Real-World Explosions and Fire Examples: Part 2

In the July 2009 Newsletter article we took a snapshot look at some real-world example explosions involving chemicals including fuels, several at industrial facilities. We concluded that the PEAC tool can be used by responders as a rapid first assessment of an incident or to help recognize a potentially dangerous situation where things can go wrong and what action can be taken. We will examine three more real-world accidents in this newsletter.

Ammonium Perchlorate Explosion and Fire, Henderson NV, 1988, 2 killed, 372 injured

Information from: United States Fire Administration report: Fire and Explosions at Rocket Fuel Plant, Henderson NV, available at http://www.rocketmotorparts.com/resources/usfa-fema_pepcon_rpt.pdf. The United States Fire Administration, created in 1974, is now part of the Department of Homeland Security.

The presence of a large quantity of a very strong oxidizing agent (ammonium perchlorate) and fuels (high-density polyethylene plastic containers used to contain the ammonium perchlorate; fiberglas; also a 16-inch pressurized natural gas line) were the raw ingredients of a chain of events leading to one of the worst industrial explosions in U.S. history. Ammonium perchlorate is not normally explosive by itself at room temperature, but the combination of a fuel and this oxidant results in an explosive mixture even if the fuel is in trace amounts, and the chemical will burn and may detonate at hot temperatures. The incident occurred on 4 May 1998 at the Pacific Engineering Production Company of Nevada (PEPCON) plant in Henderson, Nevada.

Top: You-Tube video clip taken by a television engineer less than a second after the largest detonation (shock wave boundary line defined by white/black areas).

PEPCON was under contract to produce ammonium perchlorate to be used as an oxidant for rocket fuel for the NASA Space Shuttle. For reasons that this writer was unable to determine, PEPCON continued production of ammonium perchlorate following the Space Shuttle 1986 Challenger disaster which resulted in suspension of space flights and apparently little demand for the oxidant. Without instructions from NASA to cease production, PEPCON apparently continued to produce the oxidant storing it in 55-gallon high-density polyethylene drums after their existing aluminum storage bins were filled to capacity. The polyethylene drums were also used as part of blending operations in meeting customer specifications. At the time of the disaster, on 4 May 1988, an estimated 4000 tons of ammonium perchlorate were stored at the facility. Another report estimated 10.5 million pounds. The raw ingredients for ammonium

perchlorate manufacture, which included anhydrous ammonia, hydrochloric acid, nitric acid shipped by rail and various chlorate compounds were also at the site.

According to the United States Fire Administration report, a fire originated around a drying process structure between 11:30 to 11:40 AM on 4 May 1988. The fire was initiated by use of a welding torch to repair a damaged steel frame with fiberglass walls, which caused the fiberglass to ignite. The employees initially tried in vain to put the fire out using a garden hose, but the flames quickly spread to an adjacent storage area containing ammonium perchlorate in high-density polyethylene plastic containers. This began a series of explosions starting at 10 to 20 minutes after ignition. The 75 employees at the facility immediately evacuated fleeing on foot and in cars. The company Comptroller stayed behind to notify the Clark County Fire Department and apparently assist evacuation. The employees of a nearby business, Kidd & Co. (produces marshmallows), also evacuated. The quick evacuation from the area saved many lives before the major explosion occurred, apparently when the 300 psig natural gas line directly under building containing the exploding ammonium perchlorate ruptured and "exploded" with more ammonium perchlorate. The only two deaths were the company Comptroller who remained behind and a wheelchair-bound employee who was unable to escape with no one providing assistance. Most of the 372 people injured were the result of flying glass.

The Fire Chief of the City of Henderson approached the scene as employees were escaping. At about 11:54 AM, the first of two major explosions sent a shock wave that shattered the windows of his car and showering him and his passenger with glass. A fleeing driver of a heavily damaged vehicle warned the Fire Chief of possible subsequent larger explosions; the Fire Chief turned around and as he fled, the second explosion (four minutes after the first explosion) nearly destroyed his car injuring him and his passenger with flying glass. A responding Henderson Fire Department vehicle was also severely damaged with firefighters injured with flying glass. Nearby firefighting units assisted the injured firemen at a staging area 1.5 miles from the scene. The explosions (seven in all) and fires were beyond their firefighting activities. The natural gas company shut off the natural gas supply at 12:59 hours at a valve about one mile away.

