Safety Bulletin

U.S. Chemical Safety and Hazard Investigation Board

February 2010

Seven Key Lessons to Prevent Worker Deaths During Hot Work In and Around Tanks

Effective Hazard Assessment and Use of Combustible Gas Monitoring Will Save Lives

No. 2009-01-SB

Depiction of hot work from the CSB's 2008 safety video "Death in the Oilfield."

Emergency response efforts following a June 5, 2006, accident at the Partridge Raleigh Oilfield. Courtesy of Smith County Sheriff's Office.

INTRODUCTION

The CSB has identified over 60 fatalities since 1990 due to explosions and fires from hot work activities on tanks. Hot work is defined as "[w]ork involving burning, welding, or a similar operation that is capable of initiating fires or explosions."[1] Hot work also includes other activities with the potential to create a source of ignition such as cutting, brazing, grinding, and soldering. Workers are potentially at risk not only in the oil and gas industry, where flammables are handled regularly, but also in many other sectors within general industry, such as food production, paper, and wastewater treatment.

This bulletin summarizes 11 accidents – nine of which the agency has investigated – to highlight seven key lessons that were found to be applicable to all or most of the incidents, especially the need for effective hazard assessment and proper monitoring of potentially flammable air concentrations in work areas.

The OSHA hot work standard 29 CFR 1910.252, which addresses welding, cutting and brazing, and a voluntary consensus standard from the National Fire Protection Association (NFPA), define practices that should be implemented during the performance of hot work.

This bulletin, however, focuses on seven key lessons drawn from incidents to emphasize recurring safety issues that deserve special attention during hot work operations. For a broader discussion of general work practices for hot work, the reader should consult these standards, as well as other informative sources listed in the references section of the bulletin.

This bulletin comes after a number of recent hot work accidents that share all or many of the same safety lessons. Seven of the accidents have occurred since July 2008. While each accident has unique features, all resulted from a flammable vapor coming in contact with an ignition source created by welding or cutting that was performed in, on, or near tanks that contained flammables. In some cases, the presence of a flammable material was completely unknown to the workers; in all cases, the workers had no knowledge that an explosive amount of flammable vapor had accumulated. While much can be learned from these hot work accidents, this bulletin highlights seven specific lessons that the CSB concludes will have the greatest safety impact if implemented in the workplace.

"It is usual to test for the presence of flammable gas or vapor with a combustible gas detector before maintenance, especially welding or other hot work, is allowed to start." (Kletz, Trevor, *What Went Wrong*, 1999, 4th ed., p.16)[2]

What is Combustible Gas Monitoring?

Flammable gas and vapor concentrations are generally determined using a portable combustible gas detector, also called an LEL[3] meter. Combustible gas detectors are relatively inexpensive and widely available. Training in LEL instrument use is a key component to effective gas testing and is a critical aspect of an effective hot work safety program.

SEVEN KEY LESSONS FROM RECENT HOT WORK ACCIDENTS

1. **Use Alternatives** – Whenever possible, avoid hot work and consider alternative methods.[4]
2. **Analyze the Hazards** – Prior to the initiation of hot work, perform a hazard assessment that identifies the scope of the work, potential hazards, and methods of hazard control.[5]
3. **Monitor the Atmosphere** – Conduct effective gas monitoring in the work area using a properly calibrated combustible gas detector[6] prior to and during hot work activities, even in areas where a flammable atmosphere is not anticipated.
4. **Test the Area** – In work areas where flammable liquids and gases are stored or handled, drain and/or purge all equipment and piping before hot work is conducted.[7] When welding on or in the vicinity of storage tanks and other containers, properly test and if necessary continuously monitor all surrounding tanks or adjacent spaces (not just the tank or container being worked on) for the presence of flammables and eliminate potential sources of flammables.
5. **Use Written Permits** – Ensure that qualified personnel familiar with the specific site hazards review and authorize all hot work and issue permits specifically identifying the work to be conducted and the required precautions.[8]
6. **Train Thoroughly** – Train personnel on hot work policies/procedures, proper use and calibration of combustible gas detectors, safety equipment, and job specific hazards and controls in a language understood by the workforce.[9]
7. **Supervise Contractors** – Provide safety supervision for outside contractors conducting hot work.[10] Inform contractors about site-specific hazards including the presence of flammable materials.[11]

Example of a combustible gas detector used to test for the presence of flammable gas or vapor.

