More on Vapor Cloud Explosions and Fires

The Chemical Safety Board, which is the federal organization that investigates chemical accidents at facilities in the United States, has recently identified two types of accidents that are occurring somewhat frequently resulting in death. That organization is recommending changes in industry standards and also regulations to minimize accidents, but first responders also need to recognize the situations. Both kinds of accidents involve natural gas or hydrocarbon vapors which contact an ignition source resulting in explosion and fire. One class of accident occurs when industry or power companies purge and vent lines or equipment with natural gas before placing into service. The other accident occurs when unauthorized people (usually teenagers) hangout at unsecured oil and gas production sites.

Kleen Energy Natural Gas Explosion, Middletown CT, Six Workers Killed.

On 7 February 2010 (Sunday), Kleen Energy at Middletown, Connecticut, experienced a catastrophic natural gas explosion which caused six deaths, at least 50 injuries, and significant damage to the billion dollar facility. The U.S. Chemical Safety and Hazard Investigation Board ("Chemical Safety Board") findings on this accident is available through links at their website, http://www.csb.gov/, e.g. http://www.csb.gov/investigations/detail.aspx?SID=91&Type=2&pg=1&.

The explosion occurred at Kleen Engergy's combined-cycle natural gas fueled power plant which was finishing the final stages of construction and beginning startup. By "combined cycle" is meant that natural gas is combusted to drive massive turbines with the residual heat from combustion used to generate steam, which in turn is used to drive more turbines as in a conventional power plant. It is essential that the flue gas (from combustion of natural gas) used to drive the turbines be clean, that is, free of anything that might deposit on the turbine blades. This means that the lines used to convey the natural gas and flue gas must be absolutely free of any debris resulting from construction. There must be pipe cleaning before startup. Kleen Energy used the natural gas available at the site at 650 pounds per square inch pressure to purge their lines venting the gas to the outside air. A total of 15 natural gas blows were completed intermittently over a four-hour period on February 7 prior to the explosion which occurred at approximately 10:15 AM. According to Chemical Safety Board calculations, a little over 2 million standard cubic feet of natural gas were used for purging in the morning with about 400,000 standard cubic feet released 10 minutes prior to the incident. Venting occurred at several outdoor open pipe locations located less than 20 feet off the ground including one as such as shown in figure 1.

The Chemical Safety Board (CSB) investigation (http://www.csb.gov/investigations/detail.aspx?SID=91&Type=2&pg=1&) noted that while Kleen Energy followed written procedures for venting and also took care to remove outdoor ignition sources, work continued inside the main power generation building including welders actively working. The building electric power was on, and diesel-fueled heaters were running. OSHA investigation also noted that several of the 150 workers on site on the day of the explosion had worked in excess of 90 hours during the previous week. Some workers inside the building made a personal decision to exit the building prior to the explosion because they were alarmed by the smell of the natural gas odorant. All six fatalities and 50+ injuries were within the building. As seen by Figure 1, the

natural gas venting may occur in somewhat confined spaces near building structures. The vents were adjacent to the south wall of the building.

The exact ignition source at Kleen Energy was never determined. CSB said that the gas blow itself can be self-igniting, from static electricity or from expelled metal debris sparking against nearby structures. The Lower Explosive Limit for natural gas is 4% natural gas in air.

Figure 1: Natural gas venting during purging of lines, photo taken on Feb. 7 before explosion (used in CSB report)

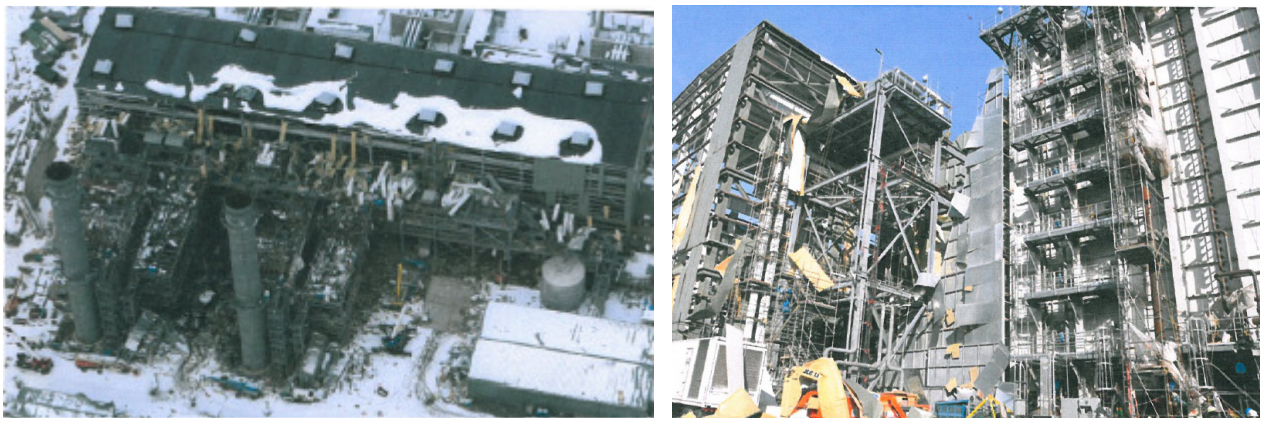

Figure 2. Damaged facility after explosion

Explosion and Fire at Calpine Wolfskill Power Plant, Fairfield California, 26 January 2003

