Volatile Organic Compounds (VOCs) and Other Hazardous Exposures in Hydraulic Fracturing – Tank Gauging Operations

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Overview

- Identification of Fatalities
- Overview of Tank Gauging, Thieving/Sampling, and Transferring Operations
- Hazards, Findings, Sample Results
- Outreach

Identification of Fatalities

- In 2013, OSHA and NIOSH were contacted by an occupational health physician regarding two recent oilfield deaths- inhalation of VOCs was suspected
- NIOSH reviewed fatalities (2010-2014) in internal O&G fatality database and monitored deaths closely
- Published 1st Science Blog in May 2014 about 4 fatalities

Fatality Case Definition

- Working in proximity to a known and concentrated source of hydrocarbon gases and vapors
- Hydrogen Sulfide (H_2S) was ruled out
- Not confined space
- Not fires/explosions
- Case by Case Review conducted by OSHA/NIOSH

2010-2014 Fatalities (N=9)

- 9 worker deaths where inhalation of petroleum hydrocarbons a likely factor
- All occurred at production tanks.
- North Dakota (3), Colorado (3), Oklahoma (1), Texas (1), and Montana (1).
- 2010 (1), 2012 (1), 2013 (1), 2014 (6)

TABLE. Sudden deaths caused by inhalation of hydrocarbon gases and vapors and oxygen deficiency among oil and gas extraction workers — United States, January 2010–March 2015

Worker	Year of death	Age (yrs)	State	Job title	Job task	Location/position of decedent when found	Time of day found	Coroner's stated cause of death
1	2010	30	Montana	Crew worker	Gauging	Slumped over on catwalk	3:00 a.m.	Hypertensive and atherosclerotic cardiovascular disease
2	2012	21	North Dakota	Flow tester	Gauging	On catwalk next to open hatch	12:30 a.m.	Hydrocarbon poisoning due to inhalation of petroleum vapors
3	2013	39	North Dakota	Truck driver	Collecting sample	On knees, slumped over catwalk railing in front of open hatch	10:20 a.m.	Sudden cardiac arrhythmia (primary), morbid obesity and arteriosclerotic heart disease (contributory)
4	2014	57	Oklahoma	Truck driver	Collecting sample	Slumped over on catwalk next to tank	10:12 a.m. (time of death)	Undetermined (no autopsy performed)
5	2014	51	Colorado	Truck driver	Collecting sample	Hanging from guardrail, hooked by clothing	10:39 a.m. (time of death)	Sudden cardiac death due to ischemic heart disease
6	2014	57	Colorado	Truck driver	Collecting sample	Collapsed over open hatch	10:30 a.m.	Atherosclerotic cardiovascular disease
7	2014	59	Colorado	Truck driver	Collecting sample	Collapsed over open hatch	1:40 p.m.	Toxic gas inhalation and oxygen displacement by volatile hydrocarbons (primary), atherosclerotic cardiovascular disease
8	2014	63	Texas	Tank gauger	Gauging	At bottom of catwalk stairs	4:14 a.m.	Arteriosclerotic and hypertensive cardiovascular disease
9	2014	20	North Dakota	Flow tester	Gauging	Face down over open hatch	5:00 a.m.	Cardiac arrhythmia, with cardiac hypertrophy, coronary artery hypogenesis, obesity and petroleum hydrocarbon vapors

What is Flowback?

- Process fluids from wellbore return to the surface and are collected after hydraulic fracturing is completed.
- Returned fluids can contain volatile hydrocarbons from the formation and treatment chemicals used during hydraulic fracturing.
- Risks for exposures: measuring flow, gauging tanks, working around tanks and process fluids