The importance of these lessons is evident upon review of the 11 accidents briefly described in this bulletin. While each lesson will reduce the likelihood of a catastrophic hot work accident, special attention should be paid to Key Lessons #2 and #3 – the importance of analyzing the hazards and utilizing a combustible gas detector to monitor for a potential flammable atmosphere.

These safety lessons are not new; the Environmental Protection Agency (EPA) in 1997 issued a Chemical Safety Alert warning of recent serious aboveground atmospheric storage tank accidents involving flammable vapor explosions, a number of which were ignited by hot work. The EPA recommended hazard reduction measures that included improved hazard assessment and "proper testing of the atmosphere for explosivity."[12]

While the OSHA standard prohibits hot work in an explosive atmosphere, it does not explicitly require the use of a combustible gas detector. However, other good practice guidance documents from the National Fire Protection Association (NFPA), American Petroleum Institute (API), and FM Global stress the need for gas monitoring to prevent fires and explosions. For example, NFPA 326 requires the use of gas detectors when conducting cleaning, repairs, or hot work on or inside tanks and containers that hold or have held flammables. (All 11 accidents described in this bulletin involved hot work in, on, or near tanks that contained flammables.) Gas testing must be conducted "before and during any hot work, cutting, welding, or heating operations."[13] If the LEL rises to 10%, NFPA 326 requires that all work shall be stopped and the source of the flammable atmosphere located and eliminated or controlled.

For the cases described in this bulletin, an appropriate safety management system, including an analysis of the hazards and the proper use of a combustible gas detector, would likely have alerted workers to the presence of a flammable atmosphere before disaster occurred.

The 11 incidents are divided into two categories: 1) those cases where no gas monitoring was conducted; and 2) those where gas testing was improperly conducted.

"Avoid hot work of any kind in areas handling, processing or storing flammable liquids or gases."

"Use a portable combustible gas analyzer before and during the work. If any detectible readings are obtained, then work cannot begin or continue until the source is found and suitably mitigated such that the concentration is maintained below 10% of the LFL." (FM Global, Property Loss Prevention Data Sheet 10-3, 2006, p.4)

HOT WORK ACCIDENTS WHERE GAS TESTING WAS NOT PERFORMED

In seven of the 11 accidents discussed in this bulletin, no gas testing was performed prior to or during the hot work activities. In these cases, an effective hazard evaluation and the proper use of gas monitoring equipment likely would have alerted workers to the unsafe work conditions.

Exterior and interior views of the fuel tank involved in the hot work accident at A.V. Thomas Produce.

A.V. Thomas Produce

Atwater, California, March 31, 2009
2 Workers Severely Burned

Two employees at A.V. Thomas Produce were using an oxygen-acetylene torch to loosen a fitting on an old fuel tank, which the company hoped to refurbish for field storage of diesel fuel. The workers, however, were unaware that the tank contained residual hydrocarbon liquid and vapor from an unknown prior use. The tank was not cleaned or purged before work began. Shortly after applying heat to the tank, an explosion occurred, blowing the end of the vessel off. Both employees were airlifted to a regional burn center, where they were treated for burns covering 30 to 50% of their bodies.

The facility had no formal hot work program, and no permit was issued for the hot work being performed. No combustible gas testing was performed prior to commencement of the hot work; the company did not have a policy that required it. In addition, many workers were mono-lingual Spanish speakers and had not been trained on safe hot work procedures or on the proper use of gas detectors in their native language.

Applicable Key Lessons

Analyze the Hazards, Monitor the Atmosphere, Test the Area, Use Written Permits, Train Thoroughly

Damage to an oil tanker sustained from the December 2, 2008, explosion at EMC Used Oil Corporation.

