas when:

a. the maximum gas:oil ratio is bbl (barrel of oil);

b. the gas phase contains a maximum of 15% hydrogen sulfide;

c. the partial pressure of hydrogen sulfide in the gas phases is a maximum of 0.07 MPa (10 psia);

d. the surface operating pressure is a maximum of 1.8 MPa (265 psia) (see Figure D-2); and

e. when pressure exceeds 1.8 MPa (265 psia), refer back to D.1.1.1.

The satisfactory service of the standard equipment in these low-pressure systems is believed to be a result of the inhibitive effect of the oil and the low stresses encountered under the low-pressure conditions.

---

[21] Reprinted from NACE Standard MRO175-94, *Standard Material Requirements Stress Cracking Resistant Metallic Materials for Oilfield Equipment.*

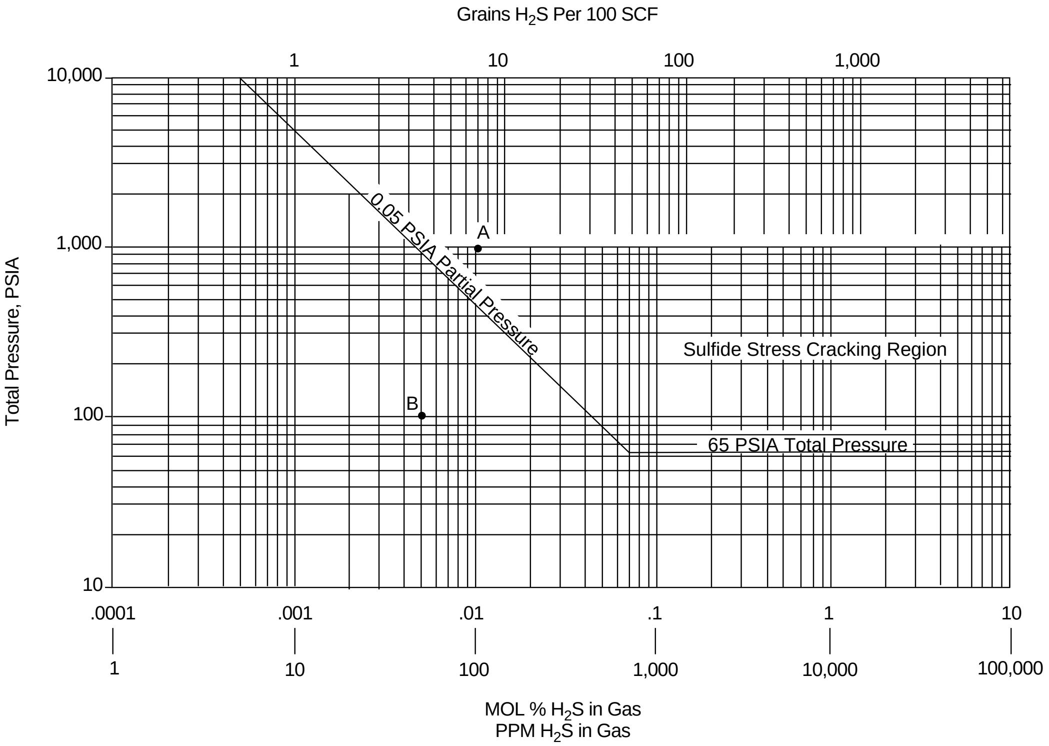
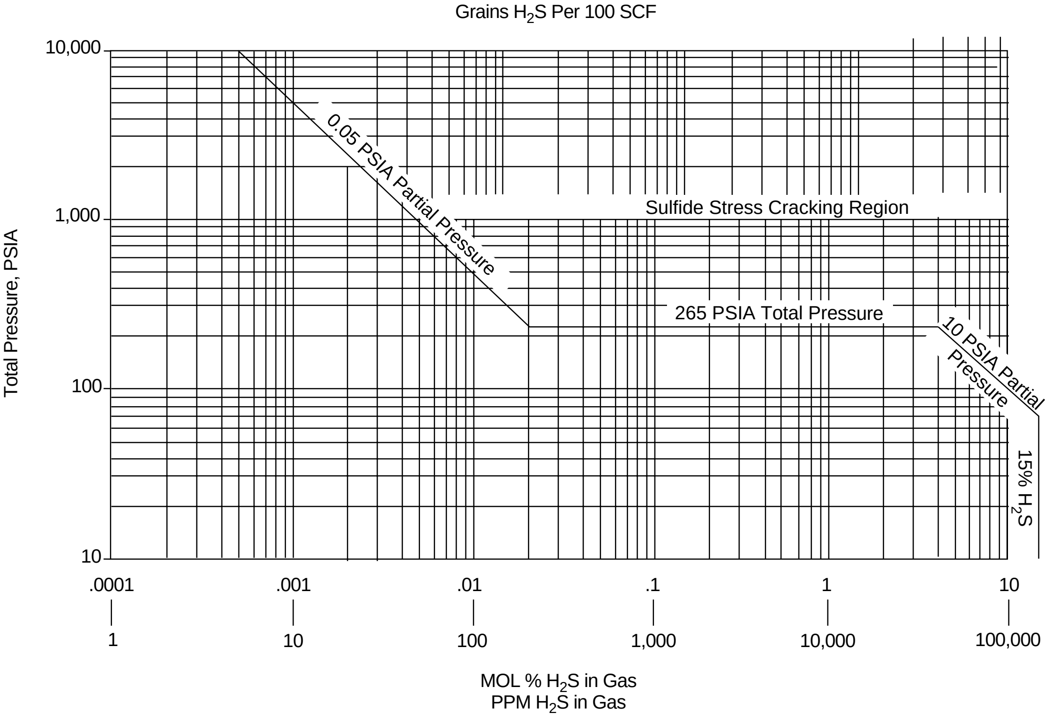


