

## H<sub>2</sub>S CONTINGENCY PLAN

**645' FSL & 825' FE, Section 26, T-31-N, R-11-W**  
**San Juan County, New Mexico**  
**Latitude 36° 52' 51.12 Longitude 107° 57' 15.30" W (NAD 83)**

Alexander Galindo  
Drilling Engineer

Terry Carpenter  
Drilling Superintendent

Shon Robinson  
Drilling Engineering Supervisor

Donnie Sperry  
Drilling Manager,

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## INTRODUCTION

ConocoPhillips is permitting to drill and complete the Wilmuth #1M well for the purpose of evaluating and exploiting hydrocarbon reservoirs.

Drilling data from offset wells indicates that hydrogen sulfide ( $H_2S$ ) may be present from the Picture Cliff formation through the Point Look Out (Mesa Verde). Hydrogen sulfide ( $H_2S$ ) is a flammable and highly toxic gas, which in relatively small concentrations, can have adverse effects on people and equipment (refer to the section - Effects of  $H_2S$ ).

Precautionary measures concerning  $H_2S$  in this plan have been formulated based on the following assumptions:

1. ConocoPhillips is expecting zero levels of  $H_2S$  from this location, but has been informed that other wells drilled through the MV of this location experienced levels of 125 ppm. An offset well, the Wilmuth #1 and the Calloway #1 was stamped for  $H_2S$  in the Mesa Verde. Please note that ConocoPhillips does not expect  $H_2S$  levels to be greater than 10 ppm drilling through the Mesa Verde formation. This contingency plan will be provided should  $H_2S$  levels arise during drilling operations.
2. Based on radius of exposure (ROE) equations provided in the Department of Interior, Bureau of Land Management, Part II, 43 CFR Part 3160, Onshore Order No. 6, Hydrogen Sulfide Operations, the **100 ppm  $H_2S$  ROE** for the proposed well is **61 feet** and the **500 ppm  $H_2S$  ROE** is **28 feet**. These ROE are based upon 150 ppm  $H_2S$  gas at a rate of **3.0 MMSCFD** which includes a safety margin.
3. No residences, schools, business, parks or other areas where the public could reasonably be expected to frequent fall within either the 100 ppm ROE or the 500 ppm ROE.

This plan has been designated as a guide for well requirements and special considerations to provide for safe and efficient drilling (or servicing) operations in the presence of hydrogen sulfide.

## GENERAL EMERGENCY ACTION

In the event an emergency situation occurs, the following action shall be initiated:

1. If the  $H_2S$  alarm sounds, stop the rotation of the drill pipe as time and conditions permit.
2. Evacuate quickly to the "Safe Briefing Area".
3. Those who must enter the hazard area must wear self-contained breathing apparatus and use other appropriate safety equipment. Secure rig and close well in, if necessary, using self-contained breathing apparatus and other appropriate safety equipment. (Use the "buddy system" at all times.)
4. Account for all personnel and take appropriate action as necessary for personnel safety.
5. Raise appropriate color warning flag to describe the type of emergency.

The ConocoPhillips Drilling Supervisor will assess the situation and assign duties to various persons to bring the situation under control. The Drilling Supervisor will advise the ConocoPhillips Drilling Manager as soon as the emergency will permit. In the event of a well kick, procedures outlined in the Operations

Plan for Drilling will be followed. Stations to be manned and duties to be performed will be listed on the doghouse bulletin board in the ConocoPhillips Drilling Supervisor's trailer and in the contract safety trailer.

Notification of local law enforcement agencies, residents and emergency vehicles as per the following Communications Directory, will be assigned by the ConocoPhillips Drilling Supervisor.

Any press inquiries are to be referred to the Implementation Manager of ConocoPhillips (Pat Bent).

**ConocoPhillips**

**(505) 326-9700**

**ALL AREA CODES ARE (505) UNLESS OTHERWISE INDICATED**

**Drilling Department**

<b><u>Name</u></b>	<b><u>Office</u></b>	<b><u>Home</u></b>	<b><u>Pager/Cellular</u></b>
<b>Drilling Managers:</b> Donnie Sperry	326-9570	325-6560	Cell: 320-2519
<b>Drilling Superintendent:</b> Terry Carpenter	324-6166	326-4876	Cell: 320-9319
Ed Jackson	599-4003	334-1640	324-7287/320-6639 Alt. Phone: 330-3271
Tom Lee	326-9785		
<b>Drilling Engineering:</b> Shon Robinson (Supervisor)	326-9746	564-3306	Cell: 320-2586
Alexander Galindo	326-9571	634-1372	Cell: 215-4778
<b>Rig Supervisors:</b> Shay Stephens.			Cell: 505-609-1148
Howell Winters			Cell: 505-215-0059

