PROPANE EXPLOSION: A CASE STUDY

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ON MONDAY DECEMBER 29, 2003, THE INTERCOURSE Fire Company of Leacock Township, Lancaster County, Pennsylvania, was dispatched to a building fire at a propane distribution facility. Multiple callers inundated the county 9-1-1 center with reports of a large explosion at the site. First-arriving fire units found a building demolished by an explosion and a sustained fire. Compounding the situation were multiple propane cylinders exposed to the intense heat and accountability of the facility employees. The exposed tanks ranged from 100-gallon portable cylinders to 30,000-gallon fixed bulk storage tanks. The incident required the response of fire departments from two counties: 49 fire apparatus, including 12 engine companies and 22 mobile water tankers. The incident tested the incident command system, operations, and responders' resources and provided valuable lessons learned that can be applied to many incident scenarios, not only those involving propane.

FIRE PROTECTION BACKGROUND

(1-3) Intense fire was encountered shortly after arrival. View is from the west. (Photos by Gordon Shuit unless otherwise noted.)

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Located in rural eastern Lancaster County, the facility is situated southeast of the village of Intercourse. The area is not supported by a municipal water system; emergency water sources are created through mobile water-tanker shuttles and various drafting points. The area is protected by an all-volunteer fire company comprised of 40 active members operating a mini-pumper, a class A pumper, a 3,500-gallon tanker, and a utility vehicle. Automatic and mutual aid are embraced

by nearly all of the county's 80 independent fire companies. As this incident illustrates, identifying resources and the need for resource depth before the incident is essential.

THE FACILITY

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The facility, owned and operated by Amerigas Propane, is a residential and commercial propane supply and distribution site. The property itself is comprised of several buildings that include an office building, a cylinder filling dock, a garage, a cylinder maintenance building, and an open truck shelter. The facility maintains an extensive inventory of propane, including dozens of portable cylinders and fixed aboveground propane storage tanks. In addition to the portable units and the three 30,000-gallon aboveground storage tanks, the site also maintains a 10,000-gallon aboveground diesel fuel tank and a 1,000-gallon aboveground gasoline tank. Both are close to the cylinder maintenance building (see Figure 1).

