ARSON HOTLINE

September 4, 2013

President's Message

As I write this (the week before Labor Day), I realize summer is almost over again. It is time to get back to serious business. As a reminder, the WAIC Annual Meeting will be September 18, 2013 at the Delafield Brewhaus. See additional information in this newsletter.

Please remember the firefighters who lost their lives in the forest fires in the West this year. A fire can change quickly. Everyone needs to prepare as best as they can to work safely during and after the fire is extinguished. Fire scene safety will be covered in the annual meeting.

Our programs for you are:

1. WAIC has FREE posters, bar coasters, etc. with the **WISCONSIN ARSON HOTLINE (800-362-3005)** on them for you to use at arson fires. The hotline is for an anonymous arson tip leading to the arrest and conviction of an arsonist. Tips can also be submitted on our website (www.wiarsonhotline.org).

2. Our new program is the Loss Investigation Equipment Grant Program to help offset fire investigation costs. Our grant can help cover costs such as digging out a basement with heavy equipment.

I would like to see all of you at our annual meeting.

William H. Schultz,
President, Wisconsin Arson Insurance Council
President@WIArsonHotline.org

Editor – Paul Hansen, P.E. (EFIGlobal, Inc.)

WAIC Board Meeting Minutes July 17, 2013

IN ATTENDANCE: Bill Schultz, Randy Dolenshek, Rick Crouse, Paul Hansen and Gary Streicher
APPROVAL OF PREVIOUS BOARD MEETING MINUTES: May 15, 2013 Meeting (No minutes available for approval)
TREASURER'S REPORT: Rick Crouse

Beginning Balance (March 20, 2013) $11,282.50
Income
Expenses
Ending Balance $11,282.50

PRESIDENT'S REPORT: Bill Schultz No Report
VICE PRESIDENT'S REPORT: Randy Dolenshek No Report
REPORTS:

Awards (Randy):

#629 – This tip had been tabled at the last meeting. The board reviewed and acted on this tip at this meeting. Due to the limited damage to property ($2,200 to a garage and $300 to an automobile) the committee settled on an award of $250.00. There were also extenuating circumstances that resulted in the lower award amount.

#607, #608, #609 – This fire was located in Racine. The trial was supposed to occur in June (2013) but has been postponed until March of 2014. No action on this tip/s until a decision has been made by the court.

#631 – This tip has already been approved for a $1,000 award. Rick is waiting on contact information from DCI.

#622 – This tip was about to be paid when Rick received a letter from the tipster. The tipster was pressuring WAIC for his money and threatened to withhold information on additional arson fires that he knows about. The statement (letter) brought doubt to his credibility. DCI wants to check with the tipster (interview) before giving the go-ahead on the payment. Rick stated that he would expect a response within a few days. WAIC will wait no more than a week for DCI's response. The award will be sent ASAP based on info from DCI. Rick will pass on DCI's information to the board for voting via e-mail. The board agreed to send the money to the tipster's probation officer.

Membership (Greg): No Report
Sustaining Membership (Rick): Rick has collected 2 memberships and is awaiting others.
Publicity:

Website update: Paul did update parts of Website, Minor changes needed. Place pictures of award posters with contact
for signs on website. Suggestions for other improvements (if needed) to the Website? Paul will update. Paul will update old info (dates etc.) and make the scholarship form generic (there will be no year, only a month and day for scholarship deadlines)

Newsletter:

Theme: Explosives expert/1st responder safety
Timetable: September 1, 2013

IAAI Seminars:

Scholarships:

Should we have one scholarship form for Spring and Fall or separate ones See Publicity

OLD BUSINESS:

Business Cards update (Randy): Rick will obtain the WAIC Logo from Paul and will create the cards via Vista Print or similar service.

Facebook (Paul): Pending

WIP Funding (Rick): In progress

FM Global Grant – The grant has been completed by Rick and turned over to Bill for mailing.

NEW BUSINESS:

Elections: Bill will e-mail Greg for election information.

Annual Meeting September 18. 2013

Location: Brewhaus

Speaker/topic/Agenda: Explosive expert/Fire Responder Safety was proposed topic at last meeting? Rick will talk to Fire Chief Frank Lockwood about speaking at the annual meeting.

Next Meeting: September 18, 2013

Other:

ADJOURN: 1315 hours

Note: The Board of Directors will have a business meeting following the annual meeting 9/18/13.

This W.A.I.C. Newsletter Issue

The theme for this issue of the W.A.I.C. Newsletter is firefighter safety issues when there is a strong possibility of an explosion. Two articles, both available on the U.S. Fire Administration / F.E.M.A. Website, were selected for their relevance. The first deals with a fire engulfing a large propane (L.P.G.) storage tank Without too much trouble, you can download the entire article from the FEMA website (http://www.usfa.fema.gov/). In the upper right corner of the FEMA home page type TR-120 in the search engine, and the link to the article will come up. It is a portable document file. The appendices, which I have not included in the newsletter for brevity's sake (after all, that is what editors do) are all there for your reading entertainment and/or edification.

The second article, just looking at the title, might seem irrelevant. However, the lessons learned from the incident are quite relevant even though we don't do much rocket fuel here in Wisconsin. There were no appendices per se for me to cut from the article, but going to the FEMA home page and searching for TR-021 will get you a whole bunch of neat photos of the incident (black and white, but nonetheless interesting).

Enjoy!

Paul Hansen P.E.

EFI Global – Editor

LP-Gas Tank Explosion Kills Two Volunteer Firefighters

Reported by: Thomas H. Miller, P.E. & Michael W. Lackman
Local Contacts: Chief Scott Carle
Carthage Fire Department
122 South Adams
Carthage, IL 62321
Attorney John Pavlou
Special Agent Ted Anderson
Office of the State Fire Marshal
1035 Stevenson Drive
Springfield, IL 62703

OVERVIEW

On Thursday October 2, 1997, two Carthage, Illinois Fire Department volunteer firefighters died, one was seriously injured, and another was injured when a horizontal liquefied petroleum gas (LP-Gas) tank BLEVE'd (Boiling Liquid Expanding Vapor Explosion). The rocketing tank struck them as they prepared to advance pre-connected hose lines from their high-pressure fog pumper about eight minutes after their arrival. The first fire company to arrive on the scene to a reported dryer fire found not only the grain dryer fire but also 30 to 40 foot intermittent fire plumes from the safety relief valves on two 1,000 gallon LP-Gas tanks, and a fully involved field tractor. Deciding on a direct attack, the first-in fire officer positioned the engine and firefighters behind a large grain silo 100 feet away from the burning tanks. But the engine's tailboard extended beyond the silo's vertical edge and was nearly inline with the end of one of the tanks. Three of the firefighters were advancing around the rear of the tailboard when a large tank section struck them.

The death of these firefighters demonstrates the serious hazards firefighters face when attacking LP-Gas tank fires. The need for first-in fire officers to be well trained in hazard and risk analysis and their ability to formulate effective action plans is critical to safe fireground operations. In many cases, LP-Gas incidents require the first-in officer to evacuate the area in anticipation of a tank failure rather than placing firefighters in position to try and prevent the failure. Analysis of the fireground factors present at the time of this incident indicate the chance of a successful direct attack to cool the tanks was unlikely given the severity of the fires.

The decision to make a direct attack is especially critical when an incident exceeds the capabilities of the initial crews to stop an escalating situation due to a lack of on-scene resources. In this incident, an immediately available and sustainable water supply for large volume hose streams was not rapidly obtainable. Even with an adequate water supply, firefighters may not have been able to apply the water with enough volume quickly enough to cool the tanks and relieve the excessive pressure before a failure occurred. The fire had been heating the tanks for over ten minutes and there was possible flame impingement on the top of the tanks.

