

Propane Fires and Explosions

Fire fighters respond to propane incidents in the United States nearly once per day on the average. According to the National Fire Incident Reporting System (the data base of the U.S. Fire Administration), the number of propane incidents on an annual basis was 301 in 2005 and 317 in 2006; as all states do not require participation in this data base, the actual number of propane incidents responded to by fire departments may be higher. Unfortunately, firefighters and emergency responders have died responding to propane incidents. Many of these incidents occurred in rural locations. There are about 17.5 million propane installations in the United States. We will look at a couple of tragic accidents.

Turkey Farm, Albert City Iowa, 9 April 1998. Two fire fighters killed, seven injured

This incident was investigated by the U.S. Chemical Safety and Hazard Investigation Board (CSB); their findings are published as report no. 98-007-I-IA, and can be downloaded from http://www.csb.gov/completed_investigations/docs/Final%20Herrig.pdf. The photos used here were taken from this report. Only a few of the total number of propane incidents are investigated by the CSB. NIOSH also investigated this accident; their report is available at <http://www.cdc.gov/niosh/fire/reports/face9814.html>.



Aerial photo of Herrig Brothers farm taken on 10 April 1998, one day later. Yellow oval shows the location of propane tank prior to the blast (photo from CSB).

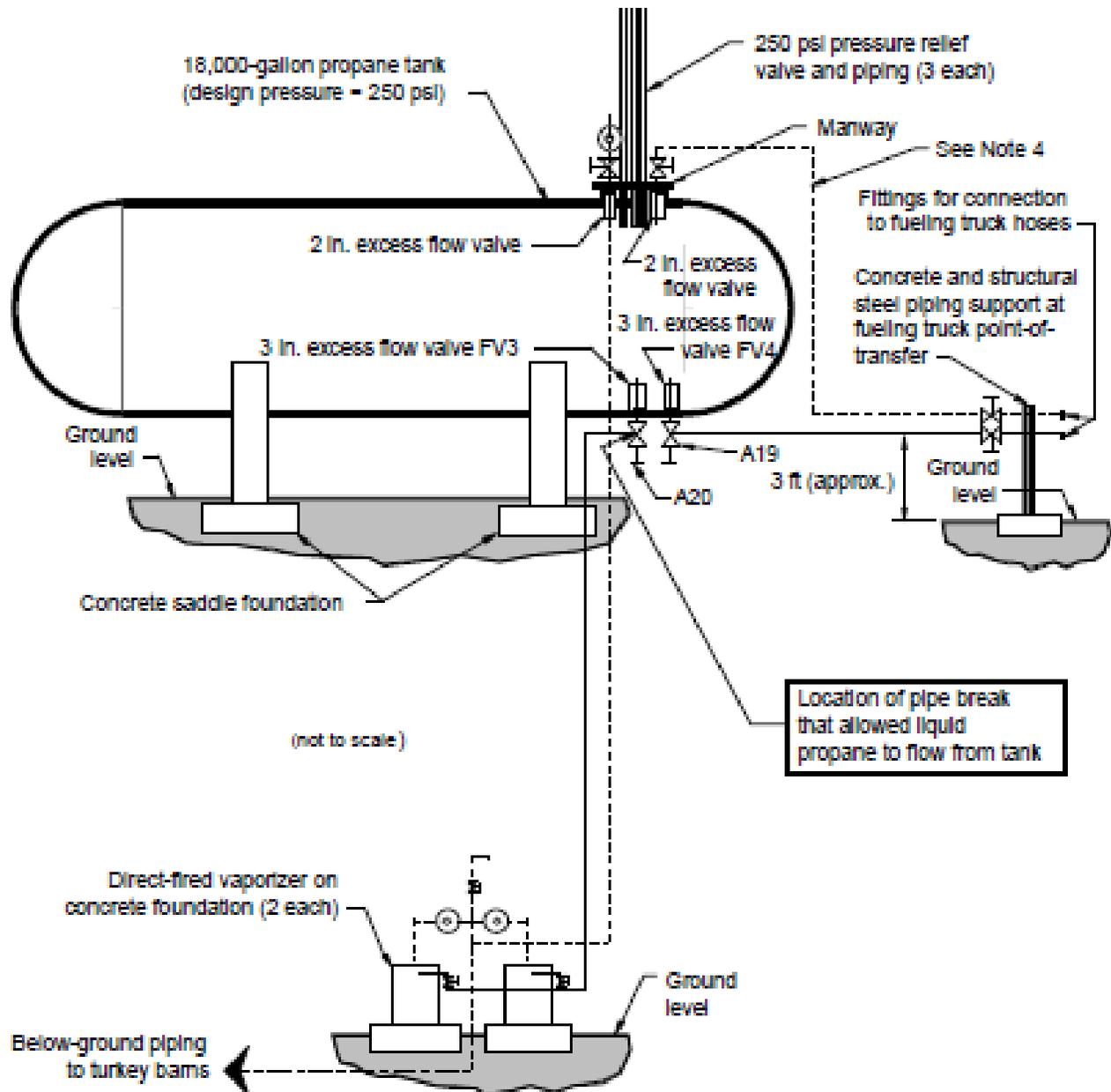