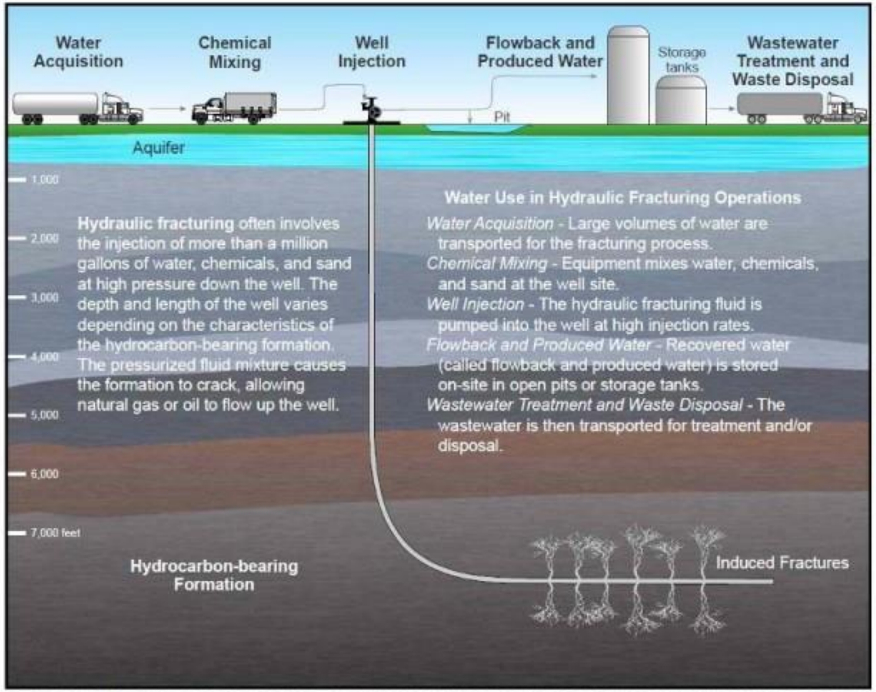


FIGURE 6. ILLUSTRATION OF A HORIZONTAL WELL SHOWING THE WATER LIFECYCLE IN HYDRAULIC FRACTURING

Slide: CDC/NIOSH

Typical Well Site

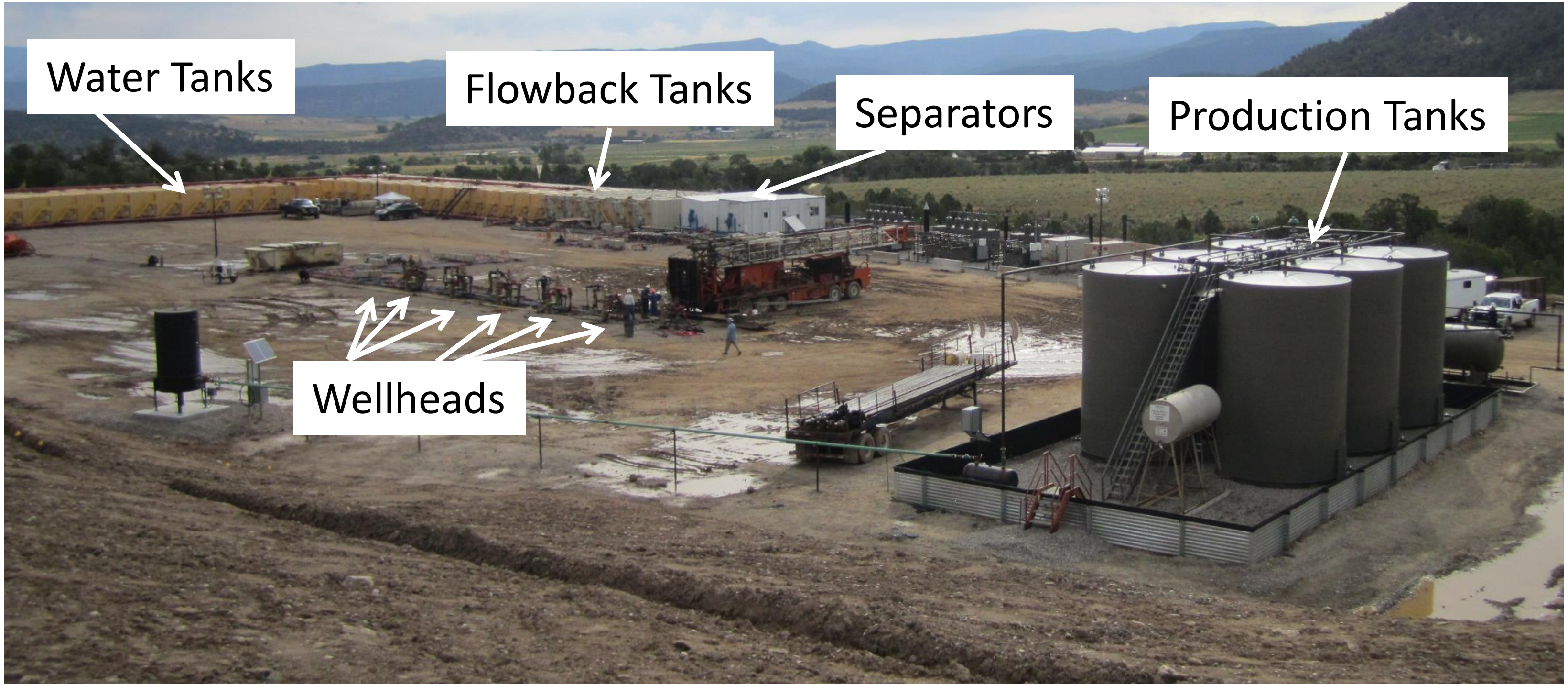


Photo: CDC/NIOSH

Light Hydrocarbon Exposures During Tank Gauging and Sampling

- Manual Gauging
- Sample Collection
- Gauging Tape/Reel/Stick

- Document production rates
- Assess load-out needs
- "Pumpers" gauge multiple locations throughout the day.

