TRACTOR TRAILER/GAS EXPLOSION

Woodruff, Utah
October 16, 1986

NFPA INTERNATIONAL

FIRE INVESTIGATIONS

NATIONAL FIRE PROTECTION ASSOCIATION

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Fire Investigation Report

BLEVE - LP-Gas Storage Tank

Woodruff, Utah

October 16, 1986

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ABSTRACT

At 7:29 P.M. on October 16, 1986, about 1/2 mile outside of Woodruff, Utah, a tractor trailer transporting 63 head of cattle veered off a road and struck the piping for two stationary LP-gas storage tanks. One tank had a capacity of 18,000 gallons and the other had a capacity of 30,000 gallons. Immediately following the impact, fire involving fuel from the truck and LP-gas from the tanks erupted.

Notified within moments of the accident, the Woodruff Fire Department responded and prepared to attack the fire, which impinged on the tractor and the storage tanks. However, before the fire fighters advanced toward the fire, a loud noise erupted and the fire fighters withdrew to a position about 800 feet from the fire area.

About 1/2 hour after the accident, the 18,000-gallon tank BLEVE'd. This propelled pieces of the tank from their original position; the largest piece of the tank struck a building and eventually came to rest about 2,600 feet from its mountings. In addition, the BLEVE caused the remaining 30,000-gallon tank to move off to one support saddle.

Following the BLEVE, gas escaping from damaged piping and openings on the 30,000-gallon tank burned openly and flames impinged upon the tank. Fearing a second BLEVE, fire fighters stayed back, evacuated the town, and let the tank continue to burn. By 5:30 A.M. the next morning, the intensity of the burning gas and the amount of flame impingement decreased dramatically. These observations lead fire officials to believe that the potential for a BLEVE was greatly reduced. After sunrise fire fighters entered the fire area to extinguish any remaining secondary fires. The fire coming from the 30,000 gallon tank was allowed to burn itself out.

This incident illustrates, again, that a BLEVE can result when LP-gas storage tanks are exposed to direct flame impingement. Responding fire fighters must recognize the danger of such situations, assess conditions on the scene, understand their water supply and operational capabilities, and take appropriate actions to ensure the safety of fire fighters and the public.

I. INTRODUCTION

The National Fire Protection Association (NFPA) investigated the Woodruff BLEVE in order to document and analyze significant factors that resulted in the loss of property. The NFPA routinely investigates technically significant fires by its Fire Investigations and Applied Research Division to document and analyze incident details and report lessons learned for life safety and property loss prevention purposes.

The NFPA became aware of the Woodruff BLEVE on October 18, 1986. Michael S. Isner, NFPA Fire Protection Specialist, traveled to Woodruff to document the facts related to this fire. An initial four days of on-site study and subsequent analysis of the event were the basis for this report. Entry to the fire scene and data collection activities were made possible through the cooperation of the Woodruff Volunteer Fire Department. This report presents the findings of the NFPA data collecton and analysis effort.

This report is another of NFPA's studies of fires having particularly important educational or technical interest. The information presented is based on the best data available during the on-site data collection phase and during the report development process. It is not NFPA's intention that this report pass judgement on, or fix liability for, the loss of property resulting from the BLEVE.

This report describes firesafety conditions at the LP-gas bulk storage facility and presents findings on contributing factors to the BLEVE based on NFPA analysis of collected data and observations during the investigation. Current codes and standards were used as criteria for this analysis so that conditions at the storage facility on the day of the fire could be compared

with current fire protecton practices. It is recognized that these codes and standards may not have been in effect during construction or operation of the LP-gas storage facility. NFPA has not analyzed the facility's compliance with the codes and standards that were in existence when the storage facility was built, or during its operation.

The cooperation and assistance of Fire Chief Cleve Erickson and Assistant Chief Stephen Huffaker of the Woodruff Volunteer Fire Department is greatly appreciated. In addition, the assistance of Fire Chief Jon Lunsford, Evanston Fire Department, and Sargent Dick Chatterton of the Utah State Highway Patrol are also appreciated.

Special thanks go to Wilbur L. Walls, P.E. retired NFPA Gases Field Service Engineer and to Theodore C. Lemoff, P.E. the present NFPA Gases Field Service Engineer, for providing technical assistance during the course of this investigation and in the analysis of the incident.

Background

Woodruff is a small farming community, with an estimated population of 300, in northeastern Utah. A state highway passes through the center of town and connects Woodruff with Evanston, Wyoming (20 miles south) and Randolph, Utah (10 miles north). Evanston (population 11,200) has a fire department which uses both paid and volunteer fire fighters; Randolph has a volunteer fire department, and the dispatch center for volunteer departments throughout the county is located in this community.