Top, A 18,000-gallon propane tank similar to the one that exploded at the Herrig Brothers Feather Creek Farm (the turkey farm) in Albert City, Iowa, from NIOSH report. Note protective fencing around piping for this tank which was lacking at the Iowa farm propane tank.



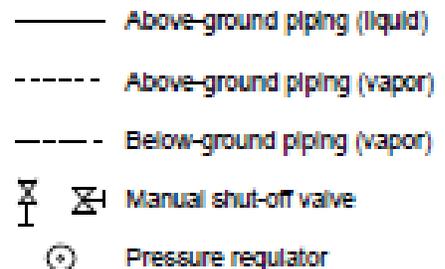
Left, Herrig Bros. 42-foot long tank before explosion. The tank was out in the open away from any buildings, and the tank and above ground piping had no protective fence to keep intruders away. Right, large tank fragment, about half of the tank, was propelled inside a turkey barn as a result of the explosion.

The following is a sketch of 18,000-gallon propane tank and piping setup at the farm, from the CSB report. The tank was estimated to contain 10,000 gallons of propane at the time of the explosion, at approximately 11:28 pm, on April 9, 1998. Two firefighters responding to a fire which engulfed the propane tank, were killed by tank fragments resulting from a BLEVE explosion (BLEVE= Boiling Liquid Expanding Vapor Explosion). Seven other people were injured, and several buildings were severely damaged by the blast. The firefighters assumed if they stayed away from the ends of the tank they would be “safe”, but exploding tank fragments were hurled in all directions.



Note:

1. Pressure, temperature, and liquid level gauges installed on tank are not shown.
2. Structural support for above-ground piping provided by vertical steel columns spaced at regular intervals.
3. Tank contained approximately 10,000 gallons of propane at time of incident.
4. Vapor line that connects tank to the fueling truck point-of-transfer is not shown in actual perspective.