**Health, Safety & Environmental Department**

**HSE Representatives:**

Way, Ben (Manager)	324-6144	832-683-4752	Cell: 832-275-1175
Ely, Jay	326-9538	325-8025	949-0238/320-2161
Wurtz, Gregg	326-9537	564-4496	324-7438/320-2653
Johnson, Monica	326-9829	320-9056	Cell: 326-2010
Smith, Robert (WSER)	599-4052	334-8618	Cell: 947-8282
Quintero, Ramon (WSER)	324-6182	334-8106	326-8349/320-2521

**Contract Safety**

**DXP Safety Alliance:**

(Farmington, New Mexico)

Martinez, Steve	(505) 325-7233	C(505) 320-0544
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**Well Control Companies**

<b>Cudd Well</b>	<b>Control Co.</b>	24 HR.	(713) 849-2769
<b><u>Landowner's in Area</u></b>			
Alden Stinson			(505) 334-2009
Ray & Wanda Stinson			(505) 334-9131
Fay I Bacon			(505) 334-6734
Melvin Chapman			Residence has no phone

**ConocoPhillips**  
**Emergency Contact Agencies (Cont.)**

**State Police/Sheriff/City Police:**

San Juan County, NM

State Police	325-7547
Sheriff's Department	911 or 334-6622
Police Department	911 or 334-6622
Ambulance	911 or 334-6622
Fire Dept.	911 or 334-6622
Air Care 1	911 or (505) 599-6046 or 1-800-452-9990

**Bureau of Land Management:**

Farmington, NM Office	505-599-8900
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**New Mexico Oil Conservation Division:**

Aztec, NM Office	505-334-6178
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**Hospitals**

San Juan Regional Medical Center, Farmington, NM	(505) 325-5011
Mercy Medical Center, Durango, CO	

## LIST OF RESIDENTS / BUSINESSES / SCHOOLS

**No** residences, schools, business, parks or other areas where the public could reasonably be expected to frequent were found to be within the 100 ppm ROE. **No** Federal, State, County, or municipal road or highway owned and principally maintained for public use is located within the 500 ppm ROE. Included are topographic maps indicating the physical location of each radii of exposure. All land within the 100 ppm radius of exposure from the wellhead is a Fee landowner. Landowner is Fay I Bacon and her contact information is included in the contacts page. Hwy 550 is the nearest pubic road and is 70 ft from wellpad.

Fay I Bacon - 505-334-6734

## RESPONSIBILITIES

### All Personnel

1. All Personnel who spend over one day on the ConocoPhillips location shall be familiarized with the procedures outlined in this directive.
2. All personnel will attend to their personal safety first.
3. If it can be done safely, help anyone who may be injured or overcome from toxic gases by administering first aid.
4. Report to the "Safe Briefing Area" and follow the instructions of the supervisor.

### ConocoPhillips Drilling Supervisor

1. It is the responsibility of the ConocoPhillips Drilling Supervisor to see that all personnel on the ConocoPhillips location observe these safety and emergency procedures.
2. The Drilling Supervisor will advise the Drilling Manager whenever the procedures as specified herein are complied with or cannot be followed. A checklist (attached) will be utilized. One (1) completed copy of the checklist will be forwarded to the Drilling Manager and one copy to ConocoPhillips EHS Department.
3. The ConocoPhillips Drilling Supervisor shall keep the number of personnel on location to a minimum during hazardous operations.
4. The Drilling Supervisor shall be trained in the use of all safety equipment and completely briefed on safety and emergency procedures. This shall include full knowledge of the requirements in this contingency plan.
5. It is the responsibility of the ConocoPhillips Drilling Supervisor to see that the Contractor has adequately trained the drilling crews in handling emergency situations. He should satisfy himself that this is the case. He should notify the ConocoPhillips Drilling Manager if the Contractor fails to fill this responsibility.
6. If an unexpected emergency occurs, or the H<sub>2</sub>S alarm sounds, the Supervisor (either ConocoPhillips or Contractor) will assess the situation and will advise all personnel what conditions exist. Action to be taken under each of three possible conditions is as follows:

CONDITION I - POTENTIAL DANGER TO LIFE (such as hazardous amount of toxic gasses detected at surface)

- a. Order nonessential personnel out of the potential danger area and display the
- b. YELLOW CONDITION I warning sign and flag.
- c. Order all essential personnel to check their safety equipment to see that it is working properly and in the proper location (see supervisor's checklist). Persons without respiratory protection cannot work in the hazard area.
- d. Notify Drilling Manager of condition and action taken.
- e. Increase gas monitoring activities and continue operations as appropriate.

CONDITION II - MODERATE DANGER TO LIFE (such as circulating out a potentially toxic gas kick). In addition to Condition I requirements:

- a. Display only the ORANGE CONDITION II warning sign and flag.
- b. Direct corrective action to control flow of gas.
- c. Set up roadblocks and restrict personnel movements to minimum.
- d. Notify other appropriate personnel listed on emergency telephone list.