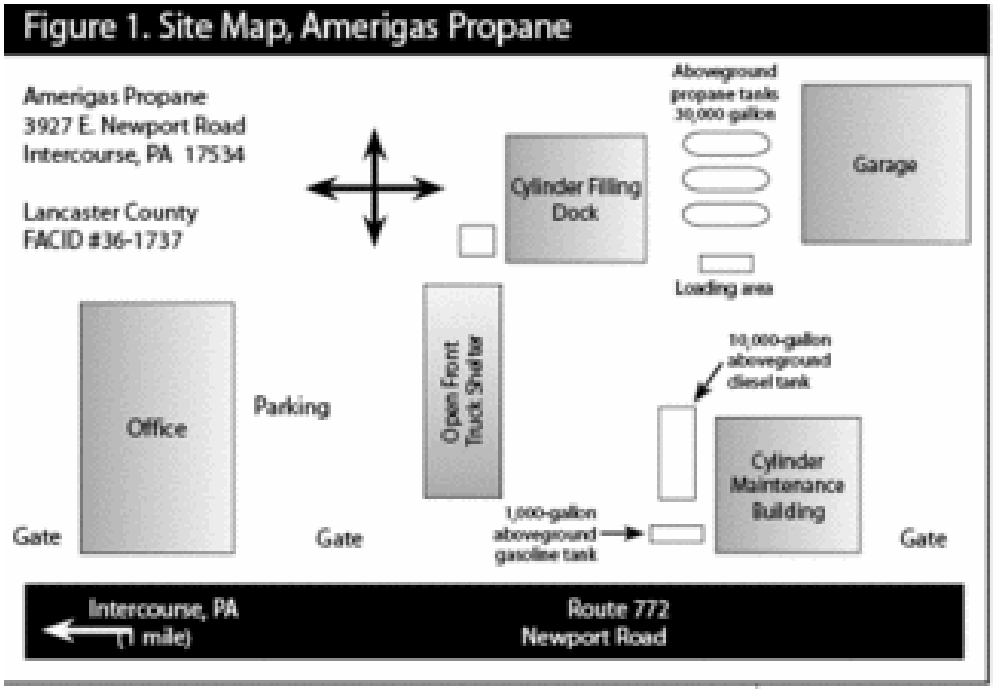

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Figure 1

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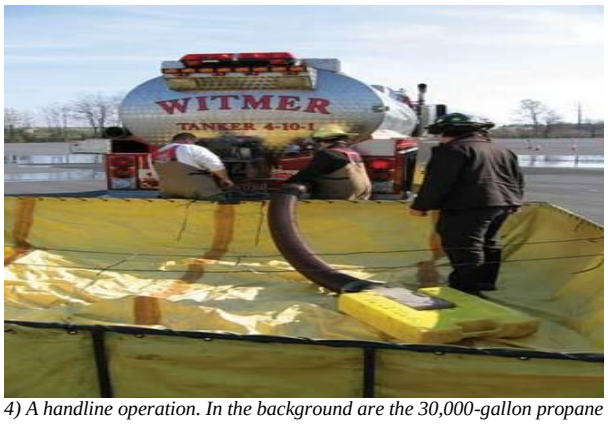
The facility is on Pennsylvania State Route 772, known locally as East Newport Road, and is the primary corridor between the villages of Intercourse and Gap, four miles to the southeast. The rural location created both access and operational challenges with regard to apparatus staging, mobile water tanker movement, and water supply. The area offered limited alternatives for secondary access, mandating mobile water tankers to travel inconvenient and time-consuming routes to access draft and dump sites.



4) A handline operation. In the background are the 30,000-gallon propane tanks and the transport truck.

Click here to enlarge image

Exposures to the property were primarily residential structures. The closest property was a residential unit 300 feet to the southwest. Another residential property was 800 feet northwest. The next closest exposure was a farm approximately 900 feet to the southeast. To the northeast was a farm approximately 2,200 feet away. No evacuations of these properties were conducted during the event.

THE INCIDENT

At 1021 hours, the Lancaster County-Wide Communications Center received its first call, which was quickly followed by numerous other calls, reporting a building explosion. At 1025 hours, a first-alarm industrial building fire assignment was dispatched, bringing three engines, a mini-pumper, three tankers, and an ambulance. On the response of the host company duty chief, additional information from communications described a building explosion and said that propane tanks were inside. Arriving less than two minutes after the dispatch, the duty chief reported a major explosion had occurred and the cylinder maintenance building was fully involved.

(5) Looking west at scene operations.

Click here to enlarge image

He immediately established command and requested a full station response from a neighboring department, which would bring an additional engine and a ladder truck. Personnel were advised to keep away from the area; traffic units were requested for crowd and traffic control.

(6) The eastside dumpsite.

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Since the incident occurred during a weekday, the number and location of employees and whether there were any patients or victims were unknown. The incident commander (IC) was able to ascertain from other facility personnel that all employees were accounted for within minutes of his arrival. Ten employees were working in the office building, and two others were at the cylinder maintenance building (which measured approximately 30 feet 20 feet) at the time

of the explosion. The two employees at the maintenance building were injured and transported to the hospital.

(7) An aerial shot of the immediate area involved, looking north. (8) An aerial view, looking south, of the entire complex. (9) A close-up aerial shot of the cooling lines in operation. (Photos by Mel Glick.)

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Further complicating matters was a 10,000-gallon propane truck at the loading area (to the rear of the fire building) with fill lines attached to the loading bulkhead. The status of the transfer operation at the time of the explosion was unknown, as was the truck driver's location. The IC communicated this hazard to personnel and issued directions for placement of apparatus. The truck driver was located and uninjured. At the time of the explosion, he was in the cab of the truck.

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The IC initiated water-supply operations. Water-source locations were defined, and units were assigned to specific sites. Because of the rural setting and the essential need to maintain a consistent water supply, identification of, access to, and prompt initiation of draft fill and dumpsites were crucial.