As it is currently organized, the Woodruff Volunteer Fire Department had been operational for only 1-1/2 years. An old four-room school house was converted for use as the fire station and town offices. The fire department's apparatus included triple combination, 1000 GPM pumper, and a military surplus 6 x 6, 1,500-gallon water tanker. Both vehicles were normally parked in the gymnasium of the school building. However, on the night of this incident, the Woodruff water tanker was at the LP-gas facility being repaired.

Since the fire department was relatively new, it was in the process of acquiring equipment for the two apparatus. The pumper was loaded with a 2-1/2 inch supply line, a wye, and two 1-1/2-inch attack lines. At normal operating pressures, the nozzles on the attack lines could provide approximately 120 gallons per minute. There were very few radios for use during fire suppression activities and in the event of an alarm, the county dispatcher would initiate the telephone notification system by calling key fire fighters.

The 12 Woodruff fire fighters have received training through many sources. Within four months of the organization of the present department members entered the state began introductory training for fire fighters. Since then, many have taken advanced fire fighter training courses offered by

the state. Monthly in-house training was also provided to the members by the chief and by representatives from other fire departments. In addition, the local utility company provided instruction for handling emergencies that involve LP-gas. The Woodruff fire chief indicated that members have also seen the NFPA film BLEVE several times during various training sessions.

Since LP-gas is the primary home fuel in this community, fire fighters have a working knowledge of LP-gas and are familiar with many of its characteristic hazards. This "grass-roots" knowledge complements information that these fire fighters have received during their formal training.

Two water storage tanks (capacity 100,000 gallons and 600,000 gallons) were located on a hill outside of town and contained water for domestic use and fire protection. Their location on the hill placed the tanks about 200 feet above the town. A system of underground water mains (12-inches to 6-inches in diameter) distributed water throughout the community. Fire hydrants have been installed in the system. The hydrant closest to the LP-gas storage facility was the last hydrant on a 6-inch dead-end main and was about 1/8 mile away from the facility.

Located about 1/2 mile north of Woodruff, the LP-gas storage facility was surrounded by alfalfa fields and cow pastures. In addition to storage of LP-gas, this privately owned company installed and maintained LP-gas tanks at homes and businesses, delivered LP-gas with trucks that were filled and maintained at the facility, had a filling service for small LP-gas tanks carried in by customers, and performed other LP-gas related services.

Many customer LP-gas tanks were stored on this property. The tanks ranged in size from 100-pound to 1000-gallon capacities and many contained LP-gas. They were primarily stored in the northeast and southwest corners of the property (see Figure 1). In addition to these customer tanks, the facility had two large storage tanks; both were in the northwest corner. These tanks

were about 100 feet from the edge of the road.

Figure 2 shows the arrangement of the storage tanks, piping, and liquid transfer pumps prior to the accident. The smaller tank had a capacity of 18,000-gallons, the larger tank had a 30,000-gallon capacity, and both containers were considered to be full[1,2].

The 18,000-gallon tank had two pressure relief valves located on the top and center (on the longitudinal axis) of the tank. The 30,000-gallon tank had three relief valves near its east end and a 2-inch brass ball valve near its west end (See Figure 2). The arrangement of piping and operational procedures did not require the use of the valve; therefore, this valve was closed and had a plug installed in the discharge outlet.

Both tanks had a 3-inch liquid line, a 2-inch liquid line, and a 2-inch vapor line, all of which were attached to the bottom of the tanks at the west end. Each of the six openings in the tank had "excess flow" protection. In addition, the three valves on the bottom of the largest tank had emergency valves activated by fusible links; however, none of these valves were arranged for manual remote operation.

Two electric-powered pumps were in the piping system. One pump moved the product to and from Area A (see Figures 1 & 2) during dispensing and tank filling operations. The second pump move product to Area B, which was used for product dispensing only. At the time of the accident, there was no dispensing or filling occurring, so the system was shut down.

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1. The capacity of a LP-gas tank is described in terms of a tank's volume when completely filled with water.

2. LP-gas storage tanks must contain both vapor and liquid products. Normally, LP-gas containers are considered full when the liquid displaces approximately 80% of the volume and vapor fills the remaining 20% of the tank's volume. The liquid to vapor ratio will change according to atmospheric temperature and other factors.