Flowback Tank Gauging

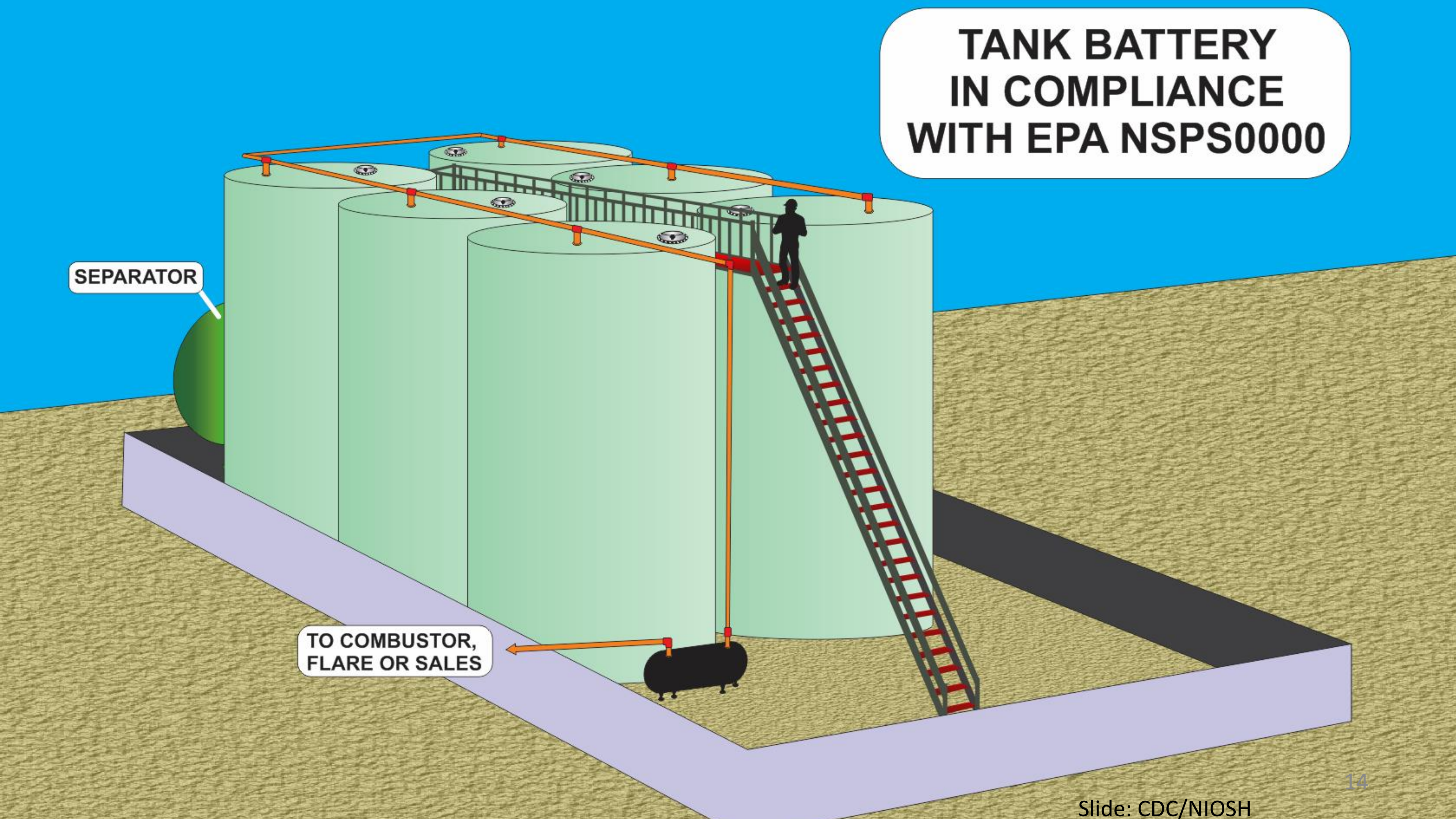
Photos: CDC/NIOSH

Thief Sampling

EPA New Source Performance Standards (NSPS OOOO) Controls

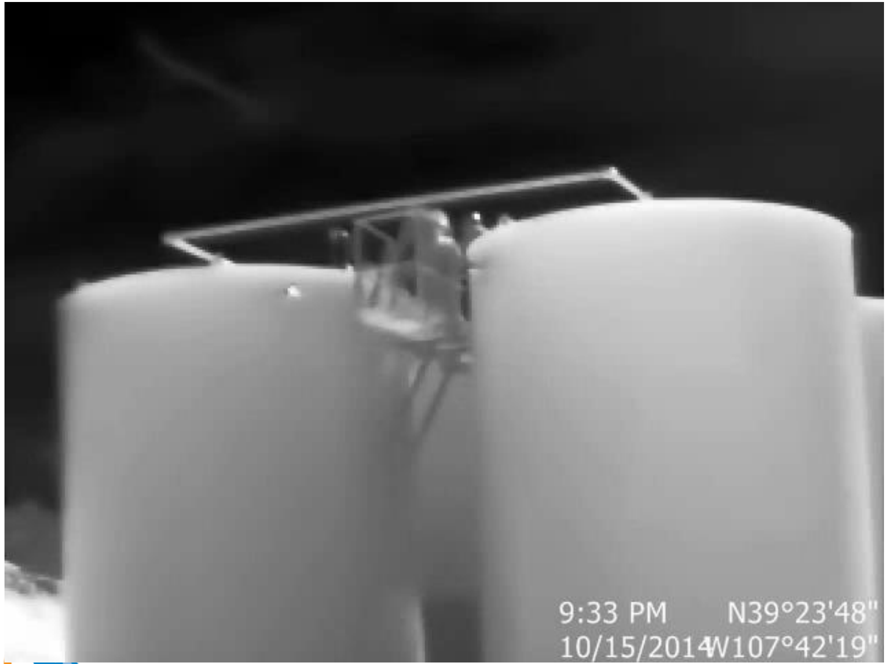
April 2012

- Control emissions from headspace by tightly sealing tanks
- Headspace in multiple tanks in a battery are connected
- Pressure (4-12 $oz/inch^2$) is required for burner/flare/VRU operation,
- Headspace typically excludes oxygen for flammability control, rich atmosphere can be result of vapor pressure of tank contents or “sweep” gas (typically methane)