When attack decisions are made, firefighters' position relative to the ends of the tank is critical. The Fire Chief knew that horizontal LP-Gas tanks fail and generally rocket in the direction parallel to the long axis of the tank and was working to avoid the ends. Firefighters located at the end of an LP-Gas tank are subject to being struck by the tank if the tank fails as this incident demonstrates. An additional concern over tank failures is the release and ignition of the liquefied gas, which quickly flashes to vapor and the energy released, can seriously burn or kill even fully protected firefighters. At this incident, the firefighters suffered no thermal injuries, but their intermediate stopping position in line with the tank's end reinforces the tactic that tanks should only be approached from the sides.

KEY ISSUES

Issues	Comments
LP-Gas Tank Location	The two tanks were located too close to buildings and too close to each other. Their location made application of cooling water difficult and created an exposure to the structure.
Tank Manifold	Connecting the two tanks by their liquid discharge to fill connections allowed liquid LP-Gas to back feed from the most exposed tank into the other, resulting in the hydrostatic failure of one tank.

Potential LP-Gas Tank Weakness	It is believed that a weak weld on a tank head to cylinder seam failed when it was subjected to excessive hydrostatic pressure. The condition would have been undetectable to the firefighters at the time.
Risk Assessment	The two 1,000 gallon LP-Gas tanks had been exposed to the burning grain dryer and likely gas being discharged from one of the tanks. The firefighters witnessed at least three intermittent releases from the pressure relief valves as they responded to the scene and prepared to attack the fire. The risk of tank failure exceeded the ability of the fire department to rapidly apply the volume of water necessary to cool the tanks.
Action Plan	Determination of the tank area exposed to heat and flame and time of exposure is critical to estimating the potential for BLEVE. Operating safety relief valves indicate high internal pressures that can lead to tank stress and possible failure. Operating relief valves are an indication that a direct attack to cool the tank surface is dangerous. When attempting such an attack, large volumes of water (typically master stream quantities) must immediately be directed upon the tank and firefighters must be positioned in safe locations.
Water Application Rate	The low flow rate, 60 gpm per hose line high pressure pre-connects were unlikely to deliver the amount of cooling water needed to prevent the tanks from failing. In addition, these lines are difficult to leave unmanned. Flow rates of 250 to 500 gpm distributed over the entire tank surface are often recommended.
Attack Positioning	Attacks should always be positioned from the tank sides and from protected locations. At failure, horizontal tanks will rocket in the direction of its longest axis and leave a large fireball in its wake. Water and firefighter protective clothing will not protect firefighters from being physically injured or being burned by the ensuing fireball.

FIRE DEPARTMENT

The City of Carthage is located in west central Illinois, approximately 12 miles east of the Mississippi River. With a population of about 3,000, the city is the county seat for Hancock County. The city was laid out on a gridded street design where the downtown commercial buildings face a large town square. The Hancock County Courthouse occupies the center of the square.

Founded in 1877, the all-volunteer municipal fire department has twenty-eight (28) members who respond to approximately 50 fire alarms per year. Operating on an annual budget of approximately $40,000, the department is organized for structural fire suppression. The department provides no emergency medical services but assists the County's ambulance service when requested. The department is one of two municipal fire departments in the county and is active in the county's mutual-aid system that is composed of eleven fire protection districts and the two municipal fire departments.

Housed in a single-story three-bay station one street off of the city square, the fire department operates six pieces of fire apparatus. The primary city fire response vehicle is a 1995 1,250 gallon per minute triple combination pumper. In support is a 1948 eighty-five (85) foot aerial ladder, a 1976, 1,600 gallon tanker without a pump, a 1979 high-pressure, 120 gpm attack pumper with 1,000 gallon tank (used primarily for rural fire attack operations), and a rescue/equipment vehicle. Additional equipment includes a 1970 triple combination pumper with high-pressure capability, a 1959 pumper also with high-pressure capability, and a 1935 antique pumper. The department members' personal protective equipment consists of NFPA compliant structural firefighting protective clothing.

The department elects it's Fire Chief and two Assistant Chiefs each May and holds monthly business and training meetings on Tuesday evenings. The training is given by the department's training officer and consists of primarily Firefighter II level training with occasional pre-fire planning "walk through" of city buildings. Two (2) of the department's members are certified Firefighter III and four (4) certified Firefighter II from the Illinois State Fire Marshal's Division of Personnel Standards and Education. Additional training provided to its members was several University of Illinois' Fire Service Institute's training programs including an LP-Gas tank firefighting drill in 1995.

Although the department is a municipal fire department supported by municipal taxes, the department responds to rural fires in unincorporated property and other small towns immediately outside the city limits. The standard response to a reported structure fire would be either the 1,250 gpm pumper or high-pressure fog attack pumper with a minimum of three firefighters, the 1,600 gallon tanker, and the rescue squad (which carries the department's personal protective clothing). For rural structure fires, the first response vehicle is the high-pressure attack pumper because of its preconnected high-pressure attack lines and its five seats. The second unit would be the rescue/equipment squad and

then the 1,600-gallon tanker. The department's standard operating procedure requires a minimum of nine firefighters to respond to rural fire incidents. As rural property owners do not pay municipal taxes, the city bills the property owner $350 for the first hour and $250 an hour thereafter for any fire incident it responds to.

Emergency calls are received into and dispatched from the Hancock County Sheriffs 9-1-1 dispatch center. Paramedic level emergency medical service is provided by Hancock County operated ambulance service. Their vehicles are typically stationed at the local hospitals.

SITE DESCRIPTION

The incident occurred on a large farm located approximately 3/4 miles north of Burnside, Illinois and about ten miles north of the City of Carthage. The farm's principal buildings consisted of an occupied single-family frame home, a large wood frame shed, two metal clad pole sheds used for farm equipment storage and repair, and two large circular metal silos. A small, frame farm office building was located near the machine shop pole shed. Three unused wood frame barns were also on the property. (See Appendix A for diagram) The farm's principle crop was corn and soybeans.

No pressurized public water supply was immediately available at the site. The closest hydrant was located about 3/4 mile away in the town of Burnside and was supplied by a four-inch water main. A second public water supply was available seven miles away. The farm had two water ponds available for drafting operations.

The fire and subsequent explosion involved the farm's grain drying operation where harvested corn or soybeans was heated to reduce the moisture content before being stored. The grain dryer and supporting equipment was located to the west of the large wood frame shed and to the north of the west large metal grain silo. Although a portable unit with wheels, the continuous flow grain dryer had been at the location for many years. The dryer was principally constructed of metal with internal conveyors and passages that provide for fan forced heated air to dry the grain. The grain and the heating fuel were the primary combustibles in the dryer.

Mechanical power for the dryer's fans, conveyors, and grain movement equipment was provided by a power take off (P.T.O.) from a field tractor at the front (north) end of the dryer. Electric power for the dryer's controls was from an outdoor panel located southeast of the dryer near the pole shed between the two grain silos. (See Appendix B for diagram.)

The fuel supply for the dryer and the field tractor was provided from two, 1,000-gallon LP-Gas fuel tanks located immediately adjacent to the west wall of the destroyed wood shed. Distance between the shed and the tank closest to it was less than three feet and the tanks were less than five feet apart. The distance from the dryer to the tank closest to it was about 15 feet. Both tanks had integral steel legs, which rested on concrete pads. One tank had been at its location for many years and the second LP-Gas tank was added several years ago. At the time of the investigation, the identity of the original tank could not be determined. The two LP-Gas tanks, when full, provided about 36 hours of fuel for the dryer and tractor.

LP-Gas moved from the tanks to the dryer and tractor by means of a rubber LP-Gas hose. The hose connected the west tank to a tee fitting located near the front of the dryer. From the tee, fuel split to the dryer and the tractor. The hose reportedly lay on top of the ground between the tank and dryer. The hose was used for both vapor and liquid fuel transfer through different valved connections to the west tank. The dryer was indicated to start with LP-Gas vapor and then switched to liquid when warmed and under load. The tractor always used liquid and it did have an integral fuel tank that should have allowed the tractor to operate while the hose contained vapor.

When either LP-Gas tank emptied, the hose and fittings would be disconnected from the empty tank and attached to the full one. The dryer would have to be restarted and potentially any trapped air removed from the fuel hose. About two weeks before the incident, the delivery driver for the LP-Gas supplier suggested a means to manifold the two tanks together and eliminate the hose transfer process.