Both the PEPCON facility and the Kidd & Co. facility were completely destroyed by the explosions and fires. The explosions created a crater 15 feet deep and 200 feet long in the ammonium perchlorate storage area. The largest explosion was equivalent to 1000 tons of TNT. Broken windows, doors blown off, and injuries from flying glass were reported up to 10 miles away. Moderate structural damage to buildings was reported 3 miles away. A Boeing 737 on final approach at McCarran International Airport, 7 miles away, was buffeted by the shock wave; windows were cracked and doors pushed open at the airport. The incident caused over $100 million in damages. Bankrupted PEPCON settled for $71 million in a courtroom battle involving dozens of insurance companies and over 50 law firms.

A television engineer doing maintenance on a television tower at a nearby hill 2 miles away caught the explosions and fireball on tape. The video footage has been widely shown, and it captures the shock wave for the largest explosion. The video footage is available at YouTube and MySpace and elsewhere at several web sites: http://www.youtube.com/watch?v=oc_nnnBmMbM.

http://www.youtube.com/watch?v=2K0cEX9ex3U.

http://www.youtube.com/watch?v=PMNKDP8bH2I&feature=related.

http://vids.myspace.com/index.cfm?fuseaction=vids.individual&VideoID=1253314.

http://patdollard.com/2008/06/pepcon-explosion-henderson-nv-1988/.

http://www.chemaxx.com/explosion1.htm.

The PEAC tool carries a warning that ammonium perchloride may explode in fires. At ordinary temperatures, the chemical will not burn, but the autoignition temperature is 240°C (464°F), and the chemical may detonate.

White crystalline solid; may be used as a solid oxidizer for an explosive mix

NFPA Information

Health (Blue): 1 Slightly Hazardous
Fire (Red): 0 Will not burn
Instability (Yellow): 4 May Detonate
Special (White): Oxidizer

Physical and Chemical Properties

Formula: NH_4ClO_4

Molecular Weight: 118
Flash Point: May Explode in Fires
Auto Ignition Temp.: 240°C
Melting Point: 240°C
Solid Specific Gravity: 1.95

The PEPCON facility was originally built in the 1950's in an isolated area well away from businesses and residential areas. But the Las Vegas metropolitan area grew, and eventually the town of Henderson completely surrounded the facility while PEPCON remained in an unincorporated area within Clark County. The closest residential area was 1.5 miles away, but other businesses were closer. The 16-inch natural gas pipeline under the facility served Las Vegas.

The United States Fire Administration report was critical of land use decisions. The magnitude of the incident was much greater than had been contemplated by urban planners. Urban planner and others in decision making capacity must be aware of worst case scenarios of accidents that can happen.

The United States Fire Administration report was also critical of hazardous materials training given to firefighters. Some aspects of hazardous materials training are very specialized, and specialized expertise must be brought into play when unusual or "exotic hazardous materials" are known to be present in a plant or location. The "worst case" situation needs to be anticipated. If the Fire Chief had not been warned of possible big explosions at the last moment by fleeing employees, the entire fire department could have been wiped out. Fortunately, the Fire Chief made the correct decision to turn around and withdraw, and firefighters set up a staging area 1.5 miles away to provide emergency treatment.

The industrial facility was not rebuilt. The area was converted to residential development.

Hydroxylamine Explosion, Lehigh Co., PA, 1999, 5 Killed, 14 People Injured

This incident was investigated by the Chemical Safety Board. Their final report 1999-13-C-PA is available at http://www.csb.gov/assets/document/Concept_case_study.pdf.

Photo by Tom Volk, "The Morning Call", used in the CSB Report

On 19 February 1999, at 8:14 PM, a process vessel containing several hundred pounds of hydroxylamine exploded at the Concept Sciences. Inc. (CSI) production facility in the Lehigh Valley Industrial Park near Allentown, PA. Four CSI employees and one employee of an adjacent business were killed; 14 people were injured including six firefighters. The incident occurred during startup of a new production facility for this chemical. The CSI facility was located close to other commercial buildings which were damaged by the blast.

The CSI process involved mixing hydroxylamine sulfate with potassium hydroxide to produce hydroxylamine as a 30% slurry in water. The precipitated potassium sulfate solids are then filtered out leaving a 30% solution of hydroxylamine in water. The next step is to concentrate the solution to 50% using a vacuum distillation system and a heat exchanger column operating at 140°F, followed by ion exchange purification of the distillate, and final product packaging. CSI also had a ready customer for the 50% aqueous product (Ashland Chemical Company), who planned to use it to strip process residues from integrated circuits.