Slide: CDC/NIOSH

Light Hydrocarbon Exposures During Tank Gauging



Videos: CDC/NIOSH

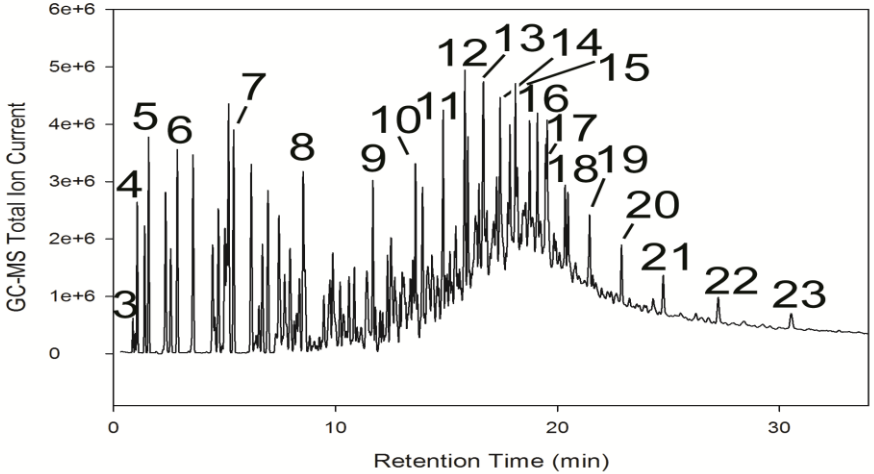
Poor work practices routinely observed

Employee Interviews

- During interviews <u>all</u> employees described cases where chemical exposures caused light-headedness and weakness of knees requiring the need to sit down and rest until symptoms disappeared.
  - Increased incidents when hatches are “fluttering” due to higher gas pressures

Light Hydrocarbon Exposures During Tank Gauging

- Bulk Air Sample
  - Breathing Zone
- Benzene, Cyclohexane, Ethyl Benzene, Heptane, n-Hexane, Pentane, Toluene, Xylene, Propane, Butane



Substance	OSHA 8-hr TWA (ppm)	OSHA Ceiling (ppm)	OSHA Max Peak above Ceiling for 8-hr Shift (ppm)	NIOSH IDLH (ppm)	Cal/OSHA PEL (ppm)	NIOSH REL (ppm)	ACGIH® 2016 TLV® (ppm)
Benzene (Z-2, .1028 exclusion for O&G)	10	25	50 (10 min)	500	1 5 (ST)	0.1 1 (ST)	0.5 2.5 (ST)
n-Butane	None	None	None	1,600 (10%LEL)	800	800	1000 (ST)
Cyclohexane	300	None	None	1300 (10%LEL)	300	300	100
Heptane	500	None	None	750	400 500 (ST)	85 440 (ST, 15min)	400 500 (ST)
N-Hexane	500	None	None	1100 (10%LEL)	50	50	50
Pentane	1000	None	None	1500 (10%LEL)	1000	120 610 (C, 15min)	1000
Propane	1000	None	None	2100 (10%LEL)	1000	1000	Appx. F TLV Book

Sampling Results

Area grab samples ~1' above hatch during gauging, only includes analytes measured >1,000 ppm; breakthrough observed

Analyte	Concentration (ppm) (Average of 3 Replicate samples)	IDLH (ppm)	Severity
Propane – Plume 1 Propane – Plume 2	41,678± 12,041, RSD=28% Proportion of total hydrocarbons = 19% 44,232 ± 5,801, RSD=13% Proportion of total hydrocarbons = 25%	2,100	~20X
n-Butane – Plume 1 n-Butane – Plume 2	107,836 ± 11,891, RSD=11% Proportion of total hydrocarbons = 49% 91,050 ± 5,511, RSD=6.1% Proportion of total hydrocarbons = 51%	1,900*	~57X

*Based on 10% of LEL

Sampling Results

Area grab samples ~1' above hatch during gauging, only includes analytes measured >1,000 ppm; breakthrough observed

Analyte	Concentration (ppm) (Average of 3 Replicate samples)	IDLH (ppm)	Severity
n-Pentane– Plume 1 n-Pentane – Plume 2	35,816 ± 9,476, RSD=27% Proportion of total hydrocarbons = 16% 21,591 ± 5,526, RSD=26% Proportion of total hydrocarbons = 12%	1,500*	~24X
2-Methylbutane – Plume 1 2-Methylbutane – Plume 2	20,692 ± 2,918, RSD=14% Proportion of total hydrocarbons = 9% 14,351 ± 2,426, RSD=17% Proportion of total hydrocarbons = 8%	1,400*	~15X

*Based on 10% of LEL

Sampling Results

Area grab samples ~1' above hatch during gauging, only includes analytes measured >1,000 ppm; breakthrough observed