INITIAL OPERATIONS

The IC first designated west and east operational sectors. Operations at the incident would have to take place from two vantage points because the facility was located along the main corridor.

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Having apparatus and personnel continually pass the site would have increased the risk. Two operational areas required double the resources to initiate and maintain water supply and, in some cases, long hoselays. Fire company officials later noted that the water supply needed for this incident was the greatest in the fire company's history.

ADDITIONAL RESOURCES

The county's emergency management office was notified of the incident at 1027 hours. Because of the nature and location of the site, the 9-1-1 center was instructed to dispatch the county's state-certified hazardous materials response team, which assisted with air monitoring, testing of runoff water, and assessing the damage to numerous thermally stressed pressurized cylinders.

(10) Bravo side of the building; the vapor of the overturned tanks generated much heat.

Click here to enlarge image

Also, understanding the seriousness of the incident, a company whose engine was dispatched initially also sent its 2,500-gallon tanker and hose unit equipped with 2,300 feet of five-inch hose on a reel.

(11) Alpha side of the building. Note the 100-gallon tanks to the left, center, and right of the photo.

Click here to enlarge image

The IC then requested that two additional tankers be dispatched and respond from the east, to support operations on the east side of the incident. A truck company was placed on the east side of the incident; its ladder pipe was set up to protect exposed propane cylinders. At 1039 hours, the IC requested two additional engines for fill-site operations. At 1042 hours, four more tankers were requested. Predicting a long-term incident and understanding the need to ensure that the exposed tanks were cooled, he requested four more tankers at 1046 hours.

OBJECTIVES

(12) Firefighters survey the damage at the Alpha side. The heat being generated in the right of the photo indicates the incident is still active.

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Incident objectives were as follows:

• To limit the number of personnel operating in the area.

• To protect exposures, including the sixty 100-gallon propane tanks located immediately to the exterior of the building.

• To remove tanks not involved or those that could become involved from the area.

• To allow the fire to burn itself out.

All of these objectives hinged on maintaining a consistent water supply so that both involved and exposed containers could be cooled. After the water supply was established and maintained, we could begin to remove the individual nonbulk containers. Initially, on the west side, while water supply locations were set up, three-inch and 1 3/4 -inch hand-lines were placed in service to cool tanks. On the east side, two 2 1/2 -inch handlines were deployed.

(13) Note the close proximity of the fire apparatus. One lesson learned was the importance of site management and control. The properties of propane and the potential for a BLEVE significantly increased the risk to personnel.

Click here to enlarge image

Once the water supply sites were established, the staffed handlines were replaced with three unstaffed ground monitors and an unstaffed elevated master stream.

CHALLENGING CIRCUMSTANCES

The 100-gallon cylinders were situated outside the cylinder maintenance building, primarily on the west and north sides, and presented an extraordinary challenge. When the building exploded, debris landed on top of this inventory, providing a shield from the cooling water streams. This caused some tanks to be unprotected, initiating pressure relief valves (PRV) and influencing thermal stressors on other tanks. Some tanks were knocked on their sides as a result of the explosion. When the PRV on these overturned tanks activated, the vapor ignited, resulting in a horizontal flame that impacted other cylinders.

WATER SUPPLY

Because of the criticality of maintaining a consistent water supply, five water sources were used:

• Draft Site #1-a dry hydrant located at a creek nearly two miles southwest of the incident.

• Draft Site #2-a 40,000-gallon cistern located 1.5 miles north of the incident. Because of the limited supply, this site was exhausted within an hour of its establishment.

• Draft Site #3-at another point along the creek 1.5 miles southeast of the incident.

• Draft Site #4-a 120,000-gallon cistern located at the Intercourse Fire Company, 2.5 miles northwest of the incident. This site was also depleted.

• Draft Site #5-along the main creek bed nearly a mile west of Draft Site #1.

There were two dumpsites designated “East” and “West” at which the mobile water tankers would support and offload their supply.