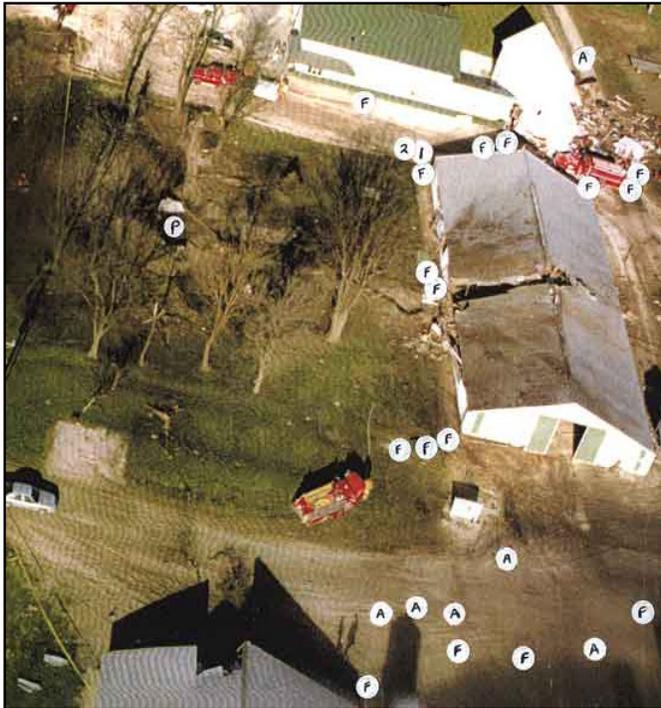


The Herrig Brothers Feather Creek farm raised turkeys, which were housed in seven barns. Propane was used as fuel for space heaters and furnaces, which provided heat for the turkey barns. On the evening of 9 April 1998, eight high-school teens gathered at the farm for a party. The owners, which did not live at the farm, said that they did not have knowledge or consent of the event although they were aware of other social gatherings took place in the past. One of the youths began driving an all-terrain vehicle (ATV), which struck two above ground pipes which ran parallel to each other at the tank location and were used to transport propane to vaporizers located 37 feet away. Liquid propane leaked out of the ¾-inch pipe at the point of the break. An excess flow valve protecting the liquid pipe line leaving the tank failed to function. Propane may also have leaked from the second line struck by the ATV, but this was not conclusively established. As the liquid propane sprayed from the line, it quickly vaporized and ignited within a few minutes, presumably from one of the direct-fired vaporizers located 37 feet away. The time of ignition was estimated to be roughly 11:05 PM (based on later CSB interviews of the teenagers). Two teens drove to a neighbor located ½ mile away, who called the 911 operator at 11:10 PM to report the fire.

Twenty members of the Albert City Volunteer Fire Department and two Buena Vista County Sheriff Deputies arrive at the farm at 11:21 PM. The firefighters observed flames originating from the west end of the tank, and also from pressure relief valve pipes located on top of the tank. One fire fighter said that the propane tank was fully engulfed in flames and flames shot 70 to 100 yards into the air. Because of the fire, the firefighters did not attempt to reach a manual shutoff valve on the broken pipe. The plan was to let the fire burn itself out and to setup the fire trucks to spray water on nearby buildings which were getting hot. One of the fire trucks was sent away to get more water.

At approximately 11:28 PM, as fire-fighting equipment was being moved into position, the tank exploded scattering tank fragments in all directions. One large piece hurled to the northwest struck and killed two volunteer firemen located 100 feet away from the tank. The same piece narrowly missed the Fire Chief. Another large piece was propelled to the north narrowly missing two firefighters. Seven firefighters were injured, including some with severe burns. The largest piece was hurled to the east and came to rest inside one of the turkey barns (shown in the photo). At least 36 pieces (possibly 40 pieces) were later located by investigators, some in fields off the 14-acre property site. Unfortunately, while the CSB report identified the fragments and locations, there were no distances presented as to how far the fragments were thrown.

The CSB report established that the propane explosion was a BLEVE, a Boiling Liquid Expanding Vapor Explosion. Unpressurized propane is a gas (at room temperature) with a normal boiling point of about -42°C (-43°F), but it is normally stored in tanks as a liquid under pressure. At the estimated 38°F ambient temperature before the incident, the vapor pressure of the liquefied propane inside the tank would initially be at about 80 psi. When responders arrived at 11:21 PM, the tank was engulfed in flames, and the safety release valves at the top of the tank designed to vent at 250 psi gauge were obviously working, based on firefighter reports that the noise from the release valves was “like standing next to a jet plane with its engine at full throttle”. It is not known at what pressure the propane tank failed, but the CSB report estimated it to be somewhat less than 1000 psi. The sudden release of pressure resulted in a rapidly expanding boiling liquid and vapor and explosion.



Left photo, Aerial view of Incident scene showing locations of firefighters and equipment at time of explosion, from NIOSH report at <http://www.cdc.gov/niosh/fire/reports/face9814.html>.