Analyte	Concentration (ppm) (Average of 3 Replicate samples)	IDLH (ppm)	Severity
n-Hexane – Plume 1 n-Hexane– Plume 2	5,534 ± 2,185, RSD=39% Proportion of total hydrocarbons = 3% 3,594 ± 1,500, RSD=42% Proportion of total hydrocarbons = 2%	1,100*	~5X
2-Methylpentane – Plume 1 2-Methylpentane – Plume 2	5,268 ± 1,482, RSD=28% Proportion of total hydrocarbons = 2% 3,083 ± 881, RSD=29% Proportion of total hydrocarbons = 2%	1,200*	~4X

*Based on 10% of LEL

Sampling Results

Area grab samples ~1' above hatch during gauging, only includes analytes measured >1,000 ppm; breakthrough observed

Analyte	Concentration (ppm) (Average of 3 Replicate samples)	IDLH (ppm)	Severity
3-Methylpentane – Plume 1 3-Methylpentane – Plume 2	2,348 ± 644, RSD=27% Proportion of total hydrocarbons = 1% 1,403 ± 376, RSD=27% Proportion of total hydrocarbons = 1%	1,200*	~2X

*Based on 10% of LEL

Sampling Results

Area grab samples ~1' above hatch during gauging, only includes analytes measured >1,000 ppm; breakthrough observed

Analyte	Concentration (ppm)	IDLH (ppm)	Severity
Total Hydrocarbons – Plume 1, sum of averages Total Hydrocarbons – Plume 2, sum of averages	219,173 179,303	None	None

POSSIBLE TOXICOLOGIC MECHANISMS

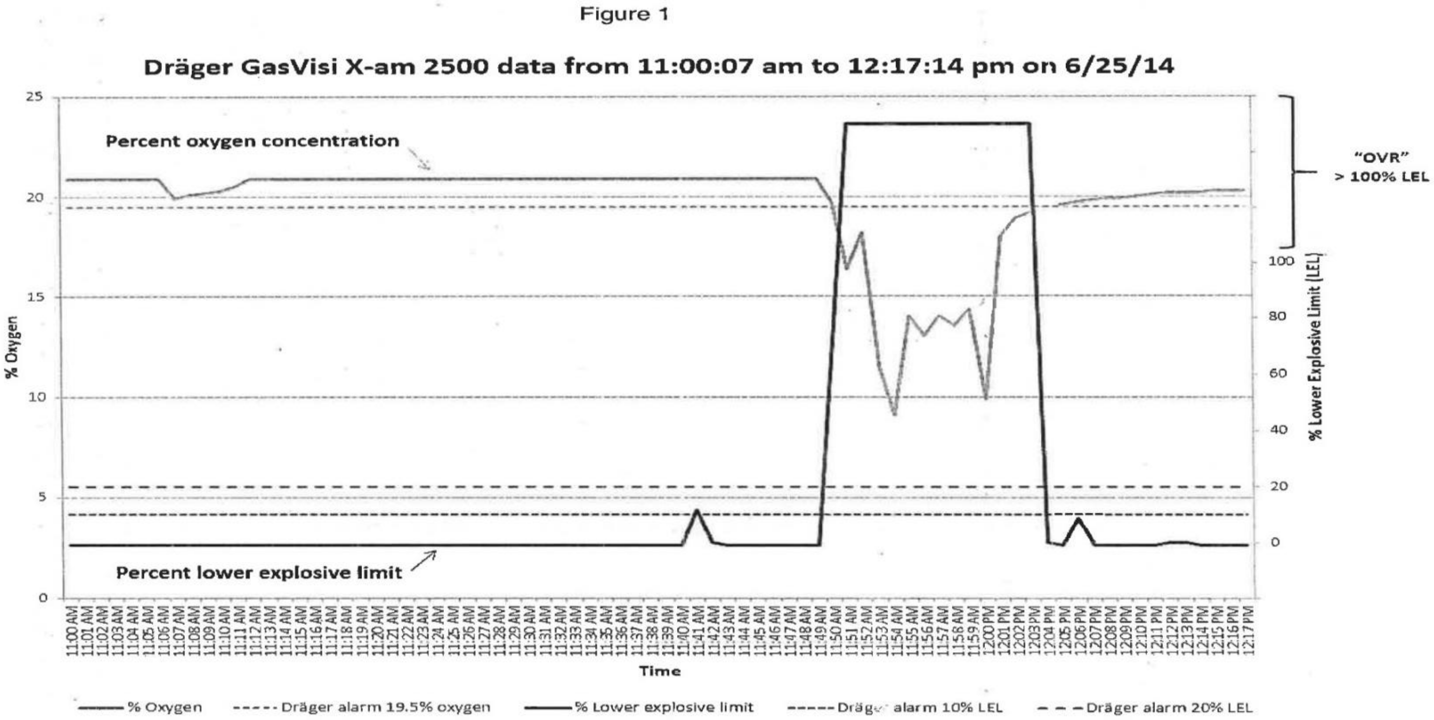
- O_2 deficiency:
  - Oxygen transport interruption to brain
  - Altered mental state, syncope, death
- VOC
  - Narcosis (1899-2001, QSAR predicting narcosis)
  - Altered mental state, syncope, death
- VOC
  - Cardiac sensitization and arrhythmia