The driver suggested attaching a liquid transfer hose, used for filling LP-Gas fueled field tractors, to the liquid withdrawal connection on the top of the east tank and to the liquid fill connection on the west tank. No similar vapor space interconnection between the two tanks was identified during investigation. The liquid transfer hose did have a manual valve at one end but there was no indication of check valves, relief valve, or excess flow valves in the hose.

The tank manifold configuration worked satisfactorily and the two tanks were filled several times during the two-week period. Prior to the explosion, roughly 35,000 bushels of grain had been dried during the current harvest season without

mishap. Both tanks had been filled in the morning of the incident and had been in operation for about seven hours without a problem.

The grain drying process began with grain brought from the field and gravity discharged into a field tractor PTO driven auger that deposited the grain into the wet bin. The wet bin was a vertical metal storage unit with a conical shaped bottom that acted as a surge bin for the dryer. It provided a continuous feed to the dryer while grain trucks from the field were changed.

From the wet bin, the grain discharged from the bottom by gravity into an electric motor driven auger, which discharged, at the top front of the dryer. Once inside the dryer, grain movement was provided by the LP-Gas fueled tractor, which mechanically powered the dryer. From the dryer, the grain discharged into another electric motor powered auger, which elevated the grain into one of the two storage silos. The unloading of the trucks from the field and discharge of grain into the wet bin was supervised. Once running and adjusted, the dryer did not require constant supervision. The dryer was started each morning and was stopped in the evening.

FIRE INCIDENT DESCRIPTION

Corn from the field harvest was being unloaded into the wet bin under supervision and the dryer was operating. Weather conditions at the time were a temperature of about 80 to 85 degrees Fahrenheit and light southwest winds of 5 mph. A loud "poof" was heard from the dryer followed shortly by a noticeable change in operating sound. Besides attracting the attention of the person unloading the corn, the noise was heard by four people working on a combine in the pole building machine shed. The unloading of corn from the field truck was stopped and the tractor PTO powered auger into the wet bin was also shut down. Fire was observed coming from the front, upper east half of the dryer. Shortly after the "poof", the LP-Gas fueled tractor, which powered the dryer, sped up. The speed change indicated that the dryer load had been lost likely due to drive belt failure on the dryer. In addition to the person unloading the corn, one of the people working on the combine came to investigate the "poof". After hearing the word fire being shouted, one of the farm's owners also left the combine to investigate.

The owner ran to the farm office and called the fire department via the county's 9-1-1 telephone system. At the same time, the person unloading the corn moved the field truck and then turned off the electric power to the dryer and auger conveyors from inside the pole shed located between the two grain silos. From inside the shed, he reported seeing the fire burning at the two LP-Gas tanks and venting from the tanks. He also reported that the fire had spread to the tractor at the front of the dryer. The tractor continued to run for a period after the fire spread to it. No one reported going to the LP-Gas tanks to shutoff the supply hose or the manifold hose.

Another witness, who arrived after the fire was reported to the fire department but before their arrival, indicated that the fire was burning on the front and east sides of the dryer and on top of the west LP-Gas tank. He also believed that liquid LP-Gas was being discharged from the liquid connection on the west tank. The liquid was spraying onto the east side of the dryer. The witness moved to a position near the farm office and reported that the fire burned violently at times and then the intensity would reduce dramatically. However, the flames never ceased entirely while he watched. He believed that the flames were concentrated on the west side of the west tank around and to the north of the tank's top connections. This area would be where the supply hose to the dryer and tractor would have passed. While he watched, a pressure relief valve began to operate intermittently producing a loud noise and flames 40 to 50 feet high. He also observed that the flames had spread to the top of the east tank, which could have been the result of the liquid hose failure between the two tanks.

The owner, after reporting the fire, went back to the machine shop and moved the combine from the building into the soybean field south of that building. Returning to a position near the farm office, he observed that the fire's intensity had doubled or tripled in the time he moved the combine. He then decided to contact the Carthage Fire Department directly rather than through the county 9-1-1 center. His purpose was to convey the worsening fire conditions and to suggest a neighboring fire department be alerted to respond for assistance. After talking with someone at the Carthage Fire station, he exited the office and observed that the east rear tire on the tractor powering the dryer was burning and that the tractor was still running.

The tank or tanks vented several more times between then and the time when the first fire units arrived. Determination of which tank vented each time could not reliably be identified. The owner met the first engine company and informed them that two, 1,000 gallon LP-Gas tanks were involved and that the tanks had been filled that morning.

FIRE DEPARTMENT RESPONSE

About 4:39 p.m., a telephone report of the fire was received at Hancock County Sheriff's 9-1-1 dispatch center for a "dryer fire" in the town of Burnside, Illinois. The Carthage Fire Department was dispatched shortly after. Their initial response was the department's routine rural response assignment to what was thought to be a clothes dryer inside a house. The responding equipment was the high-pressure fog pumper (Engine 11), a 1,600 gallon tanker (Tanker 13), and the rescue truck (Rescue 10). The personnel on the first responding unit, Engine 11, consisted of the Fire Chief (company officer), Apparatus Operator, and a Firefighter. Immediately following was Rescue 10 with three firefighters. Tanker 13 followed shortly after with three firefighters. While en route, the firefighters received a radio report from the County dispatch center that the fire involved LP-Gas tanks. The firefighters witnessed several openings of LP-Gas tank pressure relief valves from several miles away. Mutual aid was requested at this time from Dallas City/Colusa Fire Department for their 3,000-gallon tanker and from the LaHarpe Fire Department for an engine and a tanker.

Arriving at 4:48 p.m., Engine 11 and Rescue 10 pulled into the south entrance of the circular driveway, parking next to the farm office facing to the southeast. The farm's owner met the Fire Chief in the driveway and informed him that two 1,000- gallon LP-Gas tanks were involved. The owner's father also advised the firefighters that nothing involved in the fire was worth taking too big a risk and to not take any chances. The Fire Chief reported that from this position, he was able to see the tank ends, the grain dryer, and field tractor. The dryer and tractor were fully involved and the fire was burning at the two tanks. The Fire Chief and firefighters went to Rescue 10 removed and donned their protective turnout clothing.

A safety relief valve was operating intermittently and the exposure fires ignited the discharged vapors. Witness statements are not consistent regarding which tank's relief valve operated before the explosion. Before the fire department's arrival, witnesses indicated that the west tank's relief valve discharged several times. They also admit that the east tank's relief valve may have also operated because it was difficult to identify the exact tank. The fire chief believes that he observed the east tank venting at least twice before the explosion. The burning plumes were igniting the side of a wood frame shed next to the tanks.

Asking about the contents of the shed, the owner said that it only contained a few tires and some hay. The Fire Chief walked closer to the fires to better view the situation and develop a plan of attack. Concerned that the west tank was angled towards their position, he noted the east silo (Appendix A) would offer some protection from the tanks and would be a better operating position. He walked south of the west silo where he also noted the doors on both sides of the pole shed were open allowing a better view of the tanks and fires.

Returning to the engine, the Fire Chief found the firefighters had already pulled and advanced a preconnected high-pressure 1-1/4-inch handline toward the fires. He ordered Engine 11 to relocate to the south side of the east grain silo and for Tanker 13 to establish a water supply at that site. Because a pre-connect had already been pulled, the Fire Chief and firefighters had to pick up the hoseline and walk it along the left side and rear of the moving engine to the new position.

Satisfied with the new position, the Fire Chief, who was walking at the left front of the engine, dropped the hoseline as the pump operator engaged the pump. Simultaneously, the two firefighters, who were walking the hoseline behind the engine, continued to move toward the Fire Chief. The rear of the engine was not completely behind the silo and the tailboard was almost in line with the long axis of the east tank. Because the burning dryer, tractor, and tanks were visible from the rear of the engine, the two firefighters, and another not involved with the movement of the engine, likely paused to observe the fire scene through the open doors of the pole shed just as the east tank BLEVE'd.