This incident occurred on 26 January 2003 during pre-commissioning of the Wolfskill Energy Center natural gas power plant in Fairfield, California. High-pressure natural gas at approximately 630 psig was used to flush out the gas lines of debris and vented through four-inch open-ended pipe directly to the atmosphere. Seven people were at the site, either directing the operations or observing as in the case of the local fire department. Non-essential personnel were cleared from the area. Fortunately no one was injured when the explosion occurred, which shattered windows a quarter of a mile away and was heard up to ten miles from the site. The debris was projected over the heads of the people at the site and did not hit anyone. The ignition source was not determined, but Calpine's investigation concluded that the explosion was most likely ignited by static electricity. Calpine concluded that the use of natural gas to purge piping while convenient has risks. Calpine facilities now do not allow the use of natural gas to clean piping and instead use compressed air.

Figure 3. Calpine Wolfskill Power Plant, 26 January 2003. Photo from CSB report at http://76.227.217.14/UserFiles/file/FINAL%20Urgent%20Recommendation.pdf.

Figure 4. A gas blow from an electric power plant used to remove debris from piping. The brown cloud represents debris in the lines. Photo, Kleen Energy, 30 January 2010, as used in a CSB report urging changes in regulations and standards, http://76.227.217.14/UserFiles/file/FINAL%20Urgent%20Recommendation.pdf.

The Chemical Safety Board conducted a survey of combined cycle natural gas fueled power plants. Of the 62 responses received, 63% indicated use of "natural gas blows" to clean piping. One response indicated use of flare to destroy flammables vented during natural gas blows. Other facilities used pigging and air flow, air blow, nitrogen blow, chemical and water cleaning, or steam blow or a combination thereof. The organization also concluded that in the case of Kleen Energy significantly more gas was released than was actually needed to clean the piping. They also recommended revising the National Fire Protection Codes 54, 37, and 850, the ASME B31.1 standard, and FM Global's "Natural Gas and Gas Piping" standard to incorporate safer practices. OSHA regulations contain many gaps in release of flammable gas in the vicinity of workers. There are no standards specific to the power industry that address the cleaning of power plant fuel lines. There are safer methods of cleaning fuel lines. Details are at http://www.csb.gov/assets/document/Kleen%20Energy%20Public%20Meeting%20Presentation_6%2028%2010.pdf.

Accidents to Young People Hanging Out at Unsecured Oil/Gas Production Sites

The Chemical Safety Board has identified 26 accidents and 44 fatalities among teenagers and young adults hanging out at unsecured oil and gas production during the period 1983 and 2010, of which 16 deaths occurred since 2003. These deaths were not workers but involved the public less than 25 years of age having access to tanks containing flammable gases and liquids and unaware of the hazards Many of the deaths occurred when the victims apparently brought a cigarette, match, or lighter in contact with vapor from storage tanks. Some recent examples follow:

- 14 April 2010, 9 PM, near Weeletka, Oklahoma. Six young adults driving on a public road noticed an open gate and entered an unmanned oil production site containing four petroleum storage tanks and two brine tanks. The explosion occurred about 10 minutes after the young adults arrived at a site, when a 21-year-old male climbed up the catwalk leading to the top of one of the tanks and opened a hatch and peered inside. The resulting explosion, apparently caused by a lit cigarette or lighter, killed the man. A second explosion occurred in an interconnected tank. Another youth suffered second degree burns. The resulting fire burned for more than three hours before it was extinguished by several responding fire departments using foam. Figure 5, below, shows the tanks after fire departments extinguished the fire.

Figure 5. Oil production site, after fire, from http://www.csb.gov/newsroom/detail.aspx?nid=315.

CSB investigators spent 4 days at the site interviewing witnesses and determining what happened. The victim who was killed lived for a few hours after being engulfed in flames, and was able to describe the accident to emergency response personnel. The site entrance was protected only by an unmarked gate which was described as being wide open on the night of April 14, and generally open and unlocked at other times, and there was no protective fencing. The tank hatches had no mechanism to allow securement, and the catwalk leading to the tank

top was readily accessible. The CSB investigators also observed other oil and gas production sites in the area and found most of them were unsecured and had no warning signs. Oklahoma has approximately 257,000 active and unplugged oil and gas production sites, and requires fencing and warning signs only at sites that have hydrogen sulfide hazards.

