CO_2 and H_2S Safety Regulations and Recommended Practices

Stephen A. Boone III, CHCM
Professional Oilfield Safety, Inc.

ABSTRACT

This paper discusses a general review of safety hazards and regulations associated with CO_2 injection, work on H_2S contaminated leases, and liability and court litigation concerning oilfield injuries.

The safety regulations to be discussed are a compilation of various applicable International, Federal, and State regulations, recommended practices by various petroleum related associations, and interpretations of these regulations as evident through recent court litigation. Though high pressure CO_2 injection safety, along with H_2S safety, will be stressed, general lease safety recommendations will be made to help reduce operator liability risk.

INTRODUCTION

As a result of both recent and proposed changes in regulatory agency requirements and the results of recent court litigation, general lease safety is becoming a more dynamic field, and operator liability risk has been greatly increased. The purpose of this paper is to explain the operator's responsibilities by defining basic lease safety principles concerning Carbon Dioxide (CO_2) hazards, Hydrogen Sulfide (H_2S) hazards, and recommended general safety policies. Due to the difference in lease specifications, this paper will deal with general principles of safety, and not specific per-lease or per-job requirements.

GENERAL RECOMMENDATIONS

All recommendations throughout this paper are a compilation of regulatory agency requirements, general industry recommendations, and/or court litigation results. They are combined in this manner to avoid debating the pros and cons of conflicting and/or overlapping regulations. These recommendations are not being made in an effort to explain or practice law, but are designed to assist field safety personnel and other field management personnel in designing and implementing proper safety policies.

Carbon Dioxide

There are several general hazards associated with using high pressure CO_2 for injection purposes. For the purposes of this paper, we will not deal with specific rig-up and process design standards, since these will be the responsibility of your design engineering department, or in the case of a CO_2 frac, the responsibility of the contractor company.

One concern of CO_2 is its effect on the human body should an exposure type accident occur. Carbon dioxide has been reported as the cause of death when encountered in asphyxiating concentrations, those over 50,000 ppm. It is weakly narcotic at 30,000 ppm, decreasing hearing ability and increasing blood pressure and pulse. At 50,000 ppm, a fifteen (15) minute exposure may be intoxicating, leading to unconsciousness. At 70,000 ppm, unconsciousness may result in as few as three (3) minutes. Because CO_2 does affect the cardiovascular system, persons with cardiovascular illness, high blood pressure, and other related medical problems should expect health problems at lower than the "average" ppm concentrations. Also, as with any accident causing unconsciousness, death may result. For further CO_2 characteristic data, see Table A "Carbon Dioxide Properties".

Because of the relatively high ppm concentration allowables, the primary concern in a CO_2 release accident would not necessarily be CO_2 poisoning, however this is a possibility. Depending upon the location of the release and the actual processes involved, the health hazards, such as poisoning, caused by other contaminates with lower immediate dangerous to life or health (IDLH) concentrations would be a primary concern. For this reason, it is recommended that self-contained breathing apparatus (SCBA) be available and properly used when working with or around CO_2. In the past the use of cannister/filter type masks was permissible, however, this type of respiratory protection is no longer recommended for field use. The cannister/filter type masks are acceptable under the following conditions:

1. if absolutely no H_2S is present
2. if they are not used in a confined space
3. if they are not used in contaminated atmospheres greater than the filter's CO_2 rating
4. if they are not used for fire fighting
5. if accurate time/use records are kept for each cannister.

Because of the restrictions on cannister/mask use, and because SCBA is required for H_2S atmospheres, as well as other potentially toxic atmospheres, our company recommends that only SCBA equipment be used when encountering potentially toxic CO_2 atmospheres.

Other special safety equipment which should be worn by personnel includes rubber or plastic gloves to help prevent frostbite from skin contact, and eye goggles to help prevent eye injuries in the event of a release or high pressure accident. Also, general first aid equipment plus training in treatment of frostbite should be available to all field personnel.

The next group of hazards are the same as with any high pressure system. The surface injection pressures generally range from 1600 to 2000 psi, thus the CO_2 is kept near the super-critical stage. These hazards include over-pressuring the system, bleeding off overpressure, rupture due to bleed off failure and/or pipe failure, and increased corrosion. Generally, basic high pressure safety procedures will control these hazards.

To prevent overpressuring the system, the CO_2 must never be trapped or blocked in a section of the system. This is insured by:

1. not closing more than one flow valve at a time, without proper venting
2. not allowing formation of ice plugs
3. not pressurizing the system more than the weakest point rating
4. not allowing ambient temperature increases which will affect the internal pressure of the pipe, generally accomplished by burying the pipe a minimum of 2½ ft. below surface.

The corrosion problems are more evident in CO_2 floods where the CO_2 is being retrieved, treated, and reinjected and is less than 98+% pure. In this case periodic inspection of the system to determine structural integrity is recommended.