CONDITION III - EXTREME DANGER TO LIFE (when it appears that well control will be lost). In addition to Conditions I and II requirements:

- a. Contact and request local police to evacuate people and to control traffic within the danger zone. Should the condition be immediately dangerous to the public, take necessary life saving action until local police arrive. Display only the RED CONDITION III warning sign and flag.
- b. Ignite the well if necessary. (See the following section - Igniting the Well.)

**NOTE: The Drilling Manager will dispatch additional ConocoPhillips personnel and/or additional professional safety personnel to the well site as needed to assist the Drilling Supervisor.**

#### Contract Drilling Supervisor (Toolpusher)

- 1. In the absence or incapacitation of the ConocoPhillips Drilling Supervisor, the Contractor Drilling Supervisor will assume all responsibilities designated herein to the ConocoPhillips Drilling Supervisor.
- 2. Assist the ConocoPhillips Supervisor and Safety Representative in training crews for handling emergency situations.
- 3. Will be trained for all well control or emergency situations as contained herein and how to properly use all safety equipment.

#### Driller

- 1. In the absence or incapacitation of both Drilling supervisors (ConocoPhillips and Contractor), the Driller will assume their responsibilities as designated herein.



2. In the event of any emergency, the Driller will don respiratory equipment and secure the rig if time permits.
3. Assist Contract supervisor in crew preparation.

#### EHS Department

1. Shall provide safety and environmental information and guidance when required.
2. Shall review and approve any changes in safety or environmental procedures.
3. Shall assist as appropriate with operating and maintenance procedures for the safety equipment called for in this plan.
4. Shall assist with arranging initial training on safety procedures and equipment. Shall provide assistance as needed for follow up training.

#### Rig Contractor

1. Shall have personnel properly trained in First Aid/CPR and H<sub>2</sub>S Awareness
2. Shall keep personnel trained in use of safety equipment and safety procedures.

#### Visitors, Service Personnel (Vendors) and Others

1. Only personnel authorized by ConocoPhillips Drilling Supervisor shall be permitted to enter area when an emergency condition exists.
2. Shall be permitted to enter area under an emergency condition only if needed and then only after being properly instructed in use of safety equipment and have necessary equipment issued or available.
3. Vendors must have all of their personnel trained in H<sub>2</sub>S procedures who will be on location from 1,000' above the expected H<sub>2</sub>S zone through rig release.

### **Igniting the Well**

#### **1. Responsibility**

The decision to ignite the well is the responsibility of the ConocoPhillips Drilling Manager. However, the decision should be made only as a last resort and in a situation where it is clear that:

- a. Human life or property is endangered.
- b. There is no hope of controlling the blowout under the prevailing conditions at the well.

In all cases, an attempt should be made to notify the Drilling Manager of the plans to ignite the well, if time permits. However, the Drilling Manager and Drilling Supervisor must not delay a decision if human life is threatened.

**REMEMBER**, if the well is ignited, the burning H<sub>2</sub>S will be converted to sulfur dioxide (SO<sub>2</sub>), which is also highly toxic. Do not assume that the area is safe after the well is ignited. Follow through with all plans to evacuate endangered persons.

## 2. Means of Ignition

- a. In preparation for igniting the well, keep unnecessary persons in the "Safe Briefing Area". A two person team is required for the actual ignition. Both team members will wear self-contained breathing units and will have 200 feet retrieval ropes attached to safety harnesses. One team member is responsible for checking the atmosphere for explosive gasses with the explosimeter. The other member is responsible for igniting the well. Persons remaining in the "Safe Briefing Area" will closely watch the ignition team; and should either man be overcome, they will immediately pull him to safety by the retrieval ropes and apply revival measures.
- b. The primary method for igniting the well will be with a 25 mm meteortype flare gun. (The location of the flare gun will be in the ConocoPhillips Drilling Supervisor's trailer.) These guns have a range of approximately 500 feet. If this method fails or well conditions are such that a safer or better method is apparent, then an alternate method should be used.
- c. Always ignite the well from upwind and do not approach the well any closer than warranted.
- d. Select a location to fire the flare gun that provides maximum protection to the ignition team (behind equipment) while keeping in visible site by personnel in the "Safe Briefing Area".
- e. Choose a location that has good accessibility and from which retreat can easily be made.
- f. **REMEMBER**, before firing the flare gun or igniting flammable material, check the atmosphere at your location for combustible gasses with explosimeter.

## PRECAUTIONARY MEASURES

These measures are to be in effect prior to drilling out surface casing.

### General

1. Two areas shall be designated as safe briefing areas, each located, as a minimum: 150 feet from the wellhead and vent discharge area; spaced 160 degrees apart on an arc, with the wellhead as the center point; and as best suited for topographical considerations and prevailing winds. Six Niosh approved Positive Pressure SCBAs shall be located as follows: one in the Drilling Supervisor's office, one in the Tool Pusher's trailer, and two at each of the "Safe Briefing Areas". Packs should be readily accessible and properly protected from exposure to the elements.
2. Emergency equipment shall be on location as described in the H<sub>2</sub>S Contingency Equipment Checklist.
3. A copy of all emergency telephone numbers shall be posted on the doghouse bulletin board, at the "Safe Briefing Areas", in the ConocoPhillips Drilling Supervisor's office, and in the Contract Supervisor's office.
4. Wind direction indicators shall be located where at least one can be viewed from any position on the location.