The PEAC tool shows that hydroxylamine is an unstable solid which may explode if heated and may detonate:

Hydroxylamine
CAS 7803-49-8

White crystals or colorless liquid, hydroscopic, fish-like odor

NFPA Information

Health (Blue): 2 Hazardous
Fire (Red): 0 Will not burn
Instability (Yellow): 3 Shock/Heat may Detonate

Physical and Chemical Properties
Formula: NH_2OH
Molecular Weight: 33
Flash Point: Explodes above 140°C
Boiling Point: 70°C
Melting Point: 34°C

Laboratory distillation tests showed that explosive solid crystals of hydroxylamine form if the solution concentration exceeds 80%, and there is danger of fire and explosion if concentrations exceed 70%. But CSI experienced problems with its heat exchange system in the distillation column, and as a result, the concentration of hydroxylamine in the charge tank (part of the distillation system) was recorded as 86% somewhere between 7:00 and 7:15 PM on 19 February 1999. At 7:45 PM, the distillation column was shut down and cleaned with 30% hydroxylamine to wash away any crystals that may have formed. An engineering supervisor

was called at his home; he arrived at the facility at 8 PM. Exactly what happened after that was not clear, but at 8:14 PM the system exploded killing four CSI employees and another person in a nearby business. Two CSI employees survived the blast with moderate to serious injuries. Six firefighters and two security guards suffered minor injuries. Four people in a nearby building were also injured. More people could have been injured or killed if it were not for the fact that the explosion occurred on a Friday evening when most businesses were vacated.

Building damage at charge tank area, from CSB report

The explosion damaged 10 buildings within the Lehigh Valley Industrial Park and several residences. Total property damage was estimated between $3.5 and $4 million. Sections of the distillation equipment were thrown more than 1000 feet. The end manway of the charge tank was thrown 200 feet. A crater approximately 6 feet wide, 26 feet long, and 16 inches deep was found in the concrete floor where the charge tank had been located.

An OSHA contractor, Hazards Research Corporation, investigating the accident estimated that the hydroxylamine in the charge tank that exploded was equivalent to 667 pounds of TNT.

The CSB report stated that CSI knew of the explosive hazards of 80% (and higher) hydroxylamine solution, but the plant was the first of its kind in the U.S., and it was being brought on line for the first time. CSI apparently did not anticipate or allow for startup problems.

The CSB report noted another accident which occurred later in Gunma, Japan, on 10 June 2000, at the Nissin Chemical Company. Nissin used a process similar to the CSI process for concentrating hydroxylamine solution from 30% to 50%. After a shutdown for 5 hours to replace oil in a vacuum pump, the distillation was restarted. The concentration of hydroxylamine reached 85% 30 minutes after startup resulting in an explosion which killed 4 people and injured 58 others. Later studies (cited in CSB report and from various papers by Koseki available on the Internet) demonstrated the explosive hazard of 85% hydroxylamine solution in water, and while 50% hydroxylamine solution is usually “safe”, even a 50% solution could be unstable if contaminated with several parts per million of iron.

On 9 November 2000, a Federal Grand Jury indicted the president of CSI for alleged criminal violations of OSHA’s Process Safety Management (PSM) standard (see 20 CFR part 1910.119) which regulates facilities with any process that contains 2500 or more pounds of hydroxylamine. CSI contested the indictment, and on 5 September 2001 as the result of the defendant’s Motion to Dismiss, a U.S. District Court dismissed the case. The District Court said that OSHA’s PSM regulation is ambiguous as to whether CSI’s hydroxylamine production

process is covered, and informal interpretations issued by OSHA are prohibited from being used against the defendant in a criminal case.

The CSB report was critical of CSI for failure to conduct a Process Safety Analysis in the location of the facility. There were no standard engineering drawings, only basic sketches and process flow diagrams. Facility siting should consider all potential hazards (e.g. fire, explosions toxic material release) to people and the environment. This is part of the process design. The building itself where the explosion took place was also shared by other businesses.

The CSB report also noted that CSI first considered a site for the process in nearby Northampton County. But on 30 March 1998, CSI was notified by the zoning officer that CSI would not be issued a building permit or certificate of occupancy because the industrial park did not permit a manufacturing facility "whose primary use involved chemical manufacturing without conditional approval. No such conditions were imposed for Handover Township in Lehigh County. CSI provided Handover Township with MSDSs for raw materials and finished products, but did not alert the township as to process hazards.

Fire and Community Evacuation, Apex, North Carolina, 2006, No deaths, 30 people Sought Medical attention

This incident was investigated by the Chemical Safety Board. Their final report 2007-01-1-NC is available at http://www.chemsafety.gov/assets/document/EQFinalReport.pdf.

Photo from Wake County Fire/Rescue Services used in CSB Report of destroyed Environmental Quality Company facility. Notice stacked drums.