There were two one-story buildings on the property. The office (Building #1, see Figure 1) was a wood-frame structure with metal siding. In addition to office space, this building had garages for equipment storage and minor repair work. The second building, also a wood-frame structure with metal siding, was the primary location for vehicle storage and repair work. At the time of the incident several private automobiles, an LP-gas storage truck, and the Woodruff Volunteer Fire Department water tanker were parked in this building.

Weather Conditions

October 16, 1986, was a dry day with a high temperature of 68°F and low morning temperature of 17°F. The temperature at sunset (6:43 P.M.) was 59°. Winds were light and variable and coming predominately from the west.

The Incident

On the evening of Thursday, October 16, 1986, a semi-tractor trailer carrying 63 head of cattle was traveling south on State Highway 16. Local investigators estimate that the vehicle was traveling at 50-60 miles per hour as it approached the town.

A cow managed to pass through the fence surrounding a pasture and wandered onto State Highway 16. When the driver saw the cow, he applied his brakes but was unable to avoid striking the animal. The driver apparently lost control of the vehicle, which veered left and off the road. The truck traveled across the 60-foot wide shoulder for the road, smashed through the perimeter fence around the LP-gas storage facility, and struck the piping and pumps for the two large LP-gas tanks, a path over 500 feet long. Two mechanics in Building #2 (see Figure 1) heard sounds from the accident. Rushing to investigate, they saw yellow flames and some smoke above the west end of the large tanks. Because the tractor quickly became involved in the fire, the mechanics felt the situation was serious and that they could do nothing for the driver; they left the area.

Within moments of the incident, someone called the county dispatch center and reported the accident at the LP-gas facility; the call was received at 7:29 p.m. Since the Woodruff Fire Chief was out of town, the dispatcher telephoned the Assistant Chief of the Woodruff Fire Department in accordance with the established procedure. The assistant chief acknowledged that the large storage tanks were involved in fire and indicated that the fire department would respond. In turn, he made his designated calls to other fire fighters before leaving his house, which was about 3 miles from the fire station.

While responding to the station, the assistant chief could see the glow of fire in the darkening evening sky. Several fire fighters were already in the station preparing for their response when the officer arrived. The Woodruff pumper with 6 fire fighters left the station at approximately 7:39 p.m. En route, the assistant chief requested mutual aid assistance from Evanston and Randolph. He also requested that all responding law enforcement officers begin the evacuation of the buildings closest to the fire.

After leaving five fire fighters and the two 1 1/2-inch handlines about 100 feet from the scene, the driver of the pumper made a reverse lay of the 2 1/2-inch supply line to the closest hydrant, 700 feet away. Fire fighters indicated that, at this time, the fire involved both the tractor and the end of the tanks. Flames were so intense that the tractor cab had begun to melt and collapse. Still the fire fighters intended to make an attack. The assistant chief indicated that he knew there wasn't much chance that the driver was alive but the fire fighters felt they had to try to reach him.

Before they could set up their hand lines and the pump operator could charge the supply line, a loud noise (believed to be the activation of a relief valve on the 18,000-gallon tank) erupted and the fire fighters felt the conditions were becoming too unstable. As a result, all fire fighters withdrew from the immediate fire area and the assistant chief did not allow any emergency personnel past the Woodruff pumper, which was still at the hydrant. Several minutes later, units from Randolph arrived at the scene and joined the Woodruff fire fighters, who were about 800 feet from the fire.

The BLEVE of the 18,000-gallon tank occurred at 8:02 p.m., according to records of the county dispatch center.

The assistant chief stated that the ensuing fire ball was so large that it appeared to pass high over their heads. Fire fighters at the Woodruff pumper also recalled that material struck their apparatus causing a "hail-like" sound.

Fire fighters responding from Evanston were about 3 miles from the scene when the BLEVE occurred and they had a clear view of the fireball. Once the Evanston fire fighters arrived at the scene they also joined the emergency personnel at the hydrant closest to the fire. Upon the request of the Woodruff assistant chief, the Evanston fire chief assumed command of the fire scene.

A size-up of the post-BLEVE fire conditions revealed that the 30,000 gallon LP-gas tank had been knocked off one of its saddles and had fire coming from several openings in addition to the three pressure relief valves at the east end of the tank. Fearing a second BLEVE, emergency personnel were pulled back another 1/8 mile, placing fire fighters about 1/4 mile from the fire. From this position, the fire department coordinated their on-scene activities, which consisted of watching the 30,000-gallon tank burn, ensuring the civilians were evacuated from their homes, and keeping people out of the evacuation zone.