TOXICOLOGIC MECHANISMS and EXPOSURE DOCUMENTATION

- O2 deficiency
  - 2010 Montana case: 11.5%
  - 2014 Colorado case: 6%
- VOCs
  - 100% – 105% of LEL
- Cardiac arrhythmia

Fatality Exposure Data

(3 weeks before fatality)

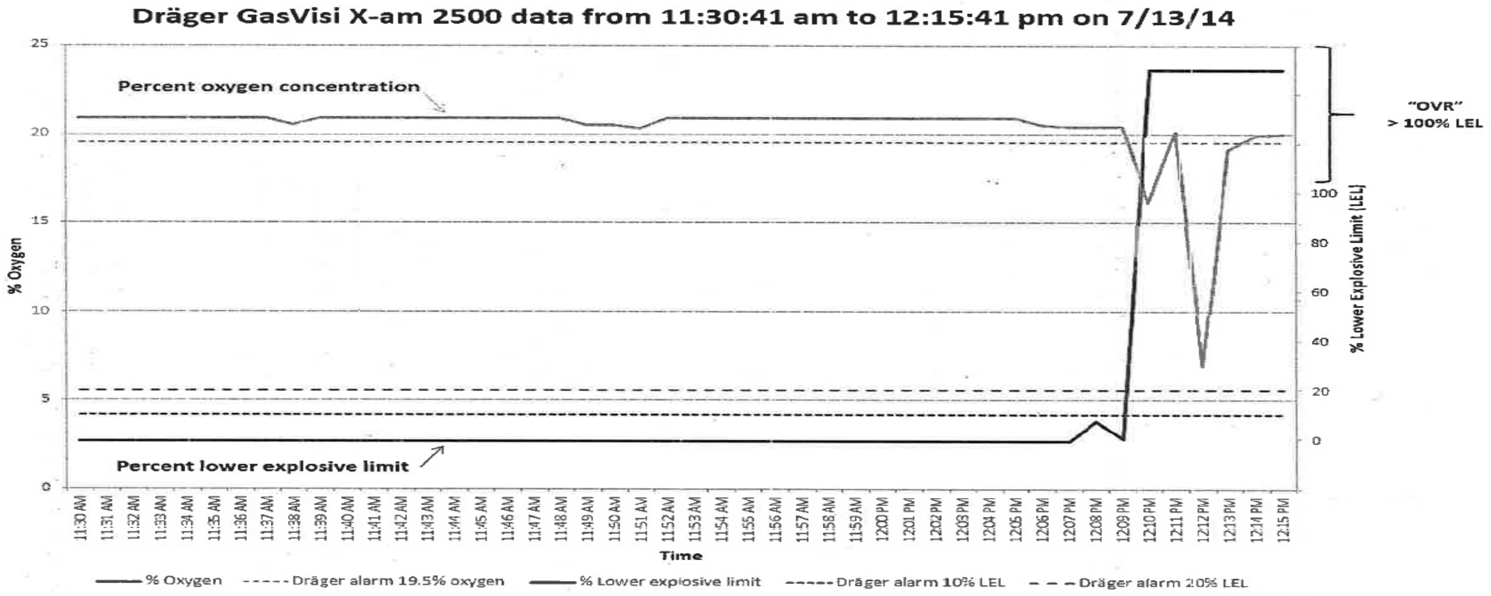


Data: Dr. Michael Kosnett, U of Colorado

Fatality Exposure Data

(day of fatality)

Figure 2



Data: Dr. Michael Kosnett, U of Colorado

Cardiac arrhythmia

- Low O_2 blood levels can exacerbate cardiac ischemia and increase release of epinephrine (adrenaline)
- High concentrations (50,000 - >100,000ppm) of low molecular weight hydrocarbons (butane) can sensitize the heart to epinephrine-induced ventricular fibrillation, a lethal cardiac arrhythmia

Cardiac arrhythmia

- Simultaneous exposure to high levels of low-molecular weight HGVs and low O_2 poses a risk of sudden cardiac arrest

NIOSH-OSHA

HAZARD ALERT

Health and Safety Risks for Workers Involved in Manual Tank Gauging and Sampling at Oil and Gas Extraction Sites

The National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) have identified health and safety risks to workers who manually gauge or sample fluids on production and flowback tanks from exposure to hydrocarbon gases and vapors, exposure to oxygen-deficient atmospheres, and the potential for fires and explosions.

Introduction

Workers at oil and gas extraction sites could be exposed to hydrocarbon gases and vapors, oxygen-deficient atmospheres, and fires and explosions when they open tank hatches to manually gauge or collect fluid samples on production, flowback, or other tanks (e.g., drip pots) that contain process fluids. Opening tank hatches, often referred to as "thief hatches," can result in the release of high concentrations of hydrocarbon gases and vapors. These exposures can have immediate health effects, including loss of consciousness and death.

Recent NIOSH and OSHA research showed that workers could be exposed to hydrocarbon gases and vapors when they work on or near production and flowback tanks. This means workers can face significant health and safety risks when they manually gauge or sample tanks [Esswein et al. 2014; Jordan 2015]. These risks are in addition to the risk of exposure to hydrogen sulfide (H_2S), a well-recognized chemical exposure hazard for those who work in the oil and gas extraction and production industry [OSHA].