5. An automatic hydrogen sulfide (H<sub>2</sub>S) monitor shall be provided, with detectors placed at the flow line, mud pit, and rig floor. Either of these detectors shall be capable of sensing a minimum of 5 ppm H<sub>2</sub>S in air and shall be able to independently activate visual and audio alarms. Both the visual alarm and the audible alarm will be activated at 10 ppm. The audible alarm must be capable of alerting people at any point on the location.
6. A sign that reads, "Caution - Poisonous Gas May be Present", will be posted at the last intersection leading to location.
7. If conditions warrant, two (2) explosion-proof, 24 inch or larger, electric fans will be located: (a) one on the rig floor to blow fumes downwind; (b) the second under the rig floor to clear gas from the substructure.
8. The well-site shall be equipped with commercial communications. The equipment should be located for safe access and should not be an ignition source.
9. The ConocoPhillips Drilling Supervisor's vehicle should always be parked a safe distance (at least 100 feet) from the rig, and in an upwind direction when feasible.
10. For all well kicks, the Operations Plan will be followed. All drilling contractor personnel shall be trained, and drills shall be conducted to insure proper well control procedures.
11. The checklist of all emergency equipment (see Drilling Supervisor's checklist) shall be completed at 1000± above the suspect formation(s) as identified in the introduction. The Drilling Supervisor shall inspect the equipment with assistance, as needed, from ConocoPhillips EHS personnel as to working condition, proper placement, etc. The inspection will be noted on the checklist. A copy of the checklist will be placed in the Drilling Supervisor's files and one copy each will be provided to the Drilling Manager and EHS Department.
12. To ensure proper hole filling during tripping operations, a stroke counter and pit level sensor will be utilized at all times.
13. DXP will be on-site security monitoring head count, enforcing that all personnel on location will have no facial hair, keeping only essential personnel on location, and all personnel on location are trained to work in an H<sub>2</sub>S environment.

### **SPECIAL SAFETY TRAINING**

The minimum training for personnel working in affected areas shall include the following elements:

1. Hazards, characteristics and symptoms of hydrogen sulfide (H<sub>2</sub>S), sulfur dioxide (SO<sub>2</sub>), carbon monoxide (CO), methane gas, and other hazardous substances as may be appropriate. Effects of these substances are discussed in a section that follows.
2. Effect on metal components of the system.
3. Safety precautions to include possible sources at the site.
4. Operation of safety equipment and life support means and systems.
5. Corrective action and shutdown procedures.
6. Detection and measurements of H<sub>2</sub>S, CO and combustible gas.

**THE CONOCOPHILLIPS SUPERVISOR ON LOCATION SHALL BE RESPONSIBLE FOR THE OVERALL ON-SITE OPERATION, INCLUDING THE SAFETY AND TRAINING PROGRAM.**

All personnel, contracted or employed on an unscheduled basis, shall be trained as a minimum in the severity of H<sub>2</sub>S and other toxic gasses, safety precautions, evacuation procedures, and as appropriate, the use of respiratory protection equipment. This training shall be completed prior to entering the H<sub>2</sub>S location. Visitors shall also be instructed regarding these matters.

To promote efficient safety procedures, an on-site toxic gas safety program, which includes a drill and training session, shall be established for all crews. Records of attendance shall be maintained on the drilling facility.

**EQUIPMENT AND MATERIAL SPECIFICATIONS**

1. Wellhead and blowout equipment is to conform as per Operations Plan.
2. BOP equipment will be tested to pressure rating prior to drilling out from the surface casing, with all testing witnessed and recorded by the ConocoPhillips Drilling Supervisor.
3. The BOP will be operationally tested on every trip. BOP drills will be held each tour prior to drilling all potential H<sub>2</sub>S bearing formations and recorded on the tour sheets.
4. The casing planned for this well is listed in the Operations' Plan. This casing has been designed in accordance with ConocoPhillips' requirements for sour service.

**Mud Requirements**

1. The pH of the mud system will be maintained above 10.0 to neutralize (disassociate) any H<sub>2</sub>S encountered. The pH will be maintained with caustic soda and/or soda ash.
2. While drilling from all potential H<sub>2</sub>S bearing formations to total depth, the Mud Engineer is to test daily for filtrate sulfide using a "Hach H<sub>2</sub>S Test Kit" and following the procedures of API Standard RP13B (copy in a following section). The results of this test are to be reported on the daily report.
3. Small concentrations of sulfide are expected and can be tolerated. However, concentrations which result in "Hach Tests" of greater than 50 ppm are potentially more serious and should be treated with H<sub>2</sub>S scavenger to reduce the concentration of acceptable levels.
4. The Hach Test will be routinely "doubled-checked" by means of the Garrett Gas Train.
5. Prior to dumping any significant quantities of drilling fluid (changing over, cleaning pits, cementing, etc.), it may be necessary to treat out sulfides with H<sub>2</sub>S scavenger in order to preclude formation of H<sub>2</sub>S gas in the reserve pit.