P = position of propane tank
 1, 2 = location of firefighters killed by fragments from exploding propane tank
 F = position of other firefighters
 A = position of apparatus

CSB Analysis:

1. The above ground piping was not protected from potential damage by vehicles, as required by Iowa law citing the 1979 edition of the National Fire Protection Association’s “Standard for the Storage and Handling of Liquefied Petroleum Gases” (NRPA 58). The lack of piping protection allowed the ATV to crash into the pipes that ran from the tank to the vaporizers.
2. The outlet propane pipe diameter was improperly sized for the excess flow valve, which was supposed to automatically shut off the flow in case of excess flow in the propane pipe. The valve was designed to shut off at 200 gpm, which in no way could occur with the ¾ inch diameter propane outlet pipe. Therefore the valve did not shut off. Had the valve shut off, the BLEVE probably would not have occurred.
3. Firefighters were too close to the propane tank. The firefighters assumed that if they kept away from the ends of the propane tank they would be safe. The CSB report cited that firefighters had receive inadequate training for responding to propane tank fires.

International Fire Service Training Association guidelines¹ for responding to propane tank fires:

1. Do not assume that the venting of propane from relief valves will prevent over pressurization and rupture of the tank.
2. Apply large quantities of water to the tank. For large propane tanks, at least 500 gallons per minute is needed.
3. If a flame is impinging on the tank, water must be applied directly to the impinged area in order to prevent a BLEVE.

4. Water should be sprayed by use of an unmanned fire hose system.
5. If a continuous supply of water is not available, withdraw and isolate the area for ½ mile in all directions.

The 1996 Emergency Response Guidebook(ERG), which was carried by the fire fighter vehicles at this incident, under Guide Number 115 which addresses propane tank fires, recommends that responders to a massive fire use “unmanned hose holders or monitor nozzles”, or if this is not possible, to “withdraw from the area and let the fire burn”. There was also a statement in the 1996 ERG to “withdraw immediately in case of rising sound from venting safety devices...”. However the 1996 ERG also contained a possible misleading statement under Guide Number 115, “ALWAYS stay away from the ends of tanks”, which could be interpreted by firefighters to mean that by avoiding the ends of the tank the sides of the tank would be safe. As the result of the Herrig Brothers propane explosion and CSB report, later editions of ERG Guide Number 115 for responding to large propane tank fires reads as follows (from 2008 ERG):

Fire involving Tanks

- Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.
- Cool containers with flooding quantities of water until well after fire is out.
- Do not direct water at source of leak or safety devices; icing may occur.
- Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
- ALWAYS stay away from tanks engulfed in fire.
- For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn.

Propane Explosion, 30 January 2007, Ghent WV, Four killed including two responders, six injured

This incident was investigated by the U.S. Chemical Safety and Hazard Investigation Board (CSB); their findings are published as report no. 2007-04-I-WV released in September 2008, and can be downloaded from

http://www.csb.gov/completed_investigations/docs/CSBFinalReportLittleGeneral.pdf.

Information including the illustrations used here were taken from this report.

This case study was used as a basis for a CSB safety training video, which can be obtained at http://www.chemsafety.gov/index.cfm?folder=news_releases&page=news&NEWS_ID=447.

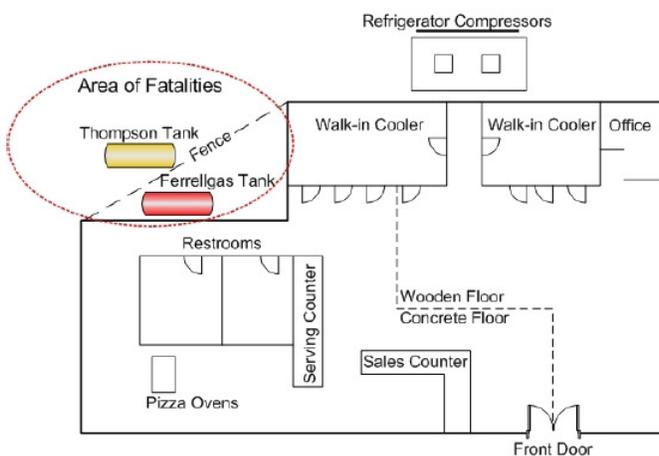
On 30 January 2007 at 10:53 AM, a propane explosion at the Little General Store in Ghent, West Virginia, killed four and injured six people. The dead included a fire department captain and an emergency medical technician from the Ghent Volunteer Fire Department and two propane service technicians. The injured included two other Ghent Volunteer Fire Department emergency responders and four store employees who were inside the store at the time of the explosion.