NIOSH and OSHA also identified nine worker fatalities that occurred while workers manually gauged or sampled production tanks from 2010–2014 [NIOSH 2015]. Exposures to hydrocarbon gases and vapors and/or oxygen-deficient atmospheres are believed to be primary or contributory factors to the workers' deaths [Harrison et al. 2016].

Working on or near oil and gas production tanks is of particular concern because these tanks may contain concentrated hydrocarbon gases and vapors that are under pressure. When the thief hatch is opened, the release of these pressurized gases and vapors can expose workers. Second, the gases and vapors can displace

A worker collecting a sample from the open hatch of a production tank. Image: J.D. Danni, OSHA.

oxygen, creating an oxygen-deficient environment. Third, the hydrocarbon gas and vapor concentrations can exceed 10% of the lower explosive limit (LEL), creating a chance for fires and explosions. Exposure to hazardous atmospheres and fire/explosion risks will vary depending on tank contents and operating conditions, the presence of ignition sources, and other factors (Box 1, page 3).

What's in this Alert?

This Hazard Alert describes the safety and health hazards when workers manually gauge or sample fluids from production, flowback, or other tanks. It recommends ways to protect workers by eliminating or reducing exposures to hazardous atmospheres, and actions employers should take to ensure that workers are properly aware of the hazards and protected from exposure to hydrocarbon gases and vapors. This alert is a supplement to the OSHA Alliance Tank Hazard Alert released in 2015 [National STEPS Network 2015].

NIOSH & OSHA Recommendations for Manual Tank Gauging and Fluid Sample Collection

1. Implement alternative tank gauging and sampling procedures that enable workers to monitor tank fluid levels and take samples without opening the tank hatch.

2. Retrofit existing tanks with dedicated sampling ports (i.e., tank sampling taps [American Petroleum Institute 2013]) that minimize worker exposures to hydrocarbon gases and vapors, thereby eliminating the need to routinely open thief hatches to sample. These sampling taps should minimize the magnitude of hydrocarbon plumes and should limit the need for workers to access the top of tanks.

3. Install thief hatch pressure indicators to provide an immediate visual indicator of tank pressures and potential hazards. Pressure indicators can show workers the pressure in the tank and allow a trained worker to follow appropriate procedures, such as actuating a blowdown valve, venting gas to a flare, or using appropriate respiratory protection, such as a self-contained breathing apparatus or an air-line respirator.

4. Conduct worker exposure assessments to determine exposure risks to volatile hydrocarbons and other contaminants. Employers may consult an occupational safety and health professional trained and certified in industrial hygiene and who has knowledge and experience with combined flammable gas and vapor exposures to ensure that an appropriate air-sampling strategy is used.

5. Provide hazard communication training in a language that employees understand to ensure that general site workers, tank gaugers and samplers, water haulers, drivers, and others who open tank hatches understand the hazards associated with opening tanks and the precautions necessary to conduct this work safely. These hazards include reduced oxygen environments, flammability hazards and possible ignition sources, and the potential for concentrations of hydrocarbons that can approach or exceed IDLH concentrations. Post hazard signage at access stairs, catwalks, and/or tanks to alert workers about the hazards associated with opening thief hatches and precautions that must be taken.

6. Ensure that workers are trained on — and correctly and consistently use — calibrated multi-gas and oxygen monitors that measure percent LEL and oxygen concentration. Workers should understand the limitations of these monitors as well as appropriate actions to take whenever an alarm occurs or they experience health symptoms (e.g., leave the hazard area, report symptoms to supervisors).

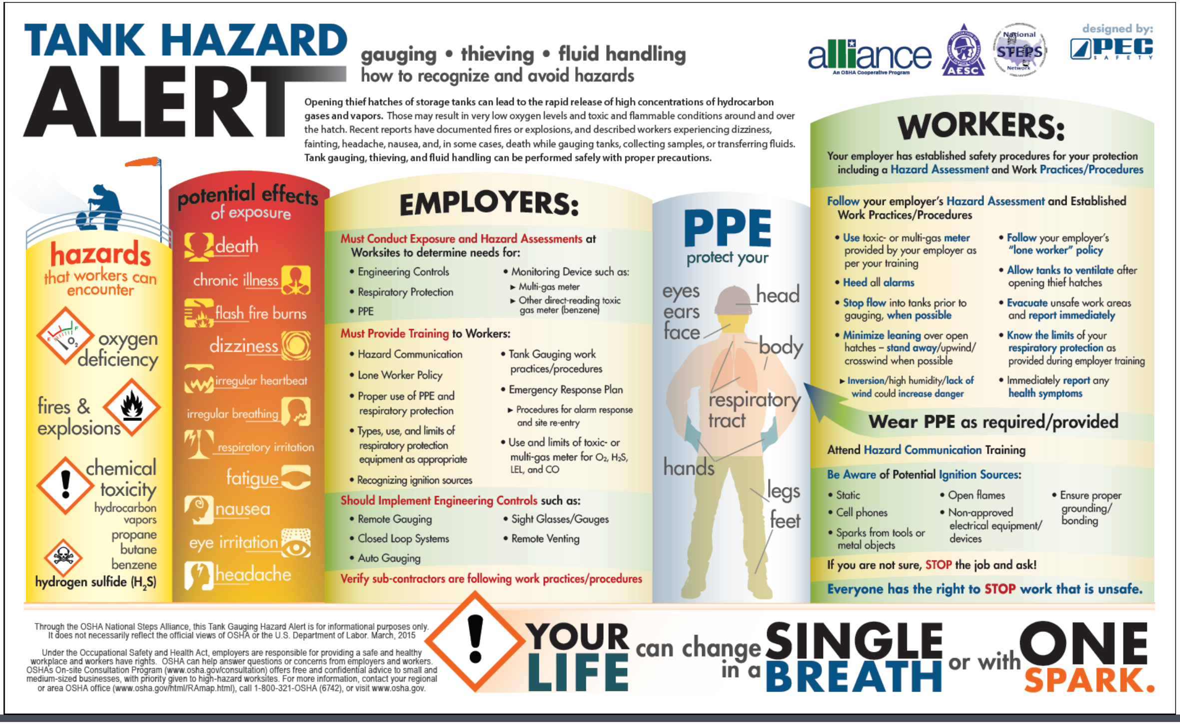
7. Do not permit employees to work alone when tank gauging or working around tanks, thief hatches, or other areas where they may encounter process fluids. Observers should be trained on proper rescue procedures and be stationed outside potentially hazardous areas.