**ConocoPhillips**  
**H<sub>2</sub>S CONTINGENCY EQUIPMENT CHECKLIST**

Well: \_\_\_\_\_

Rig N/N: \_\_\_\_\_

Date: \_\_\_\_\_

Supervisor: \_\_\_\_\_

1. \_\_\_\_ (All) **Personnel training** with attendance records on site.
2. \_\_\_\_ (2) **Cleared land areas** for use as "Safe Briefing Areas", 150' from wellhead, and 160° apart.
3. \_\_\_\_ (1) **Warning sign** with current well condition indicator, located at last intersection to location so vehicles may have turn-around area.
4. \_\_\_\_ (3) **Wind direction indicators**, located to provide visibility from any place on location.
5. \_\_\_\_ (3) **No Smoking signs** on drive posts.
6. \_\_\_\_ (3) **Safe Briefing Area signs** on drive posts.
7. \_\_\_\_ (2) **Fans** - electric motor driven and explosion proof; one located on rig floor, and one located in substructure (if conditions warrant).
8. \_\_\_\_ (1) **H<sub>2</sub>S monitor** (continuous) located on rig floor with detectors (sensitivity of 5 ppm in air) located at the flow line, mud pits discharge, and on the rig floor.
9. \_\_\_\_ (1) **Alarm system** capable of individual activation by any detector with maximum settings as follows: visual and audible alarms at 10 ppm (audible must be capable of alerting personnel at any point on location).
10. \_\_\_\_ (5) **Niosh Approved Positive Pressure SCBAs** - 30 min. self-contained breathing apparatus: one in the supervisor's office, and two at each of the "Safe Briefing Areas". Easily accessible, and protected from exposure to the elements.
11. \_\_\_\_ (1) **Flare system** with continuous pilot and remote ignitor.
12. \_\_\_\_ (1) **Trailer** - full enclosure, at location entrance (based on prevailing winds), containing the following items (#13 through #24, and also #25d).
13. \_\_\_\_ (3) **Condition warning flags** (1 each yellow, orange, and red).
14. \_\_\_\_ (1) **Length of Stain Polymetric Tube Type Detectors** with lower range tubes for CO<sub>2</sub>, H<sub>2</sub>S, and SO<sub>2</sub>.
15. \_\_\_\_ (1) **MSHA Explosimeter** (or equivalent).
16. \_\_\_\_ (1) **Flare gun** - 25mm meteor type with flares.
17. \_\_\_\_ (2) **Derrick safety belts** with 10' tail ropes.
18. \_\_\_\_ (2) **200' retrieval ropes.**
19. \_\_\_\_ (3) **Hearing protectors** - muff type.
20. \_\_\_\_ (1) **First aid kit** - 25 unit.
21. \_\_\_\_ (3) **Flashlights** w/batteries (explosion-proof & watertight).
22. \_\_\_\_ (1) **Disinfectant, cleaner, and towels** for breathing apparatus.
23. \_\_\_\_ (1) **Inspection records** for breathing apparatus and air supply.
24. \_\_\_\_ (1) **Fire extinguisher** (rated 60:BC).
25. \_\_\_\_ (4) **Emergency telephone numbers** in plastic weatherproof holders located at: rig bulletin board; ConocoPhillips Drilling Supervisor's office; Contract supervisor's office; in both Safe Briefing Area

## **EFFECTS OF HYDROGEN SULFIDE AND OTHER GASSES ON DRILLING OPERATIONS**

### Toxic Effect

#### 1. Hydrogen Sulfide - H<sub>2</sub>S

Hydrogen sulfide is a colorless, flammable, extremely poisonous gas. It is 1.2 times as heavy as air and will accumulate in low areas. It forms an explosive mixture with air between 4.3 and 46.0 percent by volume. It can be detected by smell at a concentration in air of only 0.02 ppm. Exposure to 10 ppm can be tolerated up to 8 hours without respiratory equipment. Respiratory equipment is required to protect workers should conditions exceed the foregoing allowable exposure limit. Concentrations in excess of 20 ppm have an effect on the olfactory nerve which deadens the sense of smell. Unconsciousness can occur without warning within seconds of inhalation at concentrations above 500 ppm.