Photo from West Virginia State Fire Marshall as used in CSB report

The above photo, taken from CSB report no. 2007-04-I-WV, shows the demolished store and ambulance caught in the propane explosion.

Unlike the Herrig Brothers Albert City explosion, this did not involve a tank BLEVE. The cause was a propane leak which resulted in propane concentration in and near the store to build up and exceed the lower explosive limit concentration in the air (>2.1% by volume of propane in air).



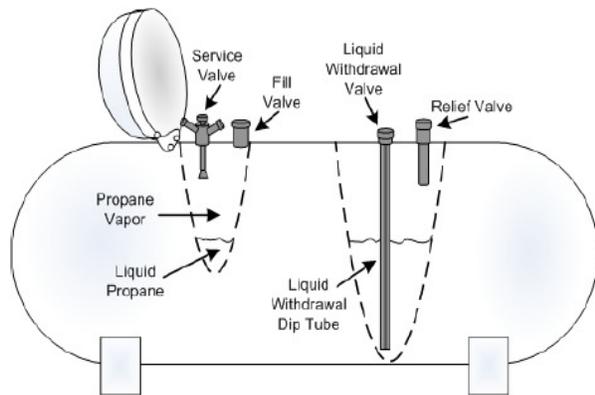
The propane leak occurred during transfer operations, when propane was being transferred from an existing older tank owned by Ferrellgas to a newly installed tank owned by Thompson Gas and Electric Services (called the Thompson tank). The two tanks were located adjacent to The Little General Store, as seen in the sketch to the left. The propane tanks were each 500 gallon capacity. The new Thompson tank was to be installed 10 feet from the building but the older tank was right next to the building.

Ferrellgas, headquartered in Kansas, is the second largest propane marketer in the United States, with customers in all 50 states. Thompson installs commercial and residential systems and delivers propane in eastern and southeastern U.S. Late in 2006, The Little General Store initiated a change in propane suppliers. Appalachian Heating, a local family owned business, has a contract with Thompson to install propane systems in the local area.

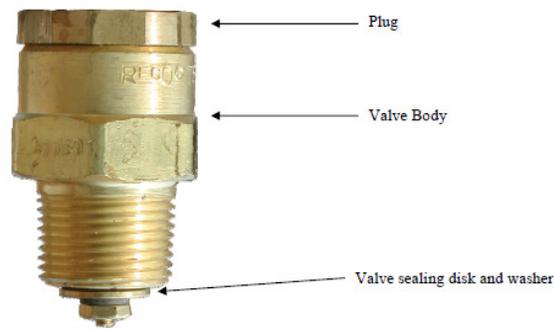
On the morning of 30 January 2007, two propane service technicians from Appalachian Heating arrived in separate vehicles at the Little General Store. The plan was to transfer propane from the existing Ferrellgas tank (installed in 1994) to the newly installed Thompson tank and place the new propane system in service. At about 9:30 AM, the lead technician left the store to make a delivery 31 miles away leaving a junior technician alone. The lead technician had earlier completed his "Certified Employee Training Program" in September 2006 for installing propane systems and had also spent nearly a full year working with experienced personnel, but the junior technician had no such training. For the next hour the junior technician worked alone preparing to transfer propane between the two tanks.

At about 10:25 AM, the junior technician removed a plug from the liquid withdrawal valve on the Ferrell tank, which resulted in liquid propane spraying from the valve. The junior technician then called (10:28 AM) the lead technician who was still off site. After the lead technician called Thompson technical support, he tried to reach the junior technician, most likely to encourage him to call "911". A deliveryman in the store at about 10:30 AM told CSB investigators that he had smelled a strong odor and noticed employee eyes were watering. A Little Store cashier checked on the junior technician who was standing outside within a dense vapor cloud near the tank, but the junior technician said that he was OK. At 10:40 AM, the junior technician called 911 to summon aid, but continued to remain near the tank within the propane vapor cloud.