The tank separated at the weld seam where the north domed head was attached to the long cylinder shaped body. The tank head was broken into two pieces ("clam shelled") and the pieces traveled north and northeast into a brush and tree covered ravine area about 600 to 650 feet away. The balance of the tank rocketed to the south in a very shallow climb through the pole shed coming to rest nearly 1,000 feet away. (See Appendix C)

The tank struck several objects as it traveled south including three Carthage firefighters. The wood shed's six foot high concrete foundation was shattered along the west side from the explosion and the structure was destroyed by the fire. The west LP-Gas tank was thrown into the air passing over the grain dryer and wet grain bin, landing nearly upside down near the tractor which powered the auger that filled the wet bin from arriving trucks. The tank was discharging burning LP-Gas and the tractor caught fire.

The rocketing tank traveled through the pole shed as it proceeded to the south striking two door posts and a pipe rack in the shed. The wood 6-inch by 6-inch northeast door post was torn out from about one foot above the ground to about five feet above the ground. The tank then struck a glancing blow to a large steel constructed pipe rack inside the shed.

The pipe rack is believed to have slightly altered the direction of travel causing the tank to turn slightly and out the open door on the south side of the shed. The wood 6 inch by 6 inch southeast door post was splintered from approximately five feet above the ground to just under ten feet.

Immediately on the other side of the shed's southeast doorpost stood the three firefighters at the rear of the Engine 11. Victim #1 was standing at the left corner of the tailboard and was knocked approximately 50 to 75 feet south. Victim #2, who had been standing to the left of Victim #1, was knocked approximately 130 feet to the south and into the soybean field. Both firefighters received severe traumatic injuries and died immediately as a result. The surviving victim, from the rear of the engine, had been standing behind Victim #1 and fell a few feet away. His injuries were serious and he was air lifted from the scene.

The tank did not strike Engine 11 although the apparatus was physically damaged. The damage consisted of some equipment mounted on the tailboard and the lower sections of the driver's side mounted ground ladders. After striking the firefighters, the tank continued south over the parked combine until it struck the ground the first time approximately 400 feet away. It continued to tumble and skip for another 600 feet through a soybean field, coming to rest approximately 1,000 feet away from its original position.

The fire chief was thrown to the ground and injured by the force of the explosion or from being struck by a flying object. He was able to request additional mutual aid assistance from the Terre Haute Fire Department, Crop Production Company, and for ambulances. After helping attend to the injured firefighters, he was also transported by ambulance to the hospital. The assistant chief arrived after the BLEVE and took command of the incident. He immediately began an accountability check of the on-scene firefighters and farm workers. A telephone call to the Carthage fire station was made for names of responding firefighters. All firefighters and farm workers were accounted for at the end of the process.

On arrival, Tanker 13 set up its 3,000-gallon drop tank off the driveway north of the farm office. Engine 14 arrived and positioned to draft out of the drop tank and to direct its pre-connected deluge gun onto the still burning west tank's position. The tank was discharging burning liquid and vapor from the connections at the top of the tank. In addition, the field tractor, which powered the auger, caught fire from being sprayed with the burning LP-Gas.

Dallas City/Colusa's 3,000-gallon tanker shuttled water to fill the dump tank. La Harpe sent an engine and a tanker. The engine led out to a pond located east of the farm buildings and attacked the well-involved wood frame shed. Their tanker assisted in the water shuttle operation. Terre Haute also sent an engine and tanker. Terre Haute firefighters assisted with the shed fire and the tanker participated in the water shuttle. Crop Production Company (private business) supplied a field tanker with two 1,000-gallon tanks, normally used to fill farm equipment, to shuttle water. Hamilton Fire Department filled the Carthage station with an engine company. (See Appendix D)

The tanker shuttle provided Engine 14 with enough water to cool the LP-Gas tank allowing it to burn out, and to suppress the fire in the field tractor. Until LaHarpe's engine established a drafting operation from the pond, water supply was a problem on the east side of the fire scene. The fires were confined to the grain dryer, two tractors, and the wood frame shed. Engine 11 did not participate in the fire suppression operations.

In addition to the fires at the farm buildings, a large field fire occurred in a combined (harvested) soybean field about 700 to 800 feet north of the LP-Gas tank position. Although the burned area was searched for an ignition source, nothing could be identified as a cause for the fire. The field was in line with the long axis of the BLEVE'd tank and on the opposite side of the ravine where the broken tank head was found. There was no fire in the ravine and the field fire did not occur until after the explosion.

The Carthage Fire Department report indicated that units returned from the incident at 9:12 p.m. that evening. However, the La Harpe Fire Department provided scene security over night since the investigation of the incident had not concluded. Mutual aid departments provided coverage for Carthage Fire Department alarms from this point until after the funeral services for the fallen fire- fighters on the following Tuesday, October 7, 1997.

BUILDING AND FIRE PREVENTION CODES

The farm is located in Hancock County, which would have code review and enforcement authority. In addition, the State of Illinois and the Office of State Fire Marshal have enacted laws and regulations for liquefied petroleum gas storage and use. The state regulations acknowledge that compliance with National Fire Protection Association (NFPA) Standards shall be accepted as compliance with state regulations.

The analysis that follows makes use of NFPA Standard No. 58, Standard for the Storage and Handling of Liquefied Petroleum Gases and National Propane Gas Association (NPGA) documents #500-93, Safe Use of Propane with Crop Dryers and NPGA #613-92, Guidelines for Manifolding Liquid Withdrawal ASME Containers not Exceeding 2000 Gallon W .C. at Construction Sites. NFPA Standard No. 54, National Fuel Gas Code does not apply to crop dryers or to the LP-Gas fueled tractor.

According to NFPA Standard No. 58, the two 1,000 gallon capacity tanks should have been located at least 25 feet from any building. The purpose of this distance is to provide exposure protection for a fire at either the tank or the building. A building fire would not immediately threaten the LP-Gas tank and a fire at the LP-Gas tank connection or relief valve would not immediately start the building on fire. Another reason for the separation distance is to minimize the potential for escaping heavier than air LP-Gas to enter the building potentially finding an ignition source.

The tanks should have also been positioned with at least three feet of space between the two tanks. This space allows access for water streams to cool the tank surfaces and for personnel to reach the valves on the top of the tank. Another important separation distance is between a gas discharge point on the tank and potential ignition sources such as the grain dryer and tractor. NFPA Standard No. 58 indicates that at least ten feet should be provided. Potential gas discharge points are the fill connections, the pressure relief valve, and hydrostatic relief on liquid piping. The NPGA also recommends that grain dryers be shut down during LP-Gas tank filling unless the distance between the dryer and the tank is over 50 feet.

NFPA Standard No. 58 limits flexible hoses to 36-inch maximum length. The LP-Gas supply hose from the tank to the dryer exceeded the maximum and should have been replaced with Schedule 80 pipe and high-pressure fittings. The heavy piping and fittings are needed because the line contains liquid LP-Gas and the operating pressure could exceed 250 psi. The piping between the tank and the dryer/tractor would also need to be protected from mechanical damage. The pipe should be buried, with adequate corrosion protection, or suspended on supports above ground. The liquid supply piping would also need an excess flow valve, shut-off valve, and a hydrostatic relief valve. The excess flow valve is to stop liquid discharge if the line fails catastrophically. The shut-off valve is the manual means to stop the LP-Gas flow or to isolate the line for other work. The hydrostatic relief valve is intended to protect the line if the trapped liquid expands as its temperature increases. The excess flow valve and hydrostatic relief valve were needed on the liquid line regardless of the line's construction material.

To comply with NFPA Standard No. 58, the pipe lines used to manifold the two 1,000 gallon tanks should have been constructed of Schedule 80 pipe with extra heavy fittings because the pipe could experience pressures over 250 psi during normal operation. The process of manifolding the two tanks involves separate connections between the vapor space and the liquid space in each tank. Two separate pipes are needed to ensure that the liquid level in each tank remains balanced as internal pressure is equalized in the two tanks. The liquid manifold line could have made use of bottom outlet connections on each tank. Alternately, tanks manufactured after July 1, 1961 have liquid top outlets, which could have been used.