A consistent water supply was difficult to maintain. Units could not maintain water supplies to the apparatus and appliances until nearly an hour into the incident. Contributing to this problem were the lack of tankers initially to ensure a consistent supply and the travel distances and travel times between the fire and the water sources. During the next three hours, the IC requested an additional three engines and nine tankers to maintain the water supply. Units from neighboring Chester County (PA) were also dispatched.

At 1214 hours, the IC requested the response of a heavy equipment company and a backhoe to construct a retention basin for runoff. The county emergency management agency, which partially activated the county Emergency Operations Center (EOC), handled this request. The EOC also notified local and state agencies, including the Pennsylvania Department of Environmental Protection. The Federal Bureau of Investigation and the Bureau of Alcohol, Tobacco and Firearms were also notified because at the time the cause of the incident was uncertain.

Other materials, including paints and solvents, were stored inside the cylinder maintenance building. The retention basin was made for runoff, which was found to be free of contaminants.

For nearly six hours, water streams were trained on the exposed cylinders to minimize container stress and the risk of a boiling-liquid, expanding-vapor explosion (BLEVE). (See “BLEVE: A Primer” on page 86.) At 1629 hours, the incident was placed under control. In all, more than 720,000 gallons of water were calculated to have been used. Of the sixty 100-gallon cylinders, approximately 30 involved PRV activation and were damaged. No container failures (i.e., BLEVEs) occurred.

INCIDENT CONSIDERATIONS

Although the incident scene presented numerous volatile circumstances, other aspects immediate and distant in proximity to the incident scene demanded consideration. Firefighter accountability was difficult because of the complexity of the incident and the varying areas being used. A rapid intervention team (RIT) was established but only addressed an hour into the incident. Support functions such as personal comfort stations were obtained, as were the services of a refueling truck to maintain fuel levels in the working apparatus.

TERMINATION

The incident was terminated at 1729 hours. No firefighters were injured. The two employees suffered first-degree burns and shrapnel injuries from the blast. Both recovered from their injuries. One was treated and released from the hospital the same afternoon. The other was admitted overnight for observation and released the next day. The cause of the incident was determined to be human error-a valve to a tank was improperly operated. The employees quickly

realized the error but could not fix the problem. They immediately vacated the area and were outside of the building when the released flammable vapors found an ignition source.

PREINCIDENT PREPAREDNESS

Because of its chemical inventory, the facility was subject to the reporting requirement of the Superfund Amendments Reauthorization Act (SARA) of 1986. The facility submitted its annual Tier II Chemical Inventory Reports as prescribed in SARA Title III section 312. Tier II reports (see my article "Tier II Chemical Reports-A Preplanning Resource," Fire Engineering, March 1998) are a good source of facility information. They, however, do not provide sufficient information to aid in developing strategies and tactics at emergencies. They provide a good starting point but are a limited resource. It is important to remember that materials may not have to be reported if inventories are below a certain threshold. The fire department received annual Tier II reports and the associated site maps supplied by the facility. All preplan information is maintained in the chief's vehicle.

The relationship between the facility and the fire department was typical. The fire department occasionally toured the facility and responded to the site periodically for odor calls. Prior to the incident, the fire company was aware of the bulk storage of propane tanks. However, during the last tour, which was within the past year, far fewer 100-gallon tanks were stored at the cylinder maintenance building than the number we encountered the day of the incident. This caught fire personnel somewhat off-guard, as we did not expect that quantity of tanks to be there.

The fire company routinely trains on water supply and is greatly involved in mutual-aid training relative to tanker shuttles. This was of great benefit for this incident. Considering the number of companies involved, especially with units from two counties, operations went fairly smoothly. The host company had developed a laundry list of preidentified water sources throughout its district that can be used, and that information is shared with mutual-aid companies.

PROPERTIES OF PROPANE

It is important to study the hazards in your area. Propane is 1.5 times heavier than air, causing it to stay low and follow the path of least resistance. It expands 270 times for each unit of measure, creating a significant vapor cloud when released. It has a relatively low flammable range of between 2.2 percent and 9.5 percent. Its boiling point is 44°F, leaving it in a ready state of ignition in most conditions. An unprotected or inadequately protected bulk storage tank with direct flame impingement can fail within 10 to 20 minutes. This creates a projectile hazard as well as an explosion hazard. Smaller cylinder shrapnel have traveled more than 300 feet. Large tanks can send container parts 10 times that distance. According to the 2000 Emergency Response Guidebook, the initial isolation perimeter for propane incidents should be 330 feet. When a tank is involved in fire, consider a mile isolation and evacuation radius. But again, this incident presented not just one tank, but multiple tanks.