At about 10:47 AM, a captain from the Ghent Volunteer Fire Department arrived on scene and assumed role of incident commander. Shortly afterwards, two EMT's arrived in an ambulance. The captain ordered the business to close, and asked the EMT's to follow him to behind the building to treat the junior technician who was still near the propane tanks and apparently had suffered frostbite from the leaking propane. Shortly after 10:50 AM, the lead technician returned, and walked back to the area of the propane tanks. The captain ordered one of the EMT's to the front of the store to check that the store was closed and that no one was smoking or pumping gas; the store was locked, but the EMT spoke to employees who were still inside the store. A firefighter then arrived in his personal vehicle and could hear the escaping propane. The captain ordered the firefighter to get all employees out of the store. As the firefighter approached the front of the store, the propane ignited and exploded. The four people near the propane tank were killed (the lead and junior service technicians, the captain, and the EMT treating the junior service technician). The four employees inside the store and two firemen were injured. The explosion leveled the store, destroyed an ambulance, and damaged many parked vehicles. The Ferrellgas tank was hurled about 80 feet due to the force of the blast.



Sketch of a propane tank showing locations of Liquid Withdrawal Valve and Fill Valve



Top: Liquid Withdrawal Valve
Left: Removed Plug, with telltail circled

CSB Analysis:

1. The Ferrellgas Propane Tank, installed in 1994, was located right next to the building in contrary to OSHA and National Fire Protection Association (NFPA) Standards which state that a 500 gallon propane tank should be located at least 10 feet from commercial or residential buildings. The OSHA standard, *Storage and Handling of Liquefied Petroleum Gases*, and NFPA 54, *National Fuel Gas Code*, and NFPA 58 Chapter 6, *Liquefied Petroleum Gas Code*, all address the location of tanks. The open building overhang above the propane tank, and the interior restroom exhaust ducts provided a direct pathway for propane gas to enter the store. It was not clear to CSB why this shortcoming was not recognized and corrected during the 12 or 13 years the tank was in service, even though it was filled many times and inspected. Another propane company prior to Ferrellgas had originally installed the tank. The new Thompson tank was to be located 10 feet away from the store.
2. The junior technician, who was hired 45 days earlier, did not undergo the “Certified Employee Training Program” (CETP) put together by the propane industries. Thompson requires its employees to be CETP-trained, and Appalachian Heating did not notify Thompson of the new employee. This training program is developed by the National Propane Gas Association (details at <http://www.npga.org>, go to “Safety/Training Programs”). The junior technician apparently did not recognize the hazard of a propane gas cloud. OSHA and DOT require employee training, but do not elaborate on the requirement.
3. Technicians only open liquid withdrawal valves when propane tanks are completely emptied of liquid. The CSB investigation found that the liquid withdrawal valve was still on the damaged tank after the accident, but the plug was removed. The investigation found that the liquid withdrawal valve itself was defective causing it to be in an “open position”, and assuming the valve was defective before the accident, this means that the plug was the only thing preventing the propane from escaping the tank. As an additional safety backup, the plug on the withdrawal valve has a telltale drilled through the treaded portion which should have released a small stream of propane once the plug was partially backed out in the case of a defective valve in open position. This should have alerted the

junior technician that the valve was leaking and something was wrong. This specific information was addressed in CETP training, which included written instructions, and which included the statement, “WHEN IN DOUBT DO NOT REMOVE THE PLUG”. The junior technician apparently did not recognize this and continued to unscrew the plug.