The liquid manifold piping would need an excess flow valve and manual valve at each tank and a hydrostatic relief valve in the line because of the possibility of trapped liquid. The vapor manifold line would also need an excess flow and manual valve at each tank.

The remains of various LP-Gas hose connections were gathered after the fire. A number of the fittings used to attach the hose were not industry approved for use with LP-Gas hose. Substandard hose fittings included stainless steel bands with adjustable screws. It is suspected that these connections did not have sufficient pressure rating for the LP-Gas liquid service.

The omission of a vapor manifold connection between the two tanks did not allow the liquid levels to equalize or balance in the two tanks. As a result, the fire heated the west tank and pushed liquid into the east tank until it was 100% liquid filled. The east tank then failed at its weakest point, the weld seam. The east tank's relief valve may have been unable to reduce the pressure fast enough or failed to operate effectively.

INVESTIGATION

A Special Agent from the Office of the Illinois State Fire Marshal was the lead investigator. He was assisted by members of the Illinois State Police; Hancock County Sheriff's Office, Hancock County Coroner, Illinois Fire Service Institute, and an independent engineering consultant. In addition to these agencies, various private cause and origin investigators and experts were permitted access to the site and equipment under supervision of the lead investigator. The objective was to identify the cause of the fire and to determine why the tank BLEVE'd.

Scene documentation began that evening and continued into the next two days. Photographs and videotape were taken at ground level and from a state helicopter. The aerial views provided an excellent means to describe the path that the east tank traveled.

The two LP-Gas tanks, parts of the LP-Gas hose fittings that were not consumed in the fire, and the two pieces of the domed tank head were transported to a secure location. The portable dryer and the LP-Gas fueled tractor, which powered the dryer, remained at the site. The extent of damage and size made their movement impractical.

The east LP-Gas tank was moved from the field where it came to rest with a tank carrier. The north head separated from the rest of the tank at the weld seam. The metal at the separation seam (fracture surface) was very smooth on both the tank and on the pieces of the head. The surface was almost like a grinder had passed over it. There were no chevrons# on either the tank or the head's fracture surfaces. The paint on the south end of the tank appeared blistered while the paint at the north end was unmarked.

At the time of the scene visit, the roll forming of the metal for the domed head to the tank cylinder weld seam was being reviewed for proper shape. In addition, the position and penetration of the weld bead at this seam was being analyzed. Both were possible contributing causes for the tank failure. Diagrams of the formed metal can be found in Appendix E and photograph of the weld seam in Appendix F.

The inside of the tank was clean with no visible corrosion or pitting. The liquid LP-Gas pickup tube had detached from the liquid withdrawal connection and was found near the tank's final resting place. The tank did receive several dents and scrapes caused by the tank striking the ground and other objects. In addition, the tank's south domed head had a hole about 1/2-inch in diameter punched through the metal. Marks inside the hole suggested that it had been threaded. A steel rod, threaded on one end, was found at the third or fourth tank shell impact with the ground. The rod matched the hole in the head and was traced to the metal pipe rack that the tank struck in the pole shed. The threaded rod was a support piece for the pipe rack.

The west LP-Gas tank was also moved with a tank carrier to a secure storage location. At the time of the site visit, the original position and direction that the tank was facing prior to the incident had not been determined. It is hoped that the hinge connection for attachment of the protective valve cover may be used to determine which end of the tank faced north. (See Appendix F for photograph of the tank.) Around the hinge connection, a two to three inch high blister in the tank shell had formed over an area about 2 feet long by 1-1/2 feet wide roughly on top of the tank. The typical cause of tank metal deforming in this fashion is the direct flame impingement from burning LP-Gas on the tank shell in the vapor space. Allowed to continue, it is likely that this tank would have also BLEVE'd from the stretched and weakened metal.

The Office of the Illinois State Fire Marshal contracted with an independent engineering consultant to assist with the identification of the cause of the original fire. The consultant's report described two possible ignition sequences:

Sequence 1: The noise from the dryer was caused by the failure of drive belts to the blower. The loss of the fan function allowed the dryer burners to flash out and consume the liquid propane lines and ignite the released propane vapors. The heat from the propane fire exposed the two 1,000 gallon LP-Gas tanks with the closer tank receiving the most heat. The heat increased the vapor level, which forced liquid propane into the other tank.

Sequence 2: Failure of the flexible LP-Gas hose lines in the area of the tractor and dryer caused a flame roll-out from the dryer. The release of propane from the hose line resulted in the exposure of the two 1,000 gallon tanks to excessive heat.

LESSONS LEARNED

1. **The position of firefighters and apparatus should avoid tank ends, which are in-line with the long axis of the tank**. When LP-Gas tanks BLEVE, the energy released will often propel parts of the tank in directions parallel with the long axis. Approach and firefighting positions should be perpendicular to the tank's long axis to minimize the risk to firefighters. The Fire Chief's plan was to position the engine behind the large grain silo to provide shielding and position handlines between the grain silo and the animal shed to the east. However, Engine 11 was stopped before it was completely behind the silo, leaving the back of the engine exposed. Although the next step in the plan was not executed, the nozzle positions would have avoided the tank ends. Options for nozzle placement to wet the entire surface of both tanks were limited because of their location. The wood frame shed obstructed access to the entire east side of the LP-Gas tanks. The burning grain dryer and tractor restricted access from the west.

2. **To effectively cool LP-Gas tanks exposed to a fire and absorb the heat energy from flames impinging directly on the tank shell, a substantial water application rate is required**. For exposure fires, the entire tank surface must be kept wet to absorb the radiant heat energy reaching the vessel. When flames are impinging on the tank, a water stream must be constantly applied at the contact point to prevent the metal from weakening and thinning out. Water flow rates of 250 to 500 gpm for the two 1,000 gallon tanks would be a recommended minimum. The high-pressure, low flow rate, pre-connected lines would not provide the necessary amount of water on the tank. Furthermore, hose lines that can be placed into operation and then left unattended are preferred over hoselines that need to be manned. It is unlikely that the pre-connected hose lines could be left operating unattended.
3. **The more time the LP-Gas tank is exposed to fire conditions, especially to fire impinging on the metal shell, the greater the risk of BLEVE**. The structural integrity - usually defined as the ability to carry the load - of anything (floor, roof, building, pressure tank, etc.) exposed to fire usually deteriorates in accordance with the length of exposure time. Long delays in beginning the application of water (cooling and suppression) from the start of fire exposure, should raise warnings about possible structural failure. In this incident, the operating pressure relief valves are indications that the LP-Gas tanks are under stress and thereby increasing the prospect of catastrophic failure (BLEVE). Long fire exposure times and operating pressure relief valves should indicate that the potential for tank failure is imminent. The incident commander should concentrate on evacuating the area parallel to the long axis of the tank and limiting exposure to firefighters and bystanders. The minimal life exposure should be a significant factor in the risk benefit analysis.
4. **Tactical plans should anticipate that "portable" and "temporary" installations are not in full compliance with fire and safety codes**. Compliance with fire and safety codes cannot be assured for equipment installed on a "temporary" or "portable" basis. Plan review and inspection of these installations is often omitted even if officials are aware of their presence. Farms and construction sites are typical locations of "portable" and "temporary" equipment installations. Fireground operations and tactics should contemplate that fire and safety code compliance is likely to be incomplete. Fire conditions, spread, and reaction may be different than your experiences from drills and previous incidents. The long LP-Gas hoses and the noncomplying tank manifold connection contributed to the failure of the east LP-Gas tank.
5. **The incident commander should anticipate that not everything will occur in a predictable manner or in accordance with drill and training**. The potentially defective weld was an invisible, unknown factor in the BLEVE. The LP-Gas tank's general condition will usually be an unknown to the incident commander. Deficiencies in the tank's design, construction, age, or quality of maintenance will become evident under fire and emergency conditions. Aggressive actions to cool the tank should be tempered with caution when the area around the tank can be quickly evacuated (few occupied buildings nearby) and information about the tank's condition (before and during the incident) is limited.