Figure D-1*—Sour Gas Systems (Refer to Par. D.1.1.1)



Metric Conversion Factor: 1 MPa = 145.089 psia

Figure D-2*—Sour Multiphase Systems (Refer to Par. D.1.1.2)

APPENDIX E—GUIDELINES FOR EVALUATION AND SELECTION OF CONTINUOUS HYDROGEN SULFIDE MONITORING EQUIPMENT

E.1 Introduction

Appendix E information is provided to make users of hydrogen sulfide monitoring equipment aware of some equipment limitations and certain desirable features of such equipment. There are a number of detection principles and analytical procedures available for monitoring the concentration of hydrogen sulfide in ambient air where the potential exists for exposure to levels that may be hazardous to health. These guidelines are intended to aid in the selection and application of continuous monitoring equipment for use in well servicing/workover operations involving hydrogen sulfide. The term "continuous hydrogen sulfide monitoring equipment" as used herein is defined as equipment capable of continuously measuring and displaying the concentration of hydrogen sulfide in ambient air. Appendix E is not applicable to personnel monitoring badges or length-of-stain or color-comparison type detector devices (refer to ANSI/ISEA 102).

E.2 General

All monitors, both portable and stationary, shall be designed on sound engineering and scientific principles and constructed of materials suitable for the application. Their design and construction should allow for ease of maintenance and repair. Instruments should be verified by a national recognized testing laboratory (NRTL) as meeting the minimum performance requirements of ISA-S12.15, Part I. Equipment should be installed, operated, and maintained in accordance with ISA-RP12.15, Part II.

It generally is recommended (and frequently required) that electrical controls for safety systems such as hydrogen sulfide monitoring equipment and other gas detector systems be installed normally energized ("fail-safe"). This means that power is supplied continuously during normal operations to devices which provide alarm(s) and corrective action if concentrations corresponding to specific alarm set points are reached. Under these conditions, interruption of power due to either deliberate safety device actuation or loss of power will initiate corrective action. It is desirable to provide a test means that will allow the system to be tested (and calibrated) without shutting in producing operations (or other corrective action), but it should be evident to operating personnel that the system is in the test (bypass) mode.