4. The Incident Commander (captain from the Ghent Volunteer Fire Department) while he initially followed procedure on assessing the situation was slow to act on ordering a complete evacuation. The Incident Commander apparently allowed the junior technician to try to stop the leak. Had the Incident Commander had certain critical pieces of information available (the technician did not have training; propane gas was entering the building), he probably would have ordered everyone to leave the area immediately. Only six minutes passed from the time the Incident Commander arrived on scene until the explosion.
5. The Ghent Volunteer Fire Department only had minimal information available (gas leak at The Little General Store at Flat Top Lake) when they were contacted by the 911 dispatcher, and the 911 operator was not trained to ask the right questions. The 911 caller said he had a propane leak, the 911 dispatcher said a gas leak. There was also no prompt card available on propane to prompt the 911 caller to ask the right questions, and the responders did not know the severity of the situation. A citizen driving past called the response team to clarify that it was a propane leak. The propane industry has prepared a script for use in situations where customers report propane leaks, which could be part of a 911 prompt card.
 - * Where is the leak?
 - * Do you hear gas escaping?
 - * Is the leak near any building?
 - * Is there odor of gas in the building?

Should a fire department permit propane service technicians to stop a propane leak from a valve or piping?

The CSB reviewed another incident, a vapor release of propane from the Southshore Mall in Aberdeen, Washington, which occurred on 23 October 2007. The 1,150-gallon propane tank was located in a utility yard approximately 25 feet from mall restaurants. Shortly after 2 PM, a mall employee heard a “pop”, and upon investigation discovered the leaking tank. The fire department was called, they evacuated the mall, and secured the scene. The fire department contacted the propane company that owned the tank for support. The propane company sent a service technician. The service technician discovered that the release was from the propane tank’s fill valve which was stuck in a partially open position. The service technician installed a double check valve on the leaking fill valve to stop the release. All this was done in less than one hour. The evacuation order was lifted at 2:45 PM. The differences between this incident and the Ghent explosion with respect to allowing a propane service technician to work on the tank was as follows:

1. The fire department first evacuated everyone and secured the area before permitting the service technician to enter.

2. The fire department already had a working relationship with the propane company and knew that the service technician was CETP-certified, and the service technician had previously worked with the fire department on propane incidents.
3. The vapor release was minor compared with the Ghent release, and the service technician knew how to correct the leak.

As of 2007, only 14 states require training for propane service technicians, and 11 of the 14 states either require or accept CETP certification for this training.

The PEAC Tool

The first duty of first responders is to evacuate and secure the area. There may be also be injured that need attending; an important step is removal of injured to a safer area if possible while evacuation takes place. The PEAC tool can provide responders on safe evacuation distances for propane, which is linked to Guide Number 115 in the Emergency Response Guidebook. In case of a large spill, the recommended evacuation distance is at least ½ mile or 800 meters. As an immediate precautionary measure, the spill or leak should be isolated for at least 330 feet (100 meters) in all directions. Guide Number 115 also gives guidance on how to fight fires and whether responders should evacuate. In the case of tank fires, responders should evacuate immediately in case of rising sound from a venting tank or a tank is engulfed in flames or becomes discolored. If there is no flame, responders should also evacuate if they hear escaping propane from a tank, or a strong tell-tale odor (rotten egg odor) is noticed. Propane itself is odorless, but trace amounts of butyl mercaptan or a similar odorous chemical is added as a warning if a leak occurs. Propane gas is heavier than air and will tend to hug the ground.

The PEAC tool does not give instructions on how to stop a leak. Only when the situation is deemed “safe” (a vapor cloud explosion or a BLEVE is not likely) should qualified technicians be allowed to approach the tank.

The PEAC tool is designed to contain considerable technical information in a small package useful for first responders. The tool is set up so the information can be extracted quickly.

Conclusions

These two examples show the complex situations involving response to emergency situations and interaction between other people. First responders do not have the benefit of hindsight when responding to an emergency situation. They must act quickly under a stressful situation, and cannot take for granted that propane or other chemical storage facilities are designed properly or people on site know what they are doing. They must recognize quickly a potentially dangerous situation and not be afraid to set priorities especially if an immediate evacuation is required.

Reference Citation

1. International Fire Service Training Association. *Hazardous Materials for First Responders* pages 276-280. Oklahoma State University, Stillwater OH, 1990.

Footnote

Remember the firefighters and their families who have died in the line of duty.
The total number of firefighter deaths and injuries for all responses on an annual basis is found at the website, <http://www.usfa.dhs.gov/fireservice/fatalities/statistics/casualties.shtm>.