An inspection of the area revealed that the largest section of the 18,000-gallon tank was nearly 1/2-mile from the original location of the container. Upon this discovery, the on-scene fire commander ordered that the staging position be moved back another 1/4-mile; the evacuation zone for civilians was also increased.

Large flames, apparently under high pressure, could be seen at both ends of the tank at times. The most intense burning would cycle between the relief valves and the broken fittings at the opposite end of the tank. Flames from the damaged fittings and the manhole impinged directly on the tank. About 2:30 A.M., the cycling slowed and a high pitch whistle began. Personnel who observed the tank from a distance through binoculars noted that small bulges began to appear on the tank's surface near the manhole cover. Everyone on the scene felt that a second BLEVE was imminent.

It did not happen, however. The whistling sound eventually subsided and the flame color changed from blue to orange. By 5:30 A.M., the high pressure intense flames had changed to low pressure, "lazy" flames. Observers once again approached the tank to inspect its condition. Once they were close enough to get a clear view with binoculars, the observers found that the frost line was very low and that the flame intensity was continually decreasing. Fire officials and a hazardous materials specialist from the Utah State Highway Patrol felt the BLEVE potential was greatly reduced and the conditions of the fire scene had begun to stabilize.

Just after sunrise, fire fighters entered the compound to extinguish the small secondary fires. A frost line at the end of the tank on the ground indicated that only a few inches of liquid LP-gas remained in the tank. Fire officials decided to let the small fires continue to burn and made no attempt to extinguish flames or to plug the open orifices on the 30,000-gallon tank. Burning on this tank continued until 11:00 A.M.

All fire fighting units except for one Woodruff piece were released by 3:00 P.M. The remaining crew from Woodruff stayed at the scene to ensure there was no rekindle of the burning materials. Following an uneventful watch, the crew left the scene at 9:00 P.M.

Casualties and Damage

The truck driver most likely died during the initial impact and fire. The blast during the BLEVE caused the most severe damage in this incident, ripping apart both the tractor and trailer, and damaging LP-gas storage tanks and equipment. Despite the fire and blast, 40 head of cattle survived the incident.

The BLEVE caused the 18,000-gallon tank to separate into three pieces. Two pieces, the west head and a section of tank body 90-inches wide, flew in a

westerly direction and landed about 500 feet away from their original position (see Figure 1). The tear that separated the smaller 90-inch section from the rest of the container occurred in the base metal about two inches from a welded seam. The third piece, which was approximately 40 feet long, rocketed in an easterly direction and struck an LP-gas delivery truck inside Building #2 (see Figure 1) knocking it out of the building. This impact changed the tank's direction of travel and the tank hit the ground for the first time about 700 feet from its original mountings. The tank then bounced for about 1,400 feet and rolled another 600 feet. It finally came to rest about 2,600 feet away from its original mountings.

Even though the 18,000-gallon tank was constructed with metal 1/2-inch thick, there was a dent nearly 20 feet long in the side of the 40-foot tank section, and many deep dents in the east head. Marks from intensive burning were left on the west end of the tank and covered the tank's surface between the "9 o'clock" and the "12 o'clock" area. In this burn area, a section of tank shell (near the 11 o'clock position) thinned down to a thickness of less than 1/16 inch.

The 30,000-gallon tank was knocked off the west concrete saddle. Apparently, valves at the west end of the tank were damaged, allowing gas to escape and burn. Eventually the gasket for the manhole began to leak and created a third burn area. The tank surface near the manhole cover was slightly deformed. During the night, the pressure relief valves at the tank's east end would open and close according to the pressure in the tank. Escaping gas from these valves also burned.

In addition to the damage to the large LP-gas tanks, the garage building (Building #2, Figure 1) collapsed and burned. All the vehicles (including the Woodruff FD Tanker) and contents were destroyed. The office building (Building #1, Figure 1) was heavily damaged by flying debris. Wreckage from

the tractor trailer and the storage tanks could be found in the compound, in adjacent fields, and on Highway 16.

Code Analysis

The scenario of LP-gas storage tanks being struck by a vehicle is an extremely rare sequence of events. This incident readily prompts one to consider the criteria which establish requirements for siting LP-gas storage containers.

NFPA 58 - Standard for the Storage and Handling of Liquefied Petroleum Gases, 1986 ed., applies to such installations. The siting criteria in this standard reflect the concern of the Technical Committee on Liquefied Petroleum Gases with regard to the exposure hazard presented by other containers, a building or group of buildings, and buildings on adjoining properties[3]. The provisions in NFPA 58 for protection against vehicle damage[4], container siting criteria[5], and distance between point of transfer and exposures[6] do not envision the sort of impact - either as to probability or severity - that occurred.