EMC Used Oil Corporation

Miami, Florida, December 2, 2008
1 Worker Killed, 1 Injured

An explosion killed a contract welder who was repairing a two-compartment oil tanker and injured another worker at the EMC Used Oil facility. The welder was in the process of welding transfer piping onto the tanker when residual hydrocarbon vapor from the 2,500-gallon rear compartment ignited, causing a powerful explosion.

The surviving worker stated that the contractors did not perform combustible gas monitoring and relied upon the host company to assure that tanks were safe for hot work. However, EMC indicated that it relied on contractors to monitor for gas; although the company owned a multiple gas detector, it was used only for confined space entry. EMC did not have a formal hot work permitting or authorization system.

Applicable Key Lessons

Use Alternatives, Analyze the Hazards, Monitor the Atmosphere, Test the Area, Use Written Permits, Supervise Contractors

Oil storage tanks involved in fire and explosion at MAR Oil.

MAR Oil

La Rue, Ohio, October 19, 2008
2 Workers Killed

An explosion killed two contract workers while they were welding above a series of three interconnected crude oil storage tanks at a MAR Oil site. The explosion occurred when the workers attempted to weld a bracket on top of one of the tanks, near an atmospheric vent. Because the tanks were interconnected, oil flowing into an adjacent tank likely displaced flammable vapor into the tank being welded. The vapor escaped through the vent and was ignited by welding sparks.

The CSB investigators found that combustible gas monitoring was not performed prior to or during the welding. There is conflicting evidence as to whether or not the welding job was authorized by the host company. MAR Oil lacked a formal hot work program that required the hot work be identified in a written permit and be authorized by a person responsible for hot work management. The company had no formal program to select or oversee contractors, and the two contractors lacked documented training on safe hot work practices.

Applicable Key Lessons

Use Alternatives, Analyze the Hazards, Monitor the Atmosphere, Test the Area, Use Written Permits, Train Thoroughly, Supervise Contractors

Philip Services Corporation[14]

Kapolei, Hawaii, October 7, 2008
1 Worker Killed, 3 Injured

A contract welder was killed while welding on a catwalk located over a 9,300-gallon waste oil storage tank at the Philip Services Corporation (PSC). Following an investigation, the Honolulu Fire Department (HFD) concluded that, during the welding, sparks dropped in and around the vent area of the tank. The contents of the tank ignited, resulting in an explosion and fire. The force of the explosion hurled the contract welder about 120 feet, fatally injuring him. Three others were injured, and the tank was thrown about 30 feet.

According to the HFD investigation, a PSC official asserted that the contractors were not authorized to weld within the dike area surrounding the tank, a hot work permit had not been issued for the welding, and combustible gas monitoring was not conducted. Conversely, the contracting company's personnel asserted that they believed that the work was authorized and that PSC had conducted combustible gas monitoring prior to the welding activity.

View of Philip Services Corporation following a October 7, 2008, waste oil storage tank explosion.

Applicable Key Lessons

Use Alternatives, Analyze the Hazards, Monitor the Atmosphere, Test the Area, Use Written Permits, Supervise Contractors

Views of the storage tank involved in the 2008 explosion at Packaging Corporation of America.

Packaging Corporation of America
Tomahawk, Wisconsin, July 29, 2008
3 Workers Killed, 1 Injured

Three workers were killed in an explosion at the Packaging Corporation of America (PCA) fiberboard manufacturing facility while they were welding on a temporary metal clamp to stabilize a damaged flange connection. The flange was located on top of an 80-foot tall storage tank that contained recycled water and fiber waste.

Facility personnel were unaware of the potential presence of flammable gas from the decomposition of the organic material in the tank, and combustible gas monitoring was not typically required or performed prior to starting work. At the time of the accident, three workers were on a catwalk above the tank; one began welding the flange into place when sparks from the welding ignited flammable vapors inside the tank. The resulting explosion ripped open the tank lid, knocking two of the workers to the ground 80 feet below. All three workers died of traumatic injuries. A fourth worker, who had been observing the work from a distance, survived with minor injuries.

The CSB analysis of the tank contents determined that anaerobic bacteria had multiplied inside the tank and water recycle system over time, feeding on organic waste material. The bacteria likely produced hydrogen, a highly flammable gas, which ignited during the welding work. The CSB found that at the time of the incident, PCA supervisors and workers were unaware of the risks of flammable gas production from anaerobic bacteria growth. PCA did not perform a hazard analysis or recognize fiber waste tanks as potentially hazardous. Combustible gas monitoring was not required for the work.