Hydrogen Sulfide

Instead of reviewing the basic H_2S safety rules normally covered in an H_2S training course, this section will deal with increasing H_2S concentration trends in contaminated leases and changes in regulations, with recommended compliance procedures.

Hydrogen Sulfide Increased Concentration Trends. One of the major concerns with H_2S contaminated leases is that sour fields tend to show an increase in H_2S content over their production life. This is due to several factors which include changes in the pH of the formation and contamination due to flooding. Since an increase in the acidity (or drop in pH) will more easily allow HS^- ions to form H_2S, care should be taken when acidizing, fracturing, injecting chemicals, and/or flooding. It has been shown in drilling programs that the pH of the mud should be kept at or above pH 10 in an effort to help control H_2S formation. In the same manner, pH during production operations should be maintained, if possible. One important note, studies indicate that increasing the pH of the formation will not necessarily dissociate the H_2S back to HS^- ions.

Along the same lines, flooding of a field generally tends to increase H_2S content both by potentially changing the pH and by contaminating the reservoir. Waterfloods are the most obvious example of reservoir contamination, because they introduce organic particulates into the formation. Any flood program, regardless of flood agent, has the potential risk of contaminating the reservoir. CO_2 floods where almost pure (98+%), "dry" CO_2 is used as the flood agent will probably run a minimal contamination risk. However, if a program is developed to recover, treat, and reinject CO_2, and the reinjected CO_2 is less than 98% pure, contamination problems could be expected.

Also, remember that any increase in production in an H_2S contaminated field will also increase the amount of H_2S produced, even if the actual ppm remains relatively constant. This will effectively increase the radius of exposure (ROE) for the H_2S hazard. Where ROE is defined as the distance of contamination for either 100 ppm or 500 ppm H_2S from the atmospheric contamination source. General definitions of100 ppm ROE and 500 ppm ROE are:

100 ppm: 1.589 x ppm H_2S x maximum escape volume per day (in millions) = Y

$Y^{0.6258}$ = 100 ppm ROE

500 ppm: 0.4546 x ppm H_2S x maximum escape volume per day (in millions) = Y

$Y^{0.6258}$ = 500 ppm ROE

Hydrogen Sulfide Regulation Revisions. As seen in Table B, historically there are differences in allowable exposures (ie. TLV-TWA, 10 minute peaks, etc.) to H_2S depending upon the regulatory agency with the most jurisdiction on a particular lease. Some regulatory agencies have also used an ROE to determine required compliance with their regulations. Currently, there are several regulatory agencies with either existing H_2S standards under revision or with new proposed standards. Although most of these standards still over-lap or conflict, several will remove the ROE principle and use expected H_2S concentration within the system regardless of pressure and hazard zone.

At present, it is our company's recommendation that standard safety procedure be to comply with all applicable H_2S safety regulations and recommendations if the potential H_2S concentration exposure anywhere in the system is 100 ppm or greater, and/or if exposure to between 50 ppm and 100 ppm will be for 10 minutes or longer. It is also standard policy that only self-contained breathing apparatus will be used for respiratory protection. Cannister/filter masks which were acceptable in the past have such a limited application range that they are undesirable.

In addition to increasing the range of the "common industry practice" of H_2S compliance. Responsibility fortraining of personnel and supervision of contractor/vendor personnel has been increased. Our company recommends that all personnel who might in any way be exposed to H_2S, or any other life threatening hazard, be trained on an annual basis in its properties, characteristics, hazards, detection, prevention, and applicable safety equipment useage. All training courses should be documented as to attendance and material discussed. All students should take a written examination to document their understanding of the hazards. All personnel on any given field location should have current certifications for all applicable hazards.

Also, all contractor/vendor personnel on a lease should be certified in all applicable areas and all necessary safety equipment should be available to them. It does not matter if the training and equipment is made available by the operator or by the contractor.

Uniform Safety Policy Applications

Probably the most important changes in general lease safety and operator safety liability are the court litigation rulings concerning uniform safety policy applications. Though a company may operate in: (1) more than one state; (2) on Federal, State, and/or private leases; (3) and/or onshore and offshore leases, no longer will they be allowed to comply with only the regulatory agency requirements directly related to that particular lease. Due to recent court litigation, a uniform set of standards must be developed and implemented company wide. The company safety policy requirements must, at minimum, comply with the strictest set of regulatory agency requirements which are in any way applicable to any part of any operation owned and/or operated by that company.