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[3] Liquefied Petroleum Gases Handbook, Wilbur Walls ed., NFPA, 1986, pg. 125.

[4] NFPA 58 - Paragraph 3-2.3.7 (c) - "Where physical damage to LP-gas containers, or systems of which they are a part, from vehicles is a possibility, precautions against such damage shall be taken."

[5] NFPA 58 - Paragraph 3-2.2.2. This paragraph requires that the above-ground containers at the Woodruff facility shall be 50 feet (minimum) away from important buildings, groups of buildings, or lines of adjoining property which may be built upon.

[6] NFPA 58 - Paragraph 4-3.3.2 (Table 4-3.3.2): This paragraph requires that points of transfer in the plant will be 25 feet or more away from public ways, including public streets, highways, thoroughfares and sidewalks.

The six container openings (three per tank) provided for the service piping were protected with excess flow check valves; this protection is required in NFPA 58, Paragraph 3-2.4.6. The 30,000-gallon tank also had emergency valves with thermal release mechanisms but there were no means for remote manual operation. NFPA 58 Paragraph 2-4.5.4 indicates that, in addition to the thermal activation mechanisms, emergency valves will be provided with provisions for manual operations from both the installed location and a remote location.

The absence of emergency shutoff valves for the 18,000 gallon tank is not consistent with Paragraph 3-2.7.9 of NFPA 58. Because the liquid piping was more than 1-1/2 inch and the vapor piping was more than 1-1/4 inch in diameter, this paragraph requires that existing installation of multiple container systems utilizing a common or manifolded liquid transfer line have emergency shutoff valve or backflow check valve protection in each leg of piping.

Though it appears that there were some variances from the criteria set forth in Paragraph 2-4.5.4 and Paragraph 3-2.7.9 of NFPA 58, these variances may not have been a factor in light of the extent to which the piping and valves were damaged from impact. The BLEVE damaged the piping and equipment so severely that investigators were unable to determine the actual mechanisms which permitted the gas to escape. Therefore, it is not possible to determine the effect that the emergency shutoff valves specified in NFPA 58 could have had on this incident.

The mechanics and the first arriving fire fighters on the scene stated that the initial fire appeared to have been fed by the diesel fuel carried in the fuel tanks for the tractor and by leaking LP-gas. The reports of leaking LP-gas indicated that the excess flow check valves did not stop the discharge of gas. It is possible that a valve or several valves were damaged during impact and could not control the flow of product. It is also possible that

the leak may have occurred in a pinched pipe or other restricted orifice. If the flow of LP-gas through these openings was at a rate less than that required to operate the excess flow valve, undamaged valves in the tanks would not have operated and stopped the discharge of gas.

Discussion

BLEVE is an acronym for Boiling Liquid Expanding Vapor Explosion. This phenomenon "is defined as a major container failure" into two or more pieces, at a moment in time when the contained liquid is at a temperature well above its boiling point at normal atmospheric pressure. The definition does not qualify the cause of the container failure or the chemical properties of the liquid. It is applicable to both flammable and nonflammable liquids.[7][8]

The explosion at Woodruff, Utah was a classic example of a BLEVE. Following the crash, flames engulfed the west end of the tanks. Unprotected pressure containers generally fail within eight to 30 minutes of flame contact to the vapor space[9]. The 18,000-gallon tank failed about 30 minutes after the truck struck the pumps and piping causing the fire that impinged the container. The small section of tank shell that was thinned down to less than 1/16 inch in thickness is most likely the area where the tank failure began. Since this thinning occurred at the 1 o'clock position on the tank, the failure began in the vapor space, as would be expected. Once a tank fails the

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[7] Author's emphasis.

[8] Wilbur L. Walls, "The BLEVE - Part 1", Fire Command. - May 1979, Vol. 46, No. 5, pp. 22-24.

[9] Wilbur L. Walls, "The BLEVE - Part 2", Fire Command. - June 1979, Vol. 46, No. 6, pp. 35-37.

pieces generally travel along the longitudinal axis, and, past experience has shown that pieces have to traveled up to 3900 feet[10]. The largest section of the Woodruff tank flew in the expected direction and came to rest approximately 2,600 away from the tank's original mountings (see Figure 2).