Applicable Key Lessons

Analyze the Hazards, Monitor the Atmosphere, Test the Area

Partridge-Raleigh Oilfield

Raleigh, Mississippi, June 5, 2006
3 Killed, 1 Seriously Injured

On June 5, 2006, contract workers were installing a new pipe between two oil tanks at a rural oilfield when sparks from a welding torch ignited flammable hydrocarbon vapor venting from one of the tanks. That tank and another nearby tank exploded, killing three workers who were standing above the tanks and seriously injuring a fourth. As in the MAR Oil accident, all of the tanks were interconnected by piping and one of the tanks contained crude oil, the source of the vapor that fueled the explosions.

The workers had not performed combustible gas monitoring prior to or during the hot work, instead relying on the unsafe and unreliable practice of using a lit torch to check one of the tanks for flammable vapor. Workers did not empty or isolate the tank that contained crude oil prior to initiating hot work activities.

Neither the contract company nor Partridge-Raleigh required written hot work permits. The contractor company did not provide hot work safety training to employees. Furthermore, Partridge-Raleigh did not have safety requirements for its oilfield contractors.

Tanks involved in the 2006 accident that killed three workers at the Partridge-Raleigh Oilfield.

Applicable Key Lessons

Use Alternatives, Analyze the Hazards, Monitor the Atmosphere, Test the Area, Use Written Permits, Train Thoroughly, Supervise Contractors

The CSB issued a report and safety video on the Partridge-Raleigh accident in 2007. Both the report and video are available from www.CSB.gov.

Bethune Point Wastewater Plant

Daytona Beach, Florida, January 11, 2006
2 Workers Killed, 1 Critically Injured

Two workers were killed and another critically injured in an explosion involving a methanol storage tank at a municipal wastewater treatment facility in Daytona Beach, Florida. The explosion occurred while the three workers were cutting a metal roof located directly above the tank vent. Sparks showered from the cutting torch and ignited methanol vapor escaping from the vent, creating a fireball on top of the tank. A corroded and ineffective flame arrester[15] on the vent allowed the fire to propagate through the device, igniting methanol vapors and air inside the tank, resulting in an explosion.

Daytona Beach public employees were not covered by OSHA standards, which is typical for local and state governments in a number of jurisdictions. The city had no formal permitting system for hot work or non-routine maintenance activities, and workers had not received any training on methanol hazards in the previous 10 years. Combustible gas monitoring was not performed or required.

Depiction of hot work from the CSB's 2007 "Public Worker Safety" video illustrating the accident at Bethune Point.

Applicable Key Lessons

Use Alternatives, Analyze the Hazards, Monitor the Atmosphere, Test the Area, Use Written Permits, Train Thoroughly

The CSB issued a report and safety video on the Bethune Point Wastewater Plant accident in March 2007. Both the report and video are available from www.CSB.gov.

HOT WORK ACCIDENTS WHERE IMPROPER GAS TESTING WAS PERFORMED

The accidents reviewed thus far demonstrate the need to monitor the atmosphere for dangerous levels of flammable vapor. The next four accidents demonstrate how hot work can have catastrophic results when hazard assessments and gas monitoring are performed improperly. The ineffective hazard assessment and monitoring practices used in these cases failed to identify the presence of a flammable atmosphere in the area where hot work was being conducted.

The gasoline storage tank at the TEPPCO McRae Terminal following the 2009 hot work accident that killed three workers.

TEPPCO Partners, LP
Garner, Arkansas, May 12, 2009
3 Workers Killed

Applicable Key Lessons
Analyze the Hazards, Monitor the Atmosphere, Test the Area, Supervise Contractors

Three contractors were using a cutting torch on top of the internal floating roof of a 67,000-barrel capacity gasoline storage tank at the TEPPCO Partners McRae Terminal when an internal explosion blew both the top of the floating roof and the secondary dome-shaped lid off the tank. All three were killed. The contractors were preparing to install a gauge pole. The gauge floats within the pole and measures the quantity of product within the tank. Part of the installation process involved cutting an opening into the floating roof for the pole to be inserted. The torch-cutting activity most likely ignited flammable vapor within the tank.