8. As an interim measure, where remote gauging or sampling is not feasible or engineering controls are not implemented, (a) train workers in proper work practices, such as tank-opening procedures, that can minimize risks for exposures, (b) ensure intrinsic safety by proper grounding and prohibiting the use of spark producing devices or equipment, (c) establish administrative controls to reduce the number of times throughout a shift a worker is required to manually gauge tanks, (d) safely reduce tank pressure prior to gauging, and (e) use appropriate respiratory protection, including a supplied air respirator (SAR) and/or self-contained breathing apparatus (SCBA) in areas where IDLH VOC exposures may occur (i.e., during manual tank gauging/sampling). Employers should consult with a trained occupational safety and health professional to determine the appropriate respirator to be used. NIOSH guidance for selecting respirators is at: http://www.cdc.gov/nioshdocs/2005-100/default.html.

9. Wear flame-resistant clothing to protect against burns from fires and explosions. Also, use appropriate impermeable gloves to limit risks for skin exposures to chemicals (e.g., benzene).

10. Establish and practice emergency procedures to provide on-scene, immediate medical response in the event of an incident, such as a collapsed worker, or workers experiencing symptoms of chemical overexposures or exposure to an oxygen-deficient atmosphere.

OSHA/NIOSH/STEPS Alliance Hazard Alert



http://www.nationalstepsnetwork.org/docs_tank_gauging/TankHazardInfographicFinal04_22_15.pdf

Sudden Deaths Among Oil and Gas Extraction Workers Resulting from Oxygen Deficiency and Inhalation of Hydrocarbon Gases and Vapors — United States, January 2010–March 2015

Robert J. Harrison, MD[1]; Kyla Retzer, MPH[2]; Michael J. Kosnett, MD[3,4]; Michael Hodgson, MD[5]; Todd Jordan, MSPH[6]; Sophia Ridl[2]; Max Kiefer, MS[2]

In 2013, an occupational medicine physician from the University of California, San Francisco, contacted CDC's National Institute for Occupational Safety and Health (NIOSH), and the Occupational Safety and Health Administration (OSHA) about two oil and gas extraction worker deaths in the western United States. The suspected cause of these deaths was exposure to hydrocarbon gases and vapors (HGVs) and oxygen (O_2)-deficient atmospheres after opening the hatches of hydrocarbon storage tanks. The physician and experts from NIOSH and OSHA reviewed available fatality reports from January 2010 to March 2015, and identified seven additional deaths with similar characteristics (nine total deaths). Recommendations were made to industry and regulators regarding the hazards associated with opening hatches of tanks, and controls to reduce or eliminate the potential for HGV exposure were proposed. Health care professionals who treat or evaluate oil and gas workers need to be aware that workers might report symptoms of exposure to high concentrations of HGVs and possible O_2 deficiency;

hydrocarbons (propane and butane), and evidence of heavier molecular weight hydrocarbons. No indication of exposure to hydrogen sulfide (H_2S) was identified. Initially, the death was attributed to cardiovascular disease and later to hydrocarbons. The occupational medicine physician subsequently identified a second worker who died from a sudden cardiac event in 2010 while performing tank gauging; H_2S was excluded as a factor. The physician contacted NIOSH and OSHA about these two deaths.

To identify other oil and gas extraction worker fatalities associated with exposure to HGVs, the physician and experts from NIOSH and OSHA reviewed media reports, OSHA case files, and the NIOSH Fatalities in Oil and Gas database. Cases were defined as nontraumatic oil and gas extraction worker deaths occurring during January 2010–March 2015, in which the workers were 1) performing tank gauging, sampling, or fluid transfer activities at oil and gas well sites; 2) working in proximity to a known and concentrated source of HGVs (e.g., an open hatch); 3) not working in a confined space; and 4) not

Questions?

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