### Physical Effects of Hydrogen Sulfide

Concentration Percent (%)	ppm	Physical Effects
0.001	10	Obvious and unpleasant odor.
0.001	10	Current ACGIH TLV allowed for 8 hour exposure.
0.01	100	Kills smell in 3 to 15 minutes, may sting eyes & throat.
0.02	200	Kills smell shortly, stings eyes & throat.
0.05	500	Dizziness, breathing ceases in a few minutes. Needs prompt artificial respiration.
0.07	700	Unconscious quickly; death will result if not rescued promptly.
0.10	1000	Unconscious at once; followed by death within minutes.

#### 2. Sulfur Dioxide - SO<sub>2</sub>

Sulfur dioxide is a colorless, nonflammable, intensely irritating gas and 2.2 times heavier than air. It is a by-product of combustion of hydrogen sulfide and is highly toxic. Exposure to 2 ppm can be tolerated for a maximum of 8 hrs. Respiratory equipment will be available and should be used by personnel measuring SO<sub>2</sub> concentration downwind from a flare.

#### 3. Methane - CH<sub>4</sub>

Methane is the major component of natural gas and is colorless, odorless and extremely flammable. The chief danger from methane is explosion. Mixture of CO<sub>2</sub>, H<sub>2</sub>S and CH<sub>4</sub> will burn if the total H<sub>2</sub>S and CH<sub>4</sub> content, in any ratio, is above 25 percent. Also the presence of methane causes an oxygen deficient environment and requires adequate ventilation for breathing.

#### 5. Carbon Monoxide - CO

Carbon monoxide is a colorless, odorless toxic gas. Its toxicity results from preferential reaction with the hemoglobin in the blood; however, it has no unique toxic action on any of the bodily tissues. CO displaces oxygen from hemoglobin and reduces the oxygen carrying capability of the blood.

The primary danger from CO is that it binds with hemoglobin within the blood, thereby preventing oxygen / blood transfer. Respiratory equipment should be considered for atmospheres containing greater than 25 ppm. Exposure to 25 ppm is allowed up to 8 hours; however, at higher levels it will tend to cause headaches, dizziness and nausea. Concentrations above 1200 ppm are considered immediately dangerous to life and health.

In addition to the toxic effects of CO, carbon monoxide burns readily in air. The flammability limits of CO in air change with pressure. At atmospheric pressure, however, the lower limit is  $\pm 12.5\%$  and upper limit is  $\pm 74\%$ .

## 6. Properties of Various Gasses

<u>Common Name &amp; Chemical Formula</u>	<u>Specific Time Gravity Air=1</u>	<u>Time Weighted Average*</u>	<u>IDLH**</u>	<u>Lethal Concentration***</u>	<u>Flammability</u>
Hydrogen Sulfide (H <sub>2</sub> S)	1.18	10 ppm	100 ppm	600 ppm	4.3% to 46% by volume in air
Sulfur Dioxide (SO <sub>2</sub> )	2.21	2 ppm	---	1000 ppm	
Methane (CH <sub>4</sub> )	0.55	Simple Asphyxiate	---	-----	5.3% to 14.0% by volume in air
Carbon Monoxide (CO)	0.97	25 ppm	1200 ppm	-----	12.5% to 74% by volume in air

\* Time Weighted Average (TWA) - Employee's average exposure in any eight-hour work, of a 40-hour work week that shall not be exceeded.

\*\* Hazardous - Concentration that may cause death.

\*\*\* Lethal - Concentration that will cause death with short term exposure.

## CORROSION EFFECTS OF H<sub>2</sub>S ON STEEL

### 1. Hydrogen Sulfide (H<sub>2</sub>S)

The three forms of hydrogen sulfide corrosion of steel are as follows:

- general or weight loss,
- localized or pitting, and
- sulfide stress cracking.

In both general and localized corrosion, hydrogen sulfide reacts with the steel to produce iron sulfide. General corrosion is characterized by the formation of an iron sulfide film on the surface of the steel. After long periods of exposure, weight loss can lead to a significant reduction in strength. Localized corrosion is much more serious and predominantly occurs in the pH range below six. Chloride or similar ions must be present for pitting to occur. Iron chloride accumulates at the metal to iron sulfide film interface and promotes a localized attack. Pitting corrosion has not presented a significant problem in drilling operations.

Of foremost concern is sulfide stress cracking or hydrogen embrittlement where failure may take place without warning or significant metal loss. This problem is related to strength of the steel, hydrogen sulfide concentration, pH, exposure time, and temperature and stress level of the steel. Hydrogen sulfide absorbed on the metal surface promotes the entry of atomic hydrogen into the metal. The atomic hydrogen that enters the steel matrix diffuses to positions of high stress where it can induce hydrogen embrittlement. Thus, brittle failure can occur at stress levels significantly less than normal yield stress. A high total dissolved sulfide concentration can be tolerated if the pH is high enough (9.5 or greater).

## **EFFECTS OF H<sub>2</sub>S ON DRILLING FLUID**

### **1. Hydrogen Sulfide - H<sub>2</sub>S**

When H<sub>2</sub>S is entrained in a drilling fluid, it will disassociate to some degree depending on the pH of the system.