An example of uniform safety policy is the "Godwin Case". This was a case settled in January, 1984, in which a transport driver was exposed to a high concentration of H_2S. The accident occurred in December, 1975, in Mississippi. Though this case did not establish the precedent, several safety concerns were reconfirmed. During the pre-trial depositions and the actual case testimony the plaintiff successfully used several safety principles, which confirm a uniform standards application. Examples are:

1. citing current Texas Railroad Commission Amended Rule 36 (making one states requirements applicable outside of that state, under the uniform company policy philosophy)
2. citing the Federal OSHA Proposed Oil and Gas Well Drilling and Servicing Standard (1910.270) and using the defendant's amount of participation in both proposal hearings and industry trade association meetings concerning 1910.270 (establishing interest in regulatory affairs)
3. citing Federal OSHA regulations in a traditional transportation driving case (superceding less stringent Federal Department Of Transportation (DOT) regulations)
4. citing "right to know" and "truth in labeling" regulations (apparently neither hydrogen sulfide or the actual H_2S content were mentioned on the run ticket or on the shipping papers).

The plaintiff's safety professional appears to have used the belief that a company should have a uniform set of rules. The basic rules should not differ when moving from one lease to another, regardless of where the leases are located. He also showed that though a specific regulation may not be written and in affect today, if a hazard is known and recognizable, there should be a strong company safety policy concerning that hazard.

Gross Negligence

Gross negligence should be of special interest to companies operating in Texas. In May, 1981, the Texas Supreme Court, in rendering a decision, redefined its interpretation of gross negligence. In the past it was the plaintiff's duty to prove that a company had been grossly negligent, thus leading to an accident and/or injury. As a result of the ruling the difference between ordinary negligence and gross negligence has been greatly diminished. Now it is the company's duty to prove that they were not grossly negligent. As a result, the foundation has been laid for an increased number of negligence related law suits. This means that companies must increase their safety awareness programs for both employees and for all contractors/vendors on location.

In increasing its safety awareness programs for employees, a company should consider the following items:

1. practical safety policies and safety procedural rules in writing, read by the employee, and verification that the employee understood the policies
2. constant updating and revision of the safety policies
3. regular, frequent safety awareness meetings and safety training with written documentation of the topic, employee attendance, and employee understanding
4. frequent job-site safety audits
5. practical, uniformly applied, reprimand systems for safety policy violations, including employment termination.

In dealing with contractor/vendor safety, a company should consider the following items:

1. written and communicated safety policies, clearly outlining both company and contractor/vendor responsibilities
2. constant updating and revision of the safety policies
3. frequent safety audits by the company to insure contractor/ vendor compliance
4. practical, uniformly applied, reprimand systems for safety policy violations, including removal from approved vendor list.

CONCLUSION

If proper safety and production procedures are followed, it is unlikely that a CO_2 release-type accident will occur. As we can see, the hazards of CO_2 exposure are minimal when compared with other hazards on a lease, and the safety procedures for other potential IDLH atmospheres are acceptable in preventing and/or controlling CO_2 releases.

Major emphasis should be given to installing company wide, uniform safety policies. These policies should at minimum comply with strictest applicable regulations, and should be constantly updated and revised.

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Table A
Characteristics and Properties of Carbon Dioxide

Chemical and Physical Properties:	
Composition	CO_2
Molecular Weight	44
Melting Point, F	-109 F (sublimes)
Boiling Point, F	-109 F (sublimes)
Flash Point, F	not combustible
LEL	not combustible
UEL	not combustible
Solubility (g/100g water @ 20 C)	0.14%
Vapor Pressure (20 C mm Hg)	>1 atm
Physical Discription:	
Color	colorless liquid; white vapor cloud with pressure re- lease
Odor	Odorless to slightly pungent when under high pressure
Hazard Ranges:	
<30,000 ppm (3%)	generally no physical effect
30,000 to 50,000 ppm	dizziness, minor respiratory discomfort, slightly elevated blood pressure and pulse rate
50,000 to 90,000 ppm	dizziness, respira- tory discomfort, labored breathing, elevated blood pres- sure and pulse
>90,000 ppm	unconsciousness in 5 to 10 minutes

Table B
Comparison of General Characteristics of Carbon Dioxide and Hydrogen Sulfide

	CO_2	H_2S
Immediately Dangerous to Life or Health (IDLH)	50,000 ppm (5%)	500 ppm (.05%)
Permissable Exposure (TLV - 8 hour period)	5,000 ppm (.5%)	20 ppm (.002%) or 10 ppm (.001%) depending upon regulatory agency
10 Minute Allowable Peak	30,000 ppm (3%)	50 ppm (.005%) or 10 ppm (.001%) depending upon regulatory agency
Respirator Equipment	Recommend using Self-contained Breathing Equipment	Self-contained Breathing Equipment required
Health Hazards		
Symptoms at Low Levels	Headaches, sweating, dizziness, restlessness, hard to breath	Headaches, stomach pains dizziness, eye irritation, fatigue, hard to breath
Symptoms at High Levels	Increased heart rate, elevated blood pressure, convulsions, frostbite, coma, paralysis of respiratory system, death	Loss of sense of smell and sight, loss of reasoning and balance, coma, paralysis of respiratory system, death
First Aid	Artificial Respiration, CPR, treat for frostbite, medical attention	Artificial Respiration, CPR, remove soiled and contaminated clothes, flush eyes, medical attention