[1] Chevrons are small v-shaped signs on a metal surface. They can be used to identify the point where a metal tear began or where a crack or fracture in the metal might have began. Protection of fracture surfaces from mechanical damage and corrosion or oxidation is very important for future metallurgical analysis. A coating of metallurgical oil is preferred but a lightweight lubricating oil can be used. Even motor oil thinned about 50% with mineral spirits has been used on fracture surfaces to delay corrosion.

Fire and Explosions at Rocket Fuel Plant
Henderson, Nevada
May 4, 1988

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OVERVIEW

A series of explosions on May 4, 1988, near the city of Henderson, Nevada, claimed two lives, injured approximately 327 people, including 15 firefighters, and caused damage estimated over 100 million dollars. The explosions affected a large portion of the metropolitan Las Vegas area and caused the activation of disaster plans by several agencies. Considering the magnitude of the explosions, the loss of only two lives, and the fact that only a few of the injuries were critical, can be described as very fortunate. The incident presented tremendous risk and unusual challenge to the fire departments involved, but they managed the incident with relatively minor casualties. The lives of most of the plant employees were saved by their decision to evacuate the plant, prior to the major explosions. This and other key issues are summarized in the table on the following page.

BACKGROUND

The incident occurred in an unincorporated industrial area of Clark County, approximately 10 miles southeast of downtown Las Vegas. The specific location is a county "island" surrounded by the city of Henderson, a rapidly growing suburb with a population of 50,000. The Henderson area has been a center of industrial production, much of it related to defense industries, since World War II.

SUMMARY OF KEY ISSUES

Issues	**Comments**
Ignition	Welding torch ignited structure of chemical plant
Construction	Fiberglass walls in steel-framed building helped spread fire
Hazardous Materials (Hazmat)	Plant produced and stored aluminum perchlorate, an oxidizer in rocket fuels. Other Hazmat, including anhydrous ammonia, hydrochloric acid, and nitric acid, were present in bulk quantities
Inter-agency Coordination	Working relationships established among fire, police, and other agencies as a result of previous hotel fires helped make management of this incident more efficient. An on-scene command post and a mulch-jurisdictional command center worked well
Public Information	News media demand for immediate information overwhelmed official sources resulting in misinformation in the media, widespread rumors, and near panic
Industrial Safety Planning	Employees saved their lives by rapid evacuation once the danger of explosions was recognized. Lack of an evacuation plan made it difficult to account for all employees after the incident
Land Development	Industrial development close to the plant was destroyed and damage was reported over a large area. Residential development near the plant was damaged, but few injuries occurred there because of the time of day
Emergency Medical Triage	Triage points set up outside hospitals kept them from being overwhelmed as the widespread injured came in for aid.

Hazmat Guidebook	Department of Transportation Emergency Response Guidebook information on large particle size ammonium perchlorate may imply less danger than exists, in light of this incident.

The Pacific Engineering Production Company of Nevada (PEPCON), site of the explosions, is one of only two free world producers of ammonium perchlorate, an oxidizer used in solid fuel rocket boosters, including the Space Shuttle and military weapons. The other producer also is located within Clark County, less than 1.5 miles away from the PEPCON facility – within the area that suffered some blast damage.

The plant occupied approximately eight acres, including six buildings and outside chemical storage and process areas. The plant was constructed in the 1950's in an isolated desert area. The isolation was reduced by rapid growth in the metropolitan Las Vegas area over the last decade.

At the time of the incident, there was a large marshmallow factory within 500 feet of the plant, and a gravel quarry was in operation nearby. While the closest residential and other commercial occupancies were approximately one and one half to two miles away, urban growth had greatly increased the population in the area affected by the explosions.

HAZMAT

Ammonium perchlorate was the only product manufactured at the PEPCON facility. The process uses several Hazmat, including anhydrous ammonia, hydrochloric acid, nitric acid, and various chlorate compounds. These chemicals were shipped to the site primarily by rail and were present in bulk quantities. An estimated 8.5 million pounds of the finished product were stored at the facility. Ammonium perchlorate is a powerful oxidizer which is mixed with combustible materials to produce rocket fuels. The mixed fuels provide a high energy release at a very rapid rate of combustion.

The rate of combustion is controlled by the mixture, particle size, and moisture content. Finely ground aluminum frequently is used as the combustible component. Without the combustible component, ammonium perchlorate is classified as an oxidizer and considered less hazardous than a mixed fuel. Normal combustion will be greatly accelerated in its presence, and contamination of ammonium perchlorate with an organic product will create explosive mixtures.

It is normally shipped in large aluminum "tote" containers, each holding several thousand pounds of the white granular material. Several hundred of the aluminum "totes" were stored in one area of the plant awaiting shipment, along with a smaller number of fiber drums. A quantity of nearly empty drums was also on hand to be refilled.

Another storage area at the plant contained several thousand 55-gallon plastic drums of the product waiting final blending to customer specifications. The plastic drums were not used to ship the product outside the plant.

The product (ammonium perchlorate) apparently had not been tested for mass (large quantity) detonation prior to this fire, and its classification was based on small scale tests. Although not previously considered to be explosive, this incident obviously gives testimony to the fact that ammonium perchlorate can explode.

According to the U.S. DOT Emergency Response Guidebook (the "yellow book" carried by many fire companies), the precautions for ammonium perchlorate are somewhat different depending on its particle sizes. There are different guide numbers, Hazmat numbers, and instructions for particle size under 45 microns and over 45 microns. A firefighter approaching a vehicle or plant might well not know which instructions to follow without detailed knowledge gained in pre-fire planning. At the Henderson plant, particle sizes were 90 microns and above, according to Deputy Chief Pappageorge of the Clark County Fire Department.

The information in the guidebook is intended to apply to quantities that would be encountered in transportation. For both particle sizes, the guide clearly notes the possibility of fire or explosion. For the smaller particle size, it provides the same information as a Class A explosive. It advises to stop traffic and evacuate to one mile away and not to fight the fire.

For the larger particle size product, the guidebook suggests the use of master streams from a safe distance and warns of irritating or poisonous gases that may be produced from a fire.

For either particle size, the firefighters are warned of the explosion potential. Bulk quantities as large as those normally stored in a plant or fixed site are not covered by the manual, but the warnings are dire enough to preclude approaching a major fire involving the product. However, the guidebook may not make it clear enough that even large particle size ammonium perchlorate can explode catastrophically.

In addition to the chemicals at the plant, a 16-inch, high-pressure (300 psi) natural gas transmission line ran underneath the plant and also supplied the plant through a pressure reducing assembly.

THE FIRE

The fire is reported to have originated in or around a drying process structure in the PEPCON plant between 1130 and 1140. The steel frame with fiberglass walls and roof structure had been damaged in a windstorm and employees were conducting repairs using a welding torch at the time. The fire spread rapidly in the fiberglass material, accelerated by ammonium perchlorate residue in the area.

As employees attempted to fight the fire with hoselines, the flames spread to 55-gallon plastic drums containing the product that was stored next to the building.

The employee efforts at extinguishment were unsuccessful, and they abandoned the effort when the first of a serious of explosions occurred in the 55-gallon drums. The time between ignition and the first explosion has not been determined exactly; it was estimated at 10-20 minutes. When the control efforts were abandoned, most of the plant employees evacuated the area by running or driving away. Approximately 75 managed to evacuate, leaving only the two who were killed in subsequent larger explosions. One of these victims stayed behind to call the Clark County Fire Department and the other was confined to a wheelchair and was unable to leave the area. The first explosion also alerted employees of the nearby marshmallow factory, and they also evacuated the area.