Undisassociated hydrogen sulfide is the molecule that attacks steel surfaces and causes corrosion and embrittlement. At a low pH, nearly all of the H<sub>2</sub>S in a system is in this molecular state. With increasing pH, H<sub>2</sub>S disassociation increases so that above pH 10, effectively all of the H<sub>2</sub>S is disassociated into bisulfide and sulfide ions. These ions are relatively harmless in the mud as long as the high pH is maintained. If pH is lowered, the reaction will be reversed and hydrogen sulfide gas will be evolved.

In addition to sulfide ions, disassociation of H<sub>2</sub>S in drilling mud produces hydrogen ions, which will react with hydroxyl ions in a high pH mud to form water. With sufficient H<sub>2</sub>S contamination, excess lime, if any, can be depleted and pH will begin to drop. A sufficient decrease in pH will, as previously stated, evolve H<sub>2</sub>S gas.

It is therefore desirable to know whether H<sub>2</sub>S has been encountered at the least possible time. This can be accomplished by testing the mud for sulfide ions daily, as described in the sulfide testing procedures that follow (API RP 13B).



**SULFIDE TESTING PROCEDURE**  
**HACH TEST**

**PROCEDURE FOR ESTIMATING FILTRATE SULFIDE**

**Equipment:** The following materials are required to estimate the sulfide concentration in the mud filtrate:

- a. Special test vial with vented cap
- b. Lead acetate test paper to fit cap
- c. Color comparison chart

(NOTE: THE HACH HYDROGEN SULFIDE TEST KIT (MODEL HS-7) CONSISTS OF ITEMS a, b, and c ABOVE.)

- d. Distilled water
- e. Hypodermic syringe
- f. Defoamer (such as octyl alcohol or sulfated castor oil)
- g. 0.1N acid, sulfuric or hydrochloric

**Procedure:** Place one disk of dry lead acetate test paper inside the dry cap of the test vial.

Measure 2.5 cm<sup>3</sup> of freshly collected mud filtrate into the test vial. Dilute to the 25 cm<sup>3</sup> with distilled water.

Add 2 cm<sup>3</sup> of 0.1N acid, immediately add a fresh seltzer tablet, and quickly place the cap with the test paper on the vial. Allow the seltzer tablet to dissolve and then wait one minute.

Remove lead acetate paper and observe for brown coloration. If no coloration can be detected, then report the soluble sulfide as zero. If brown coloration is present, compare the test paper with color comparison chart. Read the appropriate ppm value (0.1, 0.3, 0.5, 1, 2, or 5) from the color chart and multiply by 10 to obtain the test result (1, 3, 5, 10, 20, or 50).

If the test paper matches the darkest color (5 ppm) on the color chart, the test result must be interpreted as greater than 50 ppm.

To extend the test range to higher concentration, dilute the filtrate as follows:

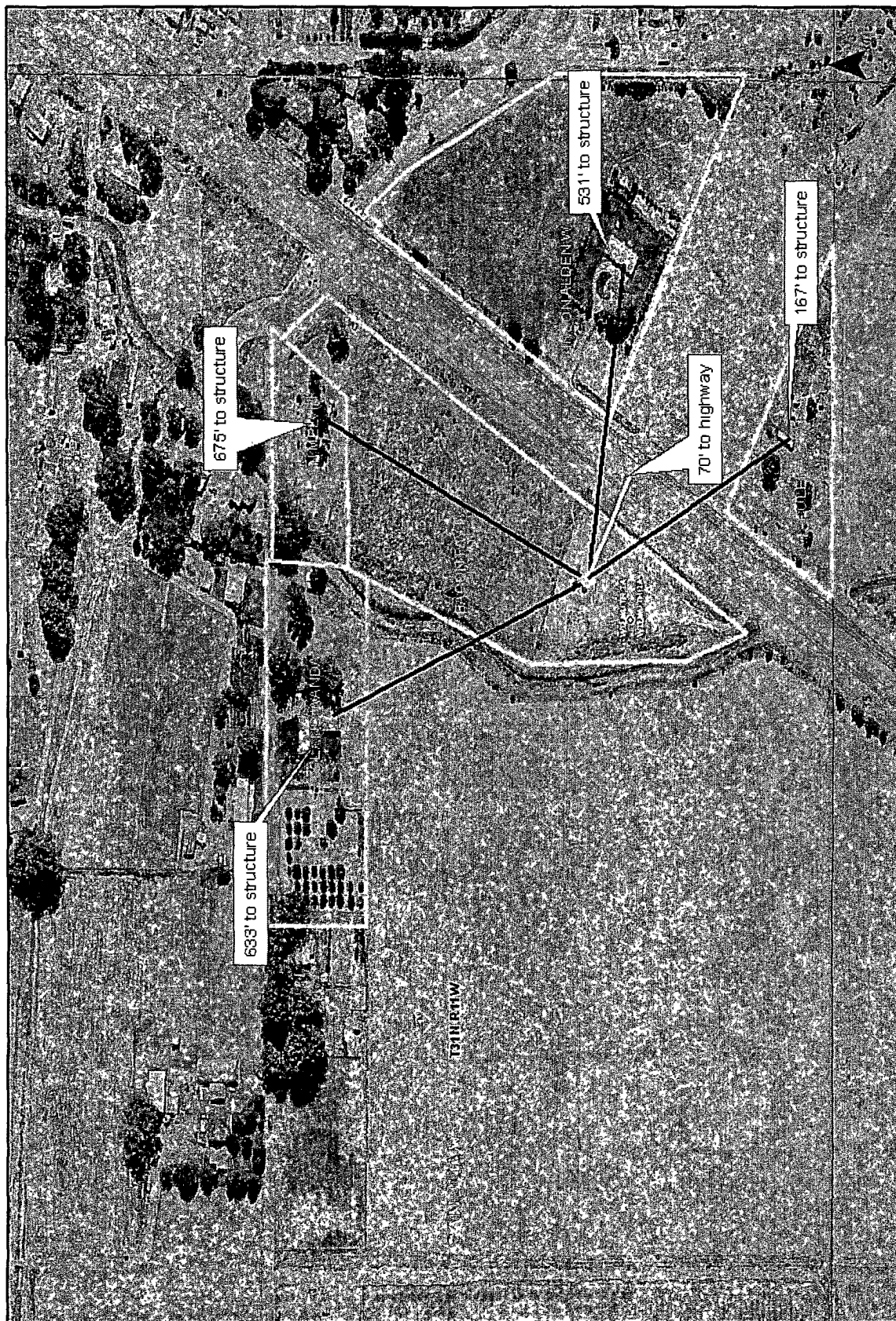
- a. For a test range of 10 to 500 ppm, dilute 1.0 cm<sup>3</sup> of filtrate with 9.0 cm<sup>3</sup> of distilled water. Use 2.5 cm<sup>3</sup> of the diluted filtrate for the sulfide determination. Multiply the color chart value by 100 to obtain the test result.