Prior to commencing work, the contractors had been issued both a confined space permit to enter the tank and a hot work permit to torch-cut the roof. The hot work permit indicated that gas testing occurred at 7:00 am, the start of the work shift. However, no documentation exists indicating that gas testing was conducted after the workers returned from lunch or when they started the hot work activities just prior to the explosion at approximately 2:30 pm. Work atmospheres can change rapidly; gas monitoring needs to be conducted immediately prior to and during hot work activities to ensure that workers are constantly aware of the potential development of an explosive atmosphere.

To effectively use a combustible gas detector, consider the characteristics of the gas (lighter or heavier than air) as well as the appropriate locations and frequency of test. Training of personnel and proper maintenance, adjustment and calibration of the device are also crucial for effective gas detector use. (API Recommended Practice 2009, 2002, p.12)

Potato-washing tank involved in the February 2009 accident at ConAgra Foods.

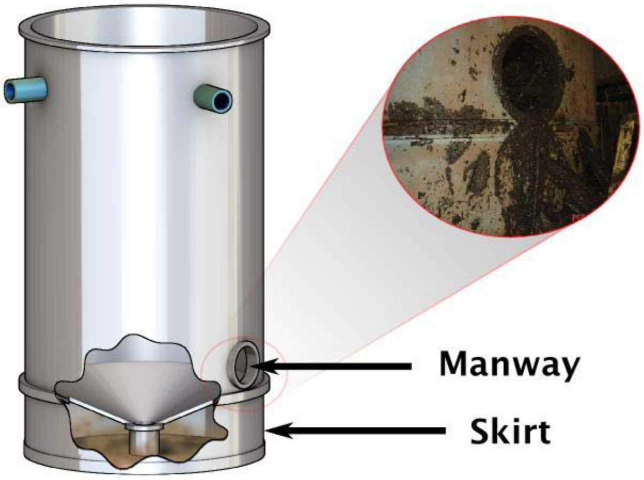
ConAgra Foods

Boardman, Oregon, February 16, 2009
1 Worker Killed

A welding contractor was killed while repairing a 1¼ by ½ inch crack on the bottom of a water clarifier tank at a ConAgra Foods facility. The 23-foot-tall tank was used to separate dirt and debris from wastewater in a potato-washing process area. The tank was open at the top and had a metal skirt around its cone-shaped base. While the welder was working inside the tank, an explosion occurred; the internal tank structures collapsed, resulting in his death.

The CSB determined that approximately 14 inches of debris-laden water had leaked through the crack in the tank and accumulated in the hidden space under the tank skirting. Examination of a sample of the liquid indicated that bacterial decomposition of the organic matter likely produced flammable gas, which was then ignited by the welding activity.

In this case, ConAgra personnel had tested for combustible gas inside the tank prior to the hot work, but only from the entrance of the tank and no flammable gas was detected. Monitoring for combustible gases was not conducted in the immediate area of the crack just prior to the initiation of the welding or in the adjacent space where flammable gas was present. Personnel were inadequately trained on the use of the specific combustible gas detector that was used and no hot work permit had been issued prior to commencing the welding.



Applicable Key Lessons

Analyze the Hazards, Monitor the Atmosphere, Test the Area, Use Written Permits, Train Thoroughly

Motiva Enterprises Refinery

Delaware City, Delaware, July 17, 2001
1 Killed, 8 Injured

A massive explosion destroyed a large storage tank containing a mixture of sulfuric acid and flammable hydrocarbons at the Motiva Enterprises Delaware City Refinery. One contract worker was killed, eight others were injured, and sulfuric acid from collapsed and damage tanks polluted the Delaware River. The explosion occurred during welding operations to repair a catwalk above the sulfuric acid tank, when flammable hydrocarbon vapor was ignited by welding sparks. This resulted in a powerful explosion inside the tank, which had holes in its roof and shell and a deficient inerting system.