The fire continued to spread in the stacks of filled 55-gallon plastic drums and created an extremely intense fireball. The first of two major explosions then occurred in the drum storage area. The fire continued to spread and reached the storage area for the filled aluminum shipping containers. This resulted in an even larger, second major explosion, approximately four minutes later. Very little fuel remained after the second explosion and the flame diminished rapidly except for the flame plume created when the high pressure natural gas line beneath the plant was ruptured in one of the explosions. The gas line was shut off at 1259 hours by the gas company, at a valve about a mile away, eliminating the fuel for this fire.

A huge column of smoke rose from the plant and was carried downwind to the east, over most of the residential and business areas of Henderson. The smoke rose on the thermal column to an altitude of several thousand feet and was spotted almost 100 miles away.

All told, seven explosions occurred involving various containers of ammonium perchlorate, with the two largest occurring in the plastic drums and then the aluminum containers. These two explosions were measured at 3.0 and 3.5 on the Richter scale at an observatory in California! Over eight million pounds of the product were consumed in the fire and explosions. A crater estimated at 15 feet deep and over 200 feet long was left in the storage area.

FIRE DEPARTMENT RESPONSE

The Clark County Fire Department had received numerous telephone calls reporting the fire after the first (small) explosion, including the call from the plant employee. These calls had begun at 1151 and a first alarm assignment was dispatched immediately. The closest Clark County units had a response of over five miles and could see the heavy smoke from their station.

At approximately the same time, the huge column was spotted by the fire chief of the city of Henderson who was leaving the main fire station, approximately 1.5 miles north of the PEPCON facility. The chief immediately ordered his units to be dispatched and headed toward the scene. As he approached within a mile of the plant, he could see a massive white and orange fireball, approximately 100 feet in diameter, and dozens of people running across the desert toward him. He advised his dispatcher to call for mutual aid assistance although he was still unaware of the nature of the fire.

As he approached the scene at 1154, the first of the two major explosions occurred. The shock wave shattered the windows of his car and showered the chief and his passenger with glass. The driver of a heavily damaged vehicle coming away from the plant advised the chief of the danger of further, even larger explosions. With this information, the chief turned around and headed back toward his station. The other Henderson companies en route to the scene stopped where they were on their own volition after the explosion (about one mile away).

Approximately four minutes after the first major explosion, the second large explosion occurred. Witnesses reported that this explosion created a visible shock wave coming toward them across the ground. Several videotape recordings of the explosions were made by people in the area, graphically demonstrating the movement of the shock wave.

The second major explosion virtually destroyed the chief's car. The chief and his passenger were cut by flying glass, but he was able to drive the damaged vehicle to a hospital to seek treatment. The windshields of the responding Henderson Fire Department apparatus were blown in, and the drivers and officers were injured by the shattered glass. The Henderson Fire Department was essentially totally incapacitated by the second major explosion. The injuries consisted of numerous cuts from flying glass, but did not require hospitalization.

The Clark County response was upgraded to a third alarm while units were still en route. Several area fire departments also responded on mutual aid. The Clark County units staged 1.5 miles from the scene and provided assistance to the injured Henderson firefighters. From this distance they attempted to size-up the situation. Both the PEPCON facility and the neighboring marshmallow plant had been destroyed in the explosions prior to their arrival. The magnitude of the fire in the PEPCON facility was beyond any fire suppression capability, and flames also were visible in the rubble of the marshmallow plant. The only hydrants were in the immediate area of the two involved plants, but there was no water supply due to the loss of electrical power to the pumps. Recognizing the danger and futility of operations, no attempt was made to approach or to fight the fire.

A command post was established more than two miles from the scene at a location that afforded a view of the involved area. Responding fire and medical units were staged as an assessment was made of the situation.

FIRE DEPARTMENT OPERATIONS

The immediate concerns for emergency response personnel were:

1. The danger of additional explosions.
2. The possibility of toxic products being released with the smoke.
3. The need to search for and treat victims in the immediate area.
4. The need for damage assessment and emergency medical treatment in the entire area affected by the explosions.

A decision was made to evacuate a 5-mile radius around the plant, concentrating on the downwind direction as the priority. This assignment was given to the Las Vegas Metropolitan Police Department, assisted by the Nevada State Police, and, later, the National Guard. The roads in the area were clogged in both directions with residents trying to leave and curious spectators headed toward the scene. The massive traffic jams took over two hours to clear.

The command post established by the Clark County Fire Department was the focal point of operations in the immediate area. The department's Hazmat Response Team attempted to make an assessment of the toxicity danger using air sampling instruments. Assistance in air sampling and evaluation also was provided by Nellis Air Force Base Fire Department personnel and locally based experts from the military, U.S. Department of Energy, and both the State and Federal Environmental Protection Agency (EPA). The plant manager was located and brought to the command post to assist in evaluating the situation.

A conclusion was reached more than an hour after the first explosions that the airborne products would be a respiratory irritant, but not highly toxic, and that the danger of further explosions was remote. Expansion of the evacuation zone to 10 miles was being considered, but implementation was canceled on the basis of this information, though several cases of respiratory irritation were reported in a small community approximately 30 miles downwind.

After the fires began to subside, a battalion chief and the fire inspector who was familiar with the plant made an initial, close-in survey and determined that there was no further risk of explosions. Overhaul was extremely difficult, since water had to be trucked in and constant evaluation of the dangers from Hazmat was necessary.

Crews donned protective clothing near the command post and were transported into the scene using self-contained breathing apparatus (SCBA). Leaking tanks of anhydrous ammonia and residue from acids and other products made progress slow and required continuing evaluation by the Clark County Fire Department Hazmat Team. During the overhaul stages, several firefighters required treatment for respiratory irritation. Overhaul continued until dusk and was resumed the following day.

During the overhaul process the remains of one plant employee were located. No trace of the second victim was ever found.

EMERGENCY MEDICAL OPERATIONS

Emergency medical treatment in the area of the explosions consisted mainly of basic life support for those injured by flying debris. The damaged cars in the area were searched and one critical (head trauma) patient was located in a car 1/2 mile from the PEPCON facility. Employees, who had run in all directions, were assembled in an area adjacent to the

command post. Over 100 employees were on the premises of the PEPCON and marshmallow plants when the incident began, but only 20 to 30 required hospital treatments, and most were released within two hours. It took over six hours to account for all of the employees and determine that two were missing.

Both the fire departments and a large private-sector ambulance service provide emergency medical treatment and transportation in the metropolitan Las Vegas area and work together effectively on routine basis. The ambulance service established a triage sector to manage patients at the scene, located near the fire department command post. The triage sector was staffed by paramedics from both private and public units and dealt mainly with the employees and others injured in the immediate area.

The major emergency medical problem was the estimated 300 patients who were injured in the surrounding area. These patients were distributed over an area of 50 to 75 square miles and suffered injuries primarily from flying glass and falling debris from ceilings and light fixtures. One infant was seriously cut by glass from a broken window, more than two miles from the scene.

Emergency medical services (EMS) treated and transported approximately 100 patients to five hospitals in the region. The remaining 200 to 300 patients presented themselves to hospitals as "walking wounded." Triage areas were set up outside hospitals to handle this influx in an orderly manner. The hospitals had activated their disaster plans, making trauma teams and operating rooms ready, but they received only a handful of seriously injured patients. Emergency room facilities were taxed by the numbers but not the severity of the injuries.

The closest hospital, St. Rose de Lima in downtown Henderson, treated over 100 patients, many in the parking lot. The hospital had many windows broken by the explosion and was operating on emergency generator power. The hospital continued to provide treatment while making preparations to evacuate, in case this became necessary.

Approximately four hours after the incident began, the hospitals were advised by the fire department that their disaster plans could be deactivated.

A total of 15 firefighters were injured, eight from flying broken glass and seven from respiratory difficulties during overhaul.

DAMAGE ASSESSMENT

Both the PEPCON and marshmallow manufacturing facilities were virtually destroyed. Damage within a 1.5 mile radius was heavy, including destroyed cars, structural damage to buildings and downed power lines. Within three miles there was extensive window breakage and moderate structural damage. Many structures had damage to suspended ceilings and overhangs, windows and doors, exterior details, and cracked walls.