In previous incidents, fires involving liquid storage tanks have posed a severe threat to fire fighters because of the possibility of a BLEVE. For example, on August 31, 1976, three fire fighters died when a 6,000-gallon gasoline storage tank was exposed to fire and resulted in a BLEVE[11]. On December 17, 1973, seven fire fighters in Mountainville, New York were injured during another BLEVE[12]. The BLEVE's that caused these fire fighter casualties involved stationary liquefied petroleum gas storage tanks. Many fire fighters have, also, been injured or killed during BLEVEs which involved transportation vehicles. Two examples are the Kingman, Arizona incident when twelve fire fighters and one civilian died[13] and the Tewksbury, Massachusetts incident on February 7, 1972, when one fire fighter died and seventeen others were injured[14].

Unlike BLEVE's in the past, however, there were no fire fighter or civilian casualities during the Woodruff incident. At first, fire fighters had

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[10] Olle Johansson, "The Disaster at San Juanico", Fire Journal. - January 1986, Vol. 80, No. 1, pp. 32-37, 92-94.

[11] "Three Fire Fighters Die When Exposure Hazard Ignored" Fire Command - January 1977, Vol. 44, No. 1, pp. 22-24.

[12] "LP-Gas Tank 'BLEVE'" Fire Command - August 1974, Vol. 41, No. 7, pp. 22-24.

[13] "LP-gas Distribution Plant Fire", Fire Journal, January 1974 ,Vol. 68, No. 1, p. 52.

[14] "Lessons from an LP-Gas Utility Plan Explosion and Fire" Fire Command - April 1972, Vol. 39, No. 4, pp. 18-25.

hoped to attack the fire so they began to position their hose lines. A sudden noise from an operating relief valve made the assistant chief feel that conditions at the scene were becoming unstable. Based upon his training and familiarity with LP-gas storage equipment, the officer chose not to expose his men to undue danger and had all fire fighters withdraw from the scene. This simple act appears to have saved their lives because the tank BLEVE occurred about 15-20 minutes after their withdrawal.

Several years ago, the NFPA organized a consortium of experts in the gases and public fire protection fields. This group discussed hazards and fire control considerations that come into play during a hazardous materials transportation incident. Their activities resulted in the publication of a topical information bulletin.[15] Among the many issues addressed and recommendations prepared, the consortium agreed that the use of unmanned monitors, that the application of at least 500 gallons per minute (gpm) of water at each point of flame contact, and that a withdrawal distance of at least 3000 feet (should evacuation of emergency personnel be necessary) can reasonably reduce the risk to fire fighters. Since the first responding crew had no unmanned monitor equipment and had the capability of discharging only an estimated 240 gpm, the fire fighters assumed a great risk to their own safety when they approached the fire scene.

When an LP-gas container is exposed to fire, the stability of the situation and the potential for BLEVE is independent of the operation of the relief valve. Relief valves are sized according to the container surface area and are intended to protect the container in the event of an enveloping pool fire. In this scenario, flames impinge the tank in the space occupied by both

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[15] Hazardous Materials Transportation Accidents, Topical Information Bulletin, No. TIB 78-1, Public Protection Division, NFPA.

liquid and vapor. Heat is transferred through the container's metal shell and causes liquid to boil. The temperature of the shell in contact with boiling liquid remains relatively low and the shell's tensile strength remains high. Properly sized relief valves will release the excess vapor and prevent over pressurization of the container. In other words, when flames contact the tank in the liquid space, the potential for BLEVE is minimal, even though the relief valves are operating.

Most thermal failures of a flammable liquid tank or liquefied gas containers occur when flames contact and overheat the container metal in the vapor space. Heat from the flames contacting this area cannot be absorbed or dissipated by the liquid product and the container begins to lose its tensile strength. Eventually, the container cannot withstand the internal pressure and releases its contents.[16] In this scenario, it is possible (but not likely) for a tank BLEVE to occur without the relief valve operating.

In retrospect, the operation of the relief valve may not have been the most important factor upon which to base a decision to withdraw. The severity of the leak, the location of the flame impingement, the exposure time, available water supplies and discharge capability, the potential for use of unmanned monitor equipment, the risk posed to life and property, etc. are some of the factors that need to be considered while deciding to approach or withdraw from a fire scene. Regardless of the stimulus, it appears that the assistant chief's decision to withdraw during the Woodruff incident was the best decision in light of equipment and water supply available to the fire fighters and in the absence of a major threat to life and property because the tanks were located in the middle of large fields away from occupied structures.

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[16] Wilbur L. Walls, "The BLEVE - Part 1", Fire Command. - May 1979, Vol. 46, No. 5, pp. 22-24.