On the day of the accident, combustible gas testing was performed only at the start of the hot work, but monitoring was not conducted for the duration of the hot work activities. Throughout the five hours between the last gas test and the explosion, the ambient temperature warmed by 14 degrees. This warming increased the evaporation of hydrocarbons inside the tank, and the resulting flammable vapor leaked out the tank's holes into the work area.

Motiva had a hot work program that included written permits, but the program was inadequate. Hot work was allowed near tanks that contained flammables including those that had known holes due to corrosion. Continuous atmospheric monitoring and the control of welding sparks were not required.

A view of the flammable storage tank involved in the accident at the Motiva Refinery.

The CSB issued its final report on the causes of the Motiva Refinery accident in August 2002. It is available from www.CSB.gov.

Applicable Key Lessons

Use Alternatives, Analyze the Hazards, Monitor the Atmosphere, Test the Area, Supervise Contractors

Pennzoil Refinery

Rouseville, Pennsylvania, October 16, 1995
5 Killed

While this case was not investigated by the CSB because the agency was not yet funded and operational, the catastrophic nature of this hot work accident and the lessons learned from it support the case's inclusion in this bulletin. An explosion and fire resulted during hot work activities, killing five employees; the ensuing fire forced the evacuation of the refinery and nearby residents.

Applicable Key Lessons

Analyze the Hazards, Monitor the Atmosphere, Test the Area

The EPA investigated the incident and found that a welding operation was in progress on a service stairway located between two liquid storage tanks that contained mixtures of waste hydrocarbons and water. The explosion was attributed to the ignition of flammable vapor from one of the tanks. The EPA report found that "the tanks containing combustible or flammable vapors were not thoroughly isolated from the hot work site …. Although combustible gas testing prior to the start of hot work early in the morning indicated vapors were not present, gradual warming could make the presence of combustible vapors more likely."[16] According to the report, gas monitoring was apparently not repeated during the midmorning hours when the explosion occurred. The EPA recommends that facilities evaluate the need for continuous combustible gas monitoring during hot work activities.

CONCLUSION

Although the hazards of hot work are well established and both regulatory and good-practice guidance exist, frequent deaths and serious injuries continue to occur in hot work-related fires and explosions. The CSB has found that hot work is one of the most common causes of worker deaths among accidents it investigates. Following the seven key lessons in this bulletin – along with other good safety practices – can prevent deaths and injuries from hot work.

In particular, host companies, contractors, permit writers, welders, and other maintenance workers should effectively analyze the hazards and conduct combustible gas monitoring before and during hot work to provide advance warning of flammable atmospheres. Training on the proper use of such devices is imperative for future hot work accident prevention.

REFERENCES AND ADDITIONAL INFORMATION

American Petroleum Institute (API). *Safe Welding, Cutting and Hot Work Practices in the Petroleum and Petrochemical Industries*, Recommended Practice (RP) 2009, Washington, DC, 2002.

Association of Energy Service Companies (AESC). *Hot Work*, Health, Safety, and Environmental Committee Technical Advisory Group publication, retrieved on-line at http://www.aesc.net/pdf/Hotwork.pdf on August 25, 2009.

Environmental Protection Agency (EPA). *Catastrophic Failure of Storage Tanks Caused by Vapor Explosion, Chemical Safety Alert*, EPA 550-G-97-002b, May 1997.

EPA. *Chemical Accident Investigation Report, Pennzoil Company Refinery, Rouseville, Pennsylvania*, March 1998.

FM Global. *Property Loss Prevention Data Sheet 10-3: Hot Work Management*, FM Global, Norwood, MA, 2006.

Kletz, Trevor. *What Went Wrong? Case Histories of Process Plant Disasters*, 4th Ed., Woburn, MA, 1999.

Levine, Steven P. & Thornton James, R. LEL monitoring during hazard surveys for issuance of hot work permits: the need for definitive requirements, *Professional Safety*, February 2004.

National Fire Protection Association (NFPA). *Standard for Fire Prevention During Welding, Cutting and Other Hot Work*, NFPA 51B, 2009.