To better ensure proper application, it is recommended that an environmental and application checklist (similar to the example shown in Appendix 1, ISA-RP12.15, Part II) be provided to prospective vendors by the user.

E.3 Construction Characteristics

The following construction and usability characteristics are desirable for hydrogen sulfide monitoring equipment.

E.3.1 PORTABILITY

Portable monitors, including all required parts and accessories, should weigh a maximum of 10 pounds and have a maximum volume of 1 cubic foot.

E.3.2 POWER SUPPLY, PORTABLE MONITORING EQUIPMENT

Portable hydrogen sulfide monitoring equipment is defined as self-contained, battery-operated, carriable or transportable instruments capable of operating within specifications from integral batteries for a period of 8 hours minimum, including a 15-minute period of maximum load conditions (with alarms, lights, etc. activated), while exposed to clean air at a nominal temperature of 14°F (-10°C). Applications requiring in excess of 8 hours of continuous operation or operation at lower temperatures should be specified by the end user.

E.3.3 RECORDER OUTPUT

For certain applications, it may be desirable for monitors to provide an output signal (e.g., 4–20 ma) proportional to hydrogen sulfide concentration for use in connection with recorders or for other purposes.

E.3.4 SIMPLICITY OF OPERATION

Monitoring and detection equipment should be readily operable by personnel without scientific background or training in instrumentation.

E.3.5 INSTRUCTION MANUALS

An instruction manual should be provided by the manufacturer with each instrument. The instruction manual should contain complete operating instructions, including procedures for startup, warm-up time, zero checks, calibration, alarm setting and testing, preventive maintenance, performance checks, and trouble-shooting. Monitors with rechargeable power supplies should be furnished with instructions for charging, storing, and maintaining the power supply. Information also should be included regarding instrument recovery time after the exposure of sensor(s) to hydrogen sulfide. The manufacturer should provide response time data and a list of interfering, desensitizing, or contaminating substances or water vapor concentrations known to the instrument manufacturer which may adversely affect proper operation and performance of the instrument (refer to E.4.7). Instruction manuals should include wiring diagrams and estimates of the life expectancy of all consumables. The manual should include a complete parts list suitable for identification of all replaceable parts and sources for procurement of these parts.

E.3.6 ELECTRICAL APPROVAL

Any portion of a stationary hydrogen sulfide monitoring instrument intended for installation or use in a hazardous (classified) location and all portable monitoring instruments shall be approved for use in such a hazardous (classified) location and marked accordingly. Refer to NFPA 70, Article 500-3, FPN No. 2.

E.3.7 RUGGEDNESS

Portable monitoring units should be sufficiently rugged to withstand routine transporting, handling, and use in the field environment, as specified by the user. Refer to ISA-S12.15 for details of a recommended "drop test" to evaluate portable unit ruggedness and a "vibration test" to evaluate ruggedness of fixed and portable monitors.

E.3.8 CALIBRATION EQUIPMENT

All accessories required to calibrate the instruments should be made available by the manufacturer. The life expectancy and any special handling required of any hydrogen sulfide test concentrations should be provided by the supplier.

E.3.9 ZERO AND SPAN ADJUSTMENTS

Zero and span adjustment controls should be readily accessible for field adjustment, and the monitor design should include provisions to apply zero and calibration gases to the sensor(s) in a non-laboratory environment. All accessories for calibration and zero should be made available with the monitor and should be usable under field conditions.

E.3.10 ALARM SYSTEMS

Fixed monitors should have provisions for external alarms. Portable monitor units should contain integral audible, visual, or physical presentation (e.g., vibrator signal) alarms as specified by the user. Hydrogen sulfide alarms should be unique to the location.

E.3.11 TESTING ALARM CIRCUITRY

Provisions should be included for the testing of alarms and alarm outputs. The test procedure should be included in the equipment instruction manual.

E.3.12 REMOTE SAMPLING

A remote sampling accessory (such as a probe) may be desirable for use with a portable monitoring unit.