Understanding the mechanisms that can lead to a BLEVE will help fire fighters decide whether they can safely make a fire attack or whether withdrawal from the area would be the best procedure when a fire involves an LP-gas other liquid storage tanks. Otherwise fire fighters may face a needless risk to their own safety.

A new NFPA film "LP Gas: Emergency Planning and Response" present, an overview of the characteristics of LP-Gas and the kinds of emergencies that can occur. Unlike the previous NFPA film "BLEVE" which emphasized the hazards to fire fighters following accidents involving LP-Gas transport vehicles, the new film discusses fire fighting tactics that are applicable to both mobile and stationary LP storage tanks.

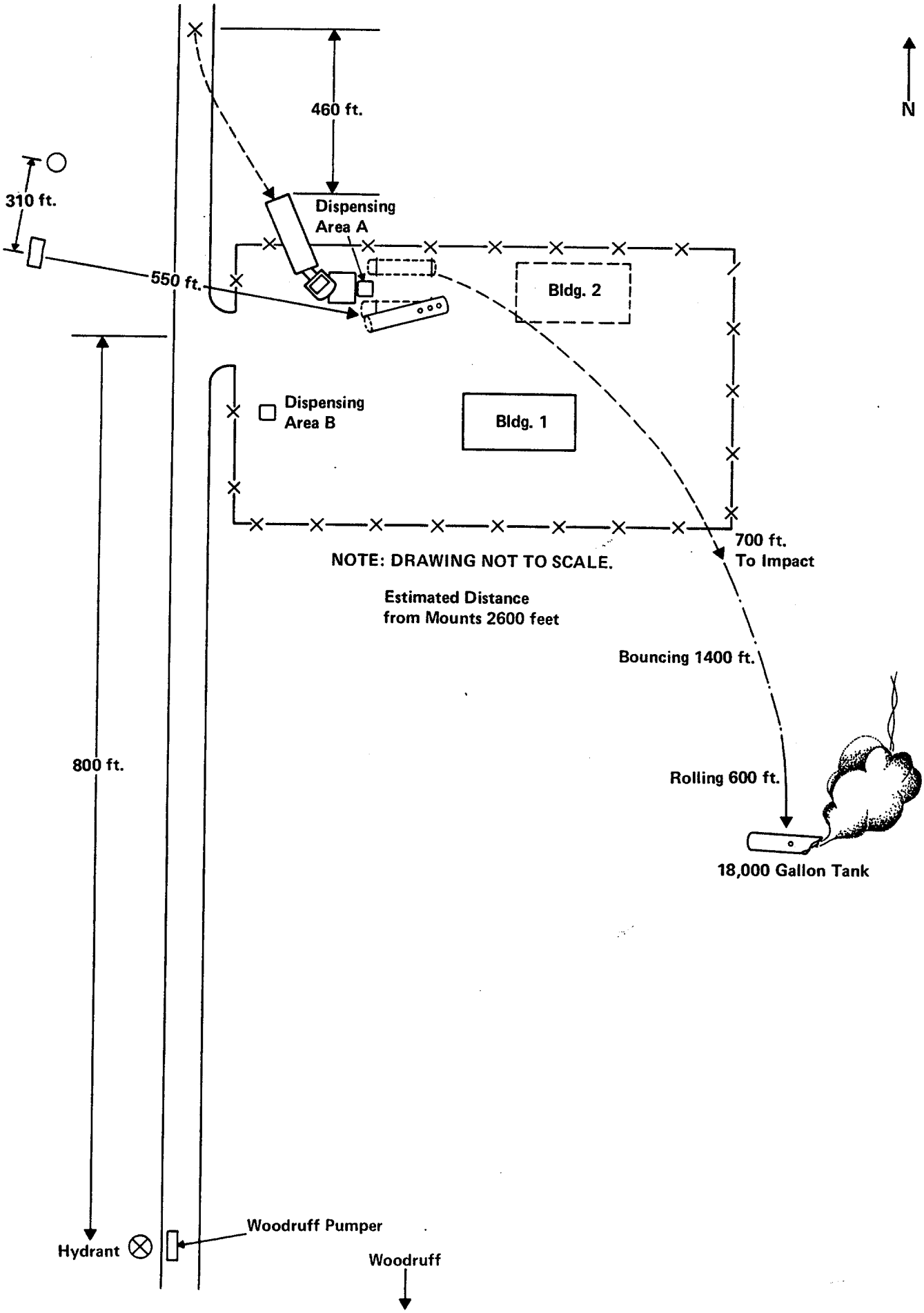
460 ft.
N
310 ft.
Dispensing
Area A
550 ft.
Bldg. 2
Dispensing
Area B
Bldg. 1
700 ft.
To Impact
NOTE: DRAWING NOT TO SCALE.
Estimated Distance
from Mounts 2600 feet
Bouncing 1400 ft.
800 ft.
Rolling 600 ft.
18,000 Gallon Tank
Woodruff Pumper
Hydrant
Woodruff