Report the test result as filtrate sulfide in ppm.

**NOTE 1:** IT IS IMPORTANT TO NOTE THAT THIS TEST IS NOT HIGHLY ACCURATE. THE RESULTS SHOULD BE INTERPRETED AS ROUGH ESTIMATES.

**NOTE 2:** THE METHOD MAY BE USED FOR WATER USING 25 CM<sup>3</sup> SAMPLES OR THE SAME DILUTION PROCEDURE USED FOR MULLED FILTRATE. THIS METHOD MAY ALSO BE USED FOR MUD BUT THE PROBABLE MEANING OF THE RESULTS IS VERY UNCERTAIN. THERE COULD ALSO BE CONSIDERABLE DIFFICULTY IN OBTAINING A REPRESENTATIVE SAMPLE OF DILUTED MUD.

ATTACHMENTS



## LIST OF REFERENCES

1. "API Recommended Practices for Safe Drilling of Wells Containing Hydrogen Sulfide", (API RP 49) American Petroleum Institute, Dallas, Texas, 1974.
2. "API Recommended Practice: Standard Procedure for Testing Drilling Fluids", (API RP 13B) American Petroleum Institute, Dallas, Texas, 1976.
3. Clark, R. K., "Hydrogen Sulfide in Water-Base Drilling Fluids - I: Chemistry, Corrosion and Treatment", Technical Progress Report BRC 35-77, Shell Development, Houston, Texas, 1977.
4. "Contingency Plan for Drilling, Completion and Workover, Sour Gas Wells, Safety Regulations and Emergency Procedures", Shell Oil Company, Michigan Operations, Traverse City, Michigan, 1974.
5. "Contingency Plan for the Drilling of Taylor DT 653, Ventura Avenue Field, Ventura County, California; Safety Procedures and Precautionary measures", Shell Oil Company, West Coast Division, Los Angeles, California, 1973.
6. "Drilling Contingency Plan for McElmo Dome Area", Shell Oil Company, Midland Operations, Midland, Texas, 1976.
7. "Drilling Fluid Engineering Manual", Magcobar Operations, Dresser Industries Inc., Houston, Texas, 1972.
8. "Rule 36: Oil, Gas or Geothermal Resource Operation in Hydrogen Sulfide Areas", Railroad Commission of Texas, Oil and Gas Division, Austin, Texas, 1976, as amended effective September 15, 1985.
9. "Safe Practices for Drilling and Well Servicing Operations", Volumes I and II, Shell Oil company Exploration and Production.
10. "Sulfide Stress Cracking Resistant Metallic Material for Oil Field Equipment", NACE Standard MR-01-75, National Association of Corrosion Engineers, Katy, Texas, 1978.
11. "Onshore Order No. 6, Hydrogen Sulfide Operations", Department of the Interior, Bureau of Land Management, 43 CFR Part 3160.