Damage extended for a radius of up to 10 miles. Buildings were damaged throughout Henderson including over 100,000 dollars damage to the main fire station and heavy structural damage to a warehouse next door. Hundreds of windows were shattered, doors were blown off their hinges, walls cracked, and scores of people were injured by flying glass and debris. At Las Vegas' McCarran International Airport seven miles away, windows were cracked and doors were pushed open. A Boeing 737 on final approach was buffeted by the shock wave.

The fire departments in the area were heavily committed to the actual incident scene and had little involvement with damage assessment or other activities away from the immediate area.

INFORMATION MANAGEMENT

One of the major challenges faced by the Clark County Fire Department in this incident was the management of information. The department itself had an urgent need for information on what had happened, was happening, and could happen, in order to formulate a plan for operations and evacuation. This required consultation with fire department personnel, plant management, and experts from other agencies, under extremes of stress and uncertainty.

While the process of planning and evaluation was taking place, there were immediate and constant pressures from the local news media for details and for information to broadcast to the public concerning the dangers and actions that should be taken. The time required to gather and analyze information resulted in some incorrect information being broadcast and caused widespread public confusion. At the same time the national news media were calling for more details. The Clark County Fire Department's public information officer responded and established an official source of media information within an hour after the explosion.

Many residents were in near panic from rumors of several different scenarios and dangers. Radio and television stations quickly devoted their air time to the situation, but lacked a source of accurate information during the first hour. Conflicting information was broadcast and, as a result, people in the area reported confusion about whether to stay indoors to avoid the smoke, evacuate, go to shelters, or take some other action. The confusion extended to schools in the area, with some keeping children inside and others sending students home.

Telephone lines were overloaded with people checking on each others welfare, seeking advice from different sources, or trying to report conditions to emergency response agencies and the news media. The 9-1-1 telephone system was rapidly overloaded with concerned callers, many seeking instructions, and the cellular telephone system was overloaded.

This emphasizes the need to establish working lines of communication with the news media. But even with a good relationship, the ability to provide accurate information and to depend upon the news media to convey instructions to the public, becomes very uncertain in an incident of this magnitude. In this case several inaccurate reports, including "confirmed reports of 9 to 14 dead" were broadcast.

There was also a concern for the safety of news gathering personnel who approached closer to the involved area than fire department personnel would venture, including helicopters circling within the danger zone.

INTERAGENCY COOPERATION

The Clark County Fire Department received valuable assistance from a number of other agencies during this incident. This included mutual aid from several fire departments, including Henderson, Las Vegas, Boulder, Nellis Air Force Base, and the U.S. Park Service. The fire department response was effectively coordinated through the on-scene command post and the communications center that serves the city of Las Vegas, Clark County, and North Las Vegas. This routine approach to mutual aid and automatic assistance also facilitated the cooperation between the public and private EMS providers. Effective planning also provided for the coordinated activation of hospital disaster plans.

The fire department received additional assistance, including extra SCBAs loaned by hotels and casinos for use by off-shift firefighters. Lighting plants were provided by Nellis Air Force Base, and a private catering firm fed all personnel at the scene, according to an established plan.

Hazmat expertise was provided by several agencies, primarily military and other Federal government agencies that are active in the area.

With fire department capabilities concentrating on the fire and Hazmat situations, the police department managed evacuation and control of traffic and spectators. The Governor of the State of Nevada responded to the scene and activated the National Guard to assist in securing the evacuated area. All of these functions were effectively coordinated through liaisons at the command post.

Several agencies, including the Red Cross and school districts, were involved in providing temporary shelter for evacuees.

LESSONS LEARNED

1. **Land development decisions must consider risks of disasters.** The potential destructive power from an incident of this type needs to be evaluated in land use decisions. The encroachment of residential and commercial development into the area around the PEPCON plant contributed significantly to the injuries and damage. The magnitude of the incident was much greater than had been contemplated by urban planners or in pre-incident planning.
2. **Need for triage outside hospitals: large numbers of even minor injuries can overwhelm a medical facility once inside.** Damage and injuries spread over a large area present unusual challenges to emergency services, which are accustomed to incidents occurring in a well-defined area. Large numbers of injured presented themselves to hospitals. Triage centers need to be set up outside hospitals to prevent overloads within the hospitals when the EMS cannot "capture" most victims at the site of the incident. Fortunately in this incident there were not large numbers of seriously injured waiting for assistance and relying on public agencies for treatment and transportation. This potential needs to be considered ore than it has been by local communities.
3. **Disaster mutual aid plans should be established, practiced, and kept up-to-date.** The value of established mutual aid and inter-agency coordination procedures was demonstrated once again. Many of these relationships came as a result of Las Vegas' experience from major fires at the MGM Grand and Hilton Hotels in 1980 and 1981. Communities should review their disaster coordination plans and make sure they are up-to- date.

4. **Hazmat incidents require size-up from a safe distance.** The need for a "stand back and assess the situation" strategy for some Hazmat incidents was well demonstrated. Had fire units continued at full speed to the scene they probably would have been destroyed.
5. **Public information needs to be accurate and timely in a disaster.** In spite of a good relationship and established procedures, dealing effectively with the media was a major problem in the early stages of the incident. Misinformation by the media and rumors among the public created near panic. Since the aftermath was not dangerous, it did not matter much here whether people stayed indoors or not. But in an environmentally serious incident, clear information should be given to the public as soon as possible on what to do, even if that must be changed as conditions change. The departments did a good job in providing information to the media as it became available, but the media did not wait for good information.
6. **Evacuation plans and implementation must consider human nature and the media.** The roads in the area were virtually gridlocked by spectators going toward the scene and local residents fleeing. Media misinformation, the failure to broadcast adequate, specific requests to stay away from the scene, and the inability to control the roads early enough, exacerbated the traffic situation. The need for traffic control around high hazards should be considered in disaster plans.
7. **The problem of assessing the immediate risk of Hazmat releases and products of combustion on the surrounding area needs additional research and development.** Determining the risk of explosion and the risk of toxic fumes to the public and to their firefighters can be extremely difficult. Some aspects of risk assessment are too specialized to be covered in general Hazmat training courses. Special expertise needs to be called into play when unusual or exotic Hazmat is known to be present in a plant or other location. The "worst case" situation needs to be anticipated. Local fire departments also need to know who to call for quick assistance in air sampling. Whatever the designated agency – most often it is the State EPA – its personnel need to be equipped, trained, and prepared to respond quickly to locations throughout their State if they are to be of real assistance. (In the Nanticoke, Pennsylvania, chemical plant fire, which occurred in March of 1987 and was also investigated by the USFA, getting assistance in air sampling was a major problem.)[1] Sampling devices to identify gases need to be improved and put into greater use. Improved methods need to be developed to make a more rapid assessment of risk.
8. **Industrial safety plans need to be established, kept up-to-date, and understood by all employees.** The employees in the chemical plant averted a life loss catastrophe by fleeing immediately after the first ("small") explosion and fireball. There was no alarm system and no evacuation plan, according to the employees. Plants such as this should have explicit emergency plans, and all employees should be trained.
9. **Safety of the handicapped needs to be considered in high-hazard occupancies.** One of the two fatalities in this fire was a wheelchair-bound employee who obviously could not just run across the desert or jump in his car, as most others did. Society now encourages and assists the handicapped to visit and work in a much wider range of occupancies, which exposes them to new risks. The handicapped need to be given realistic appraisal of their risks in a potential emergency and their alternatives for escape or refuge, even though the probability of the event occurring is low. Volunteers might be assigned to handicapped individuals to help them to escape by car or truck, or by being wheeled or carried to a safe distance. This may suffice for most emergencies, but in the face of a catastrophic explosion the value of such assignments may be moot.
10. **The section on ammonium perchlorate in the DOT Emergency Response Guidebook needs to be revised.** The danger of explosion from large (over 45 microns) particle size ammonium perchlorate when exposed to flames seems to be much greater than indicated in the manual. The small particle size might be viewed as a Class A explosive and the large particle size version as almost that dangerous.

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