- 31 October 2009, 4 AM, Carnes, Mississippi. Two teenagers (16 and 18 year old) were killed while at an unsecured and unattended oil production site when a gas condensate tank exploded. The blast hurled the 20-foot-tall tank 60 yards killing the teens. According to the Mississippi Oil and Gas Board, the explosion likely occurred when the two victims were above the tank which was accessible by a catwalk. The tank contained approximately 14 barrels of oil and had a flammable atmosphere. The site did not have fences, barriers, or warning signs. The oil tank was located near the home of one of the two boys who were killed. The CSB investigating the accident could not determine the ignition source of this incident as there were no surviving eyewitnesses, but teenagers interviewed after the accident said that it was common practice for young people to hang out and socialize at oil production sites. "When we go hang out at an oil site, a bunch of friends and I would usually get a pack of cigarettes and talk about what's been going on during the week. It's like our own little sanctuary where we can just be away from everybody", said one of the teens interviewed and was featured in an 11-minute CSB safety video titled "No Place to Hang Out: The Danger of Oil Sites". This video (figure 6), which was put together by CSB following the Mississippi deaths is available at http://www.safetyvideos.gov/newsroom/detail.aspx?nid=313&SID=0&pg=1&.

Figure 6. CSB safety video, produced after the deaths of two Mississippi teenagers

- 26 April 2010, explosion at about 1:30 AM, near New London , Texas, County Road 111 in Rusk County. Following an explosion, firefighters arriving at the scene found the body of a 24-year-old woman and a badly injured 24-year-old man about 150 to 180 feet from a group of oil well

tank batteries at the explosion site. The ignition source for the explosion was not conclusively determined, but it was believed to be a cigarette lighter that ignited fumes venting above the tank batteries, and the couple had climbed on top of the tank and lit a cigarette. The tank that exploded was mostly empty. Details and photos are available at KLTV, New London, http://www.kltv.com/Global/story.asp?S=12374145.

The example accidents reveal a similar pattern. Unauthorized people enter an unsecured oil production site usually at night. Unaware of hazards, an ignition source, usually a cigarette or lighter or match contacts flammable vapors resulting in a vapor cloud explosion and fire. With support from some of the families of young people killed, the Chemical Safety Board is advocating legislation that oil and gas production facilities be secured to prevent unauthorized access.

Lessons Learned and Relevance to PEAC Tool

Both examples describe situations where a flammable vapor or gas concentration exceeded the lower explosive limit concentration. The flammable vapor or gas ignited when it contacted an ignition source. This is basic knowledge for anyone who has to deal with hazardous materials. The PEAC tool organizes information in one package necessary to make correct decisions, for example, flammability and lower and upper explosive limits, and safe distances for "worst case" blast in case of a vapor cloud explosion. Other informational packages are available and can be used, but the PEAC tool organizes the information in one package and is easy to use under stressful situations encountered by first responders.

The examples given here demonstrate a key missing ingredient. People responsible for making decisions must recognize potentially hazardous situations and not allow distractions to get in the way. This knowledge comes with experience. Kleen Energy recognized that that the lower explosive limit for natural gas was 4% by volume in air and excluded personnel entry at outdoor locations where natural gas venting took place, but was also under pressure to bring the new power plant on line. Some of the vent lines (figure 1) were in confined areas near the power generation building where about 150 workers were assigned to other projects necessary to bring the power plant on line, and the workers were not told of the outdoor flushing activities. Furthermore, not wanting to risk a later shutdown because of deposits on turbine blades, Kleen Energy flushed much more natural gas through the lines than what was necessary, according to the Chemical Safety Board. Also, inherently safer gases (nitrogen, steam flush, etc.) could have been used for flushing when the facility was being designed. The Chemical Safety Board also found codes and standards deficient in addressing the problem of performing line flushes.

In the case of the Wolfskill Power Plant incident, decision makers recognized the hazards and only allowed essential personnel to be on site. But venting occurred in a somewhat confined

area allowing explosive mixtures of air and natural gas to build up. The ignition source was apparently a spark generated due to line debris striking a metal surface.

Companies may provide oil and gas production workers information on hazards of flammable gases, liquids, and vapors, and prohibit smoking. But sites also need to be secure against unauthorized access by the public. As a minimum, vent ports or covers on tanks and tank catwalks should be secure and warning signs displayed. The Chemical Safety Board reviewing codes and standards found a mix of "no standards or instructions" to varying degrees of specifications for securing a site depending upon the location. Some California locations require fencing around the production facility with bobbed wire at the top to make it difficult to gain access by climbing over the fence. The tendency of oil and gas production facilities is to comply with local codes and standards if they are aware of them but do no more.

Many facets must be brought together in the decision process for recognizing hazardous situations.