CAUTION: Optional probe attachments for portable monitoring units, which allow the user to manually draw samples from remote locations, inherently prevent continuous monitoring of the immediate local environment. Users should consult the manufacturer's instruction manual to determine the proper number of bulb strokes required to draw samples when non-continuous monitoring attachments are used. The remote sampling attachment should be removed after use to restore the instrument to the normal continuous monitoring mode.

E.3.13 EQUIPMENT TROUBLE (MALFUNCTION) ALARM

A trouble (malfunction) signal (indicator or output) should be provided for monitors.

E.3.14 DETECTION RANGE INDICATION

The range(s) of detection should be conspicuously marked on the instrument.

E.4 Performance Guidelines

The following recommended performance parameters are applicable to fixed and portable hydrogen sulfide monitoring equipment.

E.4.1 ACCURACY

Instruments should meet requirements of the accuracy test specified in ISA-S12.15, Part I. Users are cautioned that the class of instruments suitable for field use are not "laboratory-grade" instruments, and *an equivalent degree of precision should not be expected.*

E.4.2 ZERO DRIFT

Instruments should meet the requirements of the "Long-term Stability Test" specified in ISA-S12.15, Part I. Excessive zero drift is undesirable and can require instrument calibration at unreasonably short intervals.

E.4.3 WARM-UP TIME

The minimum warm-up time when power is first applied should be stated in the equipment instruction manual. A monitor ready-status indicator is a desirable feature.

E.4.4 RESPONSE TIME

ISA-S12.15, Part I specifies monitoring equipment minimum response time to input step changes. The toxicity of hydrogen sulfide requires that monitoring equipment have rapid response time to alert personnel of potentially dangerous concentrations. Hence, response time of monitoring equipment is an important parameter for consideration in evaluation and selection of such equipment.

E.4.5 OPERATING HUMIDITY RANGE

Monitoring equipment should meet the “Humidity Variation Test” specified in ISA-S12.15, Part I. Users should advise equipment manufacturers of the humidity ranges expected for specific equipment applications.

E.4.6 OPERATING TEMPERATURE RANGE

Monitoring equipment should be suitable for viable use in an ambient temperature range of 14°F to 122°F (-10°C to 50°C). Applications requiring equipment exposure to temperatures outside this range should be specified by the user.

E.4.7 INTERFERENCES

A list of interfering, desensitizing, and contaminating substances (e.g., carbon monoxide, sulfur dioxide, aromatic mercaptans, methanol, oxides of nitrogen, aldehydes, carbon sulfide, monoethanolamine, carbon dioxide, benzene, and methane) known by the manufacturer should be listed in the equipment instruction manual. Also, water vapor concentrations that may adversely affect proper equipment operation should be included in the instruction manual.

CAUTION: Monitoring and detector equipment and sensors should be protected from exposure to liquid spray or wash down. Such exposure can affect equipment performance and reliability.

E.4.8 FUNCTIONAL FIELD TEST

Functional field testing of monitoring equipment should be conducted under “as installed” or “as used” conditions. All instrument and system accessories normally used with this equipment should be installed and operated during functional field tests. Functional field tests may include, but are not limited to, exposing the sensor to a sample containing sufficient hydrogen sulfide to cause response of the system. Functional field testing *does not* necessarily include zero and span adjustments. The hydrogen sulfide concentration used in functional field testing of monitoring equipment should not exceed the maximum operating range of the equipment being tested.

E.4.9 AIR VELOCITY

Monitoring equipment should meet the “Air Velocity Variation Test” specified in ISA-S12.15, Part I. Accessories are often available and may be desirable for use with detector equipment installed in areas of high air velocity.

E.4.10 ELECTROMAGNETIC INTERFERENCE (EMI)

Some monitoring equipment may be susceptible to electromagnetic interference (EMI), particularly radio frequency interference (RFI). Caution should be taken when using monitoring equipment in close proximity to a radio transmitter or other EMI generators. Refer to ISA-S12.15, Part I, Sections 9.5 and 11.6.

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