POST-INCIDENT PREPAREDNESS

The incident was a catalyst for the first-due fire company to re-evaluate its required resources and make changes on response assignments to the facility. Fortunately, the host company tanker resource list was well planned and comprehensive. Had the list been limited, this would have caused some delay in identifying the next closest units. Considering how important it was to maintain the water supply for this incident, time was of the essence.

The fire department and the facility had a preexisting relationship, which has continued to grow after the incident.

LESSONS LEARNED

The fire department conducted a critique after the incident and identified the following lessons learned.

• The importance of site management and control. A point discussed was the closeness of personnel and equipment to the scene.

• We should have initiated evacuation of neighboring exposures. Fortunately, the incident occurred during the Christmas break, and a large high school located a mile southeast of the incident was vacant. The critique identified the need to communicate with special-needs facilities to determine the best means of protecting occupants, whether evacuation or sheltering in place.

• It is important to develop, maintain, practice, and reevaluate operational mediums-specifically, the depth of alarm resources and recognizing the need for additional units and the ordering of those resources. Hesitation or haphazard requesting of resources will delay incident objectives and influence the consistency with which specific tasks are accomplished, as seen with the initial inconsistent water supply. Most importantly, it may compromise firefighter safety.

During preincident planning, do not underestimate the impact an incident will have on your resources. This incident required a tremendous amount of resources to maintain water supply. The resources needed nearly exceeded the inventory provided by the fire department to the county dispatch center. Although it is difficult to say that a specific number of any resource listed is sufficient, we must evaluate this aspect after each incident and improve accordingly.

• The ICS must be expanded. The IC can become overwhelmed in a short time. It is important to expand the system as needed so that the incident can be managed in an effective and efficient manner. An ICS allows you to identify, initiate, and maintain incident support functions. In this incident, a RIT was not established until one hour into the incident.

• Getting out and understanding your facilities is essential. The time to meet facility managers is not when an emergency occurs. The time to ascertain facility emergency notification/response and employee accountability procedures is not after the emergency has occurred.

• Training must be continual. Practice maintaining a consistent water supply, not only in rural areas but in all areas. What is the desired fire flow? For buildings, using the National Fire

Academy formula is appropriate. However, in the case of a sustained incident where the strategy is cooling tanks, what method or formula are you going to employ?

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The facilities we protect present many challenges. It is important that fire departments perform the preincident intelligence full circle-from preemergency planning to incident response to effectiveness evaluation and application of lessons learned. Any breach of this circle will contribute to an inefficient response and result in an unfavorable outcome. Fire department personnel must participate in preemergency planning activities, including identifying which facilities they protect, determining and practicing their abilities to respond, and addressing any deficiencies. It is important to evaluate our incidents after they have been concluded to determine how effective we were. I often hear fire officials say that all went well because everyone went home. Although firefighter safety is and should be the primary goal for any response, assuming the incident went well just because everyone went home is not a true measure of our effectiveness. We must learn from incidents and apply the lessons learned in future incidents.

ERIC G. BACHMAN, a 22-year veteran of the fire service, is former chief of the Eden Volunteer Fire/Rescue Department in Lancaster County, Pennsylvania, and currently serves as captain. He is the hazardous materials administrator for the County of Lancaster Emergency Management Agency and currently serves on the Local Emergency Planning Committee of Lancaster County. He is registered with the National Board on Fire Service Professional Qualifications as a fire officer II, fire instructor II, hazardous materials technician, and hazardous materials incident commander. He has an associate degree in fire science and has earned professional certification in emergency management through the state of Pennsylvania. He is also a volunteer firefighter with the Manheim (PA) Fire Department.