NFPA. *Standard for the Safeguarding of Tanks and Containers for Entry, Cleaning, or Repair*, NFPA 326, 2005.

Occupational Safety and Health Administration (OSHA). *General Requirements for Welding, Cutting, and Brazing*, 29 CFR 1910.252.

Rescue efforts following the February 16, 2009, hot work accident at ConAgra Foods in Boardman, Oregon.

ENDNOTES

1 NFPA 51B, 2009, p. 51B-5.

2 In *What Went Wrong*, Kletz describes a number of accidents that demonstrate the serious consequences resulting from a failure to conduct combustible gas testing.

3 The LEL, or Lower Explosive Limit, is the concentration of a combustible material in air capable of propagating a flame in the presence of an ignition source. It is also known as the Lower Flammability Limit (LFL).

4 FM Global Data Sheet 10-3, 2006, p. 2-3. OSHA 1910.252 requires moving the hot work or fire hazard to a safe location. This guidance applies to hot work conducted outside of a designated area approved for hot work such as a maintenance shop. If the hot work or hazard cannot be relocated, OSHA requires guards to confine the sources of ignition and the protection of fire hazards. For additional guidance, see NFPA 51B, 2009, p. 51B-6.

5 For more information on conducting hot work hazard analyses, see OSHA's 1910.252(a)(2)(xiv)(A) and (B); NFPA 51B, 2009, p. 51B-6; Levine, S. P. & Thornton J. R., 2004, p. 31-39, and API RP2009, 2002, p. 5.

6 For more information about the recommended use of a combustible gas detector, see FM Global, 2006, p. 4; Levine, S. P. & Thornton J. R., 2004, p. 31-39; and the Association of Energy Service Companies (AESC) safety guidance "Hot Work." Additionally, API RP2009, 2002, p. 12 states "(a) competent person using an appropriate combustible-gas meter should perform tests to determine flammable vapor concentrations before hot work is started." While the API RP2009 applies expressly to the petroleum and petrochemical industries, it provides persuasive guidance to general industry on safe hot work management practices especially where flammables may be present.

7 OSHA in 1910.252(a)(3)(i) prohibits hot work on drums, tanks, and other containers until they have been thoroughly cleaned to remove flammable materials or other substances that when subject to heat may produce flammable or toxic vapors. For more information on proper cleaning and inerting of equipment, see FM Global Data Sheet, 10-3, 2006, p. 4.

8 For more information, see OSHA 29 CFR 1910.252(a)(2)(iv). This regulation prefers but does not require a written permit for hot work; however, good practice guidance NFPA 51B, 2009, p. 51B-6 and API RP2009, 2002, p. 13 both recommend written work permits for hot work. However, for facilities covered under OSHA's Process Safety Management Standard, 1910.119 a permit is required for hot work conducted on or near a process covered by the standard (1910.119(k)(1)).

9 OSHA 29 CFR 1910.252(a)(2)(xiii)(C); NFPA 51B, 2009, p. 51B-5; and FM Global Data Sheet 10-3, 2006, p. 4 require training on hot work safe practices.

10 FM Global Data Sheet 10-3, 2006, p. 8 states: "FM Global loss history shows the risk of fire can increase over 100% when outside contractors are involved in hot work without facility supervision."

11 OSHA 29 CFR 1910.252(a)(2)(xiii)(D) requires and NFPA 51B, recommends that management inform all contractors about the presence of all flammable materials, hazardous processes, and potentially hazardous conditions.

12 EPA, *Catastrophic Failure of Storage Tanks Caused by Vapor Explosion*, May 1997, p. 4.

13 NFPA 326, 2005, p. 326-8. The text of NFPA's general hot work standard 51B does not require combustible gas testing but the Explanatory Material of 51B (A.5.3) references NFPA 326.

14 The CSB did not deploy investigators to the Philip Services Corporation site in Hawaii but reviewed case evidence, including a report provided by the Honolulu Fire Department, Incident Report 2008-0038474-000.

15 Flame arresters are safety devices that, when properly maintained, stop a flame while allowing gases and vapors to flow freely.

16 EPA, 1998, *Chemical Accident Investigation Report, Pennzoil Company Refinery*, p. iii.