FIGURE 1

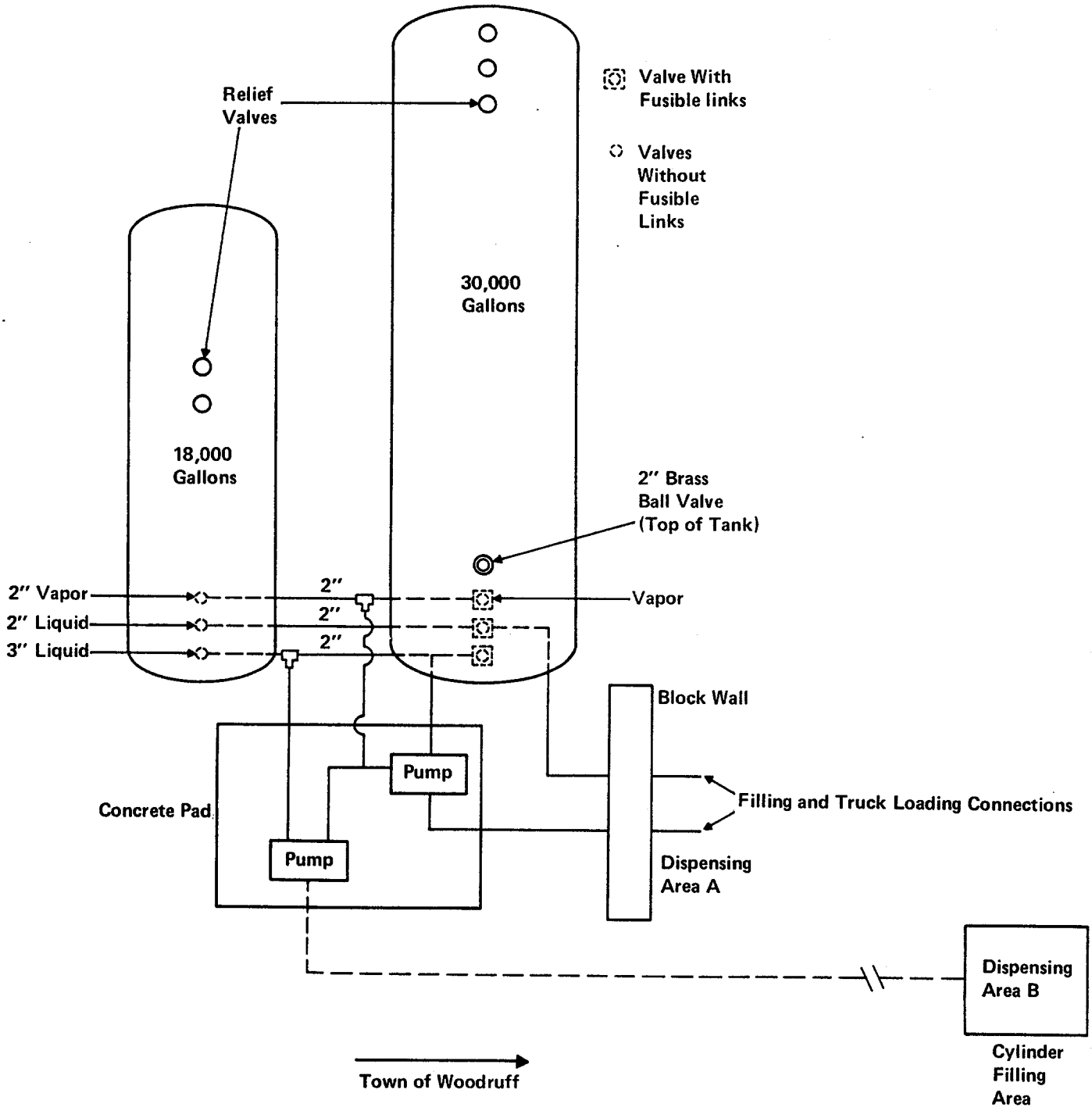

FIGURE 2

SIMPLIFIED PIPING DIAGRAM