The incident began at 9:38 PM on 5 October 2006 when a citizen driving past the Environmental Quality Company (EQ) hazardous waste facility in Apex, North Carolina, called "911" to report a haze with a "strong chlorine odor". The Apex Fire Department responding to the call confirmed the haze and chlorine odor, but could not determine immediately the source. The Apex Fire Department Chief, acting as the Incident Commander, sent two firefighter teams in personal protective equipment to investigate the source.

The firefighters located the source as coming from one of the hazardous waste bays at the EQ facility. The facility itself was vacant and was protected by a chain-like fence with a padlocked gate. A small "sofa-sized" fire was in the bay. However, the fire grew and spread to the flammable hazardous liquid storage area in the next few minutes causing 55-gallon drums to 'explode" sending fireballs hundreds of feet into the air. The EQ facility eventually collapsed as seen in the photo. About 30 people including 13 first responders sought medical attention at local hospitals for respiratory distress and nausea, although none were admitted.

Because of the unknown nature of the chemicals, the Incident Commander chose to take only defensive actions, which included:

- Precautionary evacuation of about 3300 residences and the town hall, the fire station, and town 911 center. The evacuation order continued for 2 days because of possible re-ignition and persistent smoke from the rubble.
- Control access to roads leading into the evacuation area
- Stopping rail traffic through the community
- Allowing the fire to burn itself out

The North Carolina Department of Environmental and Natural Resources (NCDENR) and the U.S. EPA began investigations about five hours after the incident, including air quality monitoring, and later, soil sampling. On 17 November 2006, the NCDENR issued a report that their environmental tests showed no offsite contamination.

Chemical Safety Board Investigations**:** U.S. Chemical Safety Board (CSB) in their investigations found 22 other fire and chemical release incidents at hazardous waste facilities in the United States in the five years prior to their 2008 report describing this EQ incident. Fifteen of these incidents involved fires and/or explosions including one at an EQ facility in Romulus, Michigan, on 9 August 2005. Seven were chemical release-only incidents. These 22 incidents included two deaths and eight community evacuations

Photo, from Chemical Safety Board Report showing an oxygen generator with activation pin circled, in EQ rubble

While the CSB never determined the cause of the EQ fire at Apex, North Carolina, the fire did originate in the bay where oxidizers were stored. Included in the oxidizer bay were unspent aircraft oxygen generators and containers of solid chlorine-based pool chemicals. The CSB report said that if EQ used fire barriers (walls) to separate the segregated bays, the fire likely would have been contained within the oxidizer bay and not spread to the bay where flammable hazardous wastes were stored. In addition, the EQ facility did not have an active fire suppression system and relied only on five portable fire extinguishers for control or to extinguish fires even though the facility stored hundreds of drums of flammable and combustible materials. The building was unoccupied at the time of the incident.

The EQ report concluded that EQ had limited contact with the Apex Fire Department prior to the fire, and EQ had not provided the fire department with written information on the types, quantities, and locations of hazardous materials in their facility.

While EPA regulations (e.g. 40 CFR 264.32) on companies handling or treating hazardous waste require information be provided to local authorities on the facility, its layout, and its hazards, the regulations do not explicitly state what information should be written or if updates are necessary. OSHA regulations (29CFR 1910.1200) exclude hazardous wastes from Material Safety Data Sheet (MSDS) requirements, and Community Right-to-Know requirements exclude materials for which a MSDS is not required.

The APEX Fire Department inspected the EQ facility annually. However the EQ facility takes in and treats or recycles many different kinds of hazardous wastes during the year meaning that the particular situation in the oxidizer bin probably would not have been discovered in the inspection.

The EQ facility was not rebuilt.

Role of the PEAC Tool

One common thread of the examples presented is that first responders did not know what was being stored or used at these facilities, or the hazards, and the owners/managers provided inadequate information to the community. Community Right-to-Know laws exist on the books, and companies generally comply. But there are gaps in the regulations leaving companies with an uncertainty of how to comply. Even the EPA Off-site consequence analysis regulations only cover some chemicals and fuels and only if large quantities are used leaving uncertainties for responders as to what is present at a facility in case of an incident.

The PEAC tool is designed for inspectors and responders to rapidly examine situations where accidents have or can potentially occur. The inspections might be done by the local fire department, by an insurance company, and also in-house. What are the chemicals used and where are they located? Where are the oxidizers, fuels, acids, and caustics located? What can happen if two or more chemicals come into contact, or are water reactive, or may explode when heated? What toxic gases may be given off? What are the worst-case scenarios?