



A Volunteer Fire Fighter Died and a Second Was Seriously Injured After Fuel Tank Explosion - Iowa

SUMMARY

On April 7, 2000, at 1056 hours, Central Dispatch notified the volunteer fire department and reported a grass fire around a large fuel tank. Responding units included Unit 504 (command vehicle), Engine 502, Engine 505, and one police cruiser. Arriving on the scene, the Chief conducted a size-up and noticed a small grass fire around a fuel tank. The Chief radioed for the other arriving units to pull a handline. The tank was lying on the ground, in an east-west orientation, with the east end of the tank slightly elevated. The grass fire was comprised of burning grass and rubbish located on the north, east, and south sides of the fuel tank. The victim and Fire Fighter #1 were on the north side of the tank and used the 1½-inch preconnect from Engine 502 to knock down the fire and to cool the tank. Also,

Death in the line of duty...

two fire fighters on the south side of the tank used the 1¾-inch preconnect from Engine 505 to knock down the fire and cool the tank. A civilian (Civilian #1) approached the Chief and informed him that he wanted to cut a hole in the end of the tank. The Chief acknowledged him and agreed, and Civilian #1 then began using a cutting torch to cut a hole near the threaded opening of the 2-inch fill pipe, while Civilian #2 (a second fatality) stood nearby and watched. *Note: The Chief later stated that he did not realize or fully understand the request the civilian was making in regards to the methods the civilian would employ when cutting the hole in the tank.* When the cutting began, there was a loud noise (reported as sounding like a jet engine), the tank swelled, and then exploded. The east end of the tank separated at the seam and was blown 114 feet in an easterly direction. The tank turned 180 degrees, with the opened east end of the tank now facing west. At the time of the explosion, the victim was in the direct path of the east end of the tank and was killed instantly. The Chief, Assistant Chief, fire fighters, and a city police officer began administering medical treatment to Civilians #1



Photo courtesy of the Madisonian.

Burning Fuel Tank Immediately After Explosion

The Fire Fighter Fatality Investigation and Prevention Program is conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of the program is to determine factors that cause or contribute to fire fighter deaths suffered in the line of duty. Identification of causal and contributing factors enable researchers and safety specialists to develop strategies for preventing future similar incidents. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. To request additional copies of this report (specify the case number shown in the shield above), other fatality investigation reports, or further information, visit the program website at

www.cdc.gov/niosh/firehome.html
or call toll free 1-800-35-NIOSH

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and #2 and Fire Fighter #1. Fire Fighter #1 was knocked to the ground and received numerous injuries to his legs. Fire Fighter #1 was transported to a nearby hospital where he received further medical treatment. Civilian #1 was knocked to the ground, receiving severe burns, and was transported to the State's burn treatment center. Civilian #2 (a second fatality) had both legs severed at the knees from the flying debris. He was life-flighted to the regional hospital where he was later pronounced dead as a result of the traumatic amputation of his lower extremities. NIOSH investigators concluded that, to minimize the risk of similar occurrences, fire departments should

- *ensure that unsupervised, isolated aboveground tanks are secured and marked in such a manner as to identify the fire hazards of the tank and its contents to the general public*

Additionally, operators conducting welding or cutting should

- *consider all containers/tanks hazardous unless they have been tested and found safe, cleaned, or rendered inert*
- *prohibit welding or cutting operations in the presence of explosive atmospheres*

- *ensure that, for fires involving potentially dangerous substances, fire fighters utilize and follow the guidelines set forth in the U.S. Department of Transportation's North American Emergency Response Guidebook*
- *develop, implement, and enforce standard operating procedures (SOPs) that address fire fighter safety regarding emergency operations for hazardous substance releases*
- *ensure that emergency response personnel adhere to the procedures outlined in 29 CFR 1910.120(q)2 - Emergency response to hazardous substance releases*

Additionally, owners of aboveground storage tanks should

- *register all tanks, existing or new, with the State Fire Marshal*
- *ensure that aboveground tanks are in compliance with NFPA 30 2-3.6 "Emergency Relief Venting for Fire Exposure for Aboveground Tanks"*

INTRODUCTION

On April 7, 2000, one 25-year-old male volunteer fire fighter (the victim) was instantaneously killed when a fuel tank exploded. Fire Fighter #1 was seriously injured and transported to the regional hospital for medical treatment. Civilian #1 was severely burned and transported to the state's burn treatment center. Civilian #2 (61-year-old male, a second fatality) was transported by helicopter to the regional hospital where he was later pronounced dead.

The National Institute for Occupational Safety and Health (NIOSH) was notified of this incident by the U.S. Fire Administration (USFA) on April 10, 2000. On August 7, 2000, two safety and occupational health specialists from the NIOSH Fire Fighter Fatality Investigation and Prevention Program investigated this incident. Meetings were conducted with the chief of the department and an investigator from the State Fire Marshal's Office. Interviews were conducted with the officers and fire fighters involved in this incident. NIOSH investigators obtained from the State Fire Marshal's office, copies of site maps, autopsy reports (for the victim and Civilian #2), witness



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statements, a report of the tank's usage and modification history, lab results of samples taken from the tank that exploded, and reports completed by the State Fire Marshal's office. A site visit was also conducted and the incident site photographed. The site was a vacant lot containing a total of two steel gravity-flow fuel tanks (one 15,000-gallon fuel storage tank [Tank #2] and one 10,000-gallon fuel storage tank [Tank #1, which exploded]), and several abandoned vehicles. Samples taken from Tank #1 by the State Fire Marshal's Office found traces of gasoline and a heavy petroleum distillate (kerosene). *Note: Samples were not taken from Tank #2.* The fire department involved in this incident consists of one station with a total of 21 uniformed fire fighters. The department serves a population of approximately 10,000 in a geographic area of 235 square miles. The fire department requires all new fire fighters to receive International Fire Service Training Association (IFSTA) fire training for Fire Fighter Level I. The victim was certified as Fire Fighter Level I and II. The victim also received training in apparatus operation, first aid, CPR, and search and rescue. The victim had six years of volunteer fire fighting experience.

INVESTIGATION

On April 7, 2000, at 1056 hours, Central Dispatch received a call from the owner of the garage adjacent to the incident site, reporting a grass fire around a large fuel tank. Central Dispatch notified the volunteer fire department at 1056 hours. The units responding at 1056 hours included Unit 504 (Chief and Assistant Chief/driver), Engine 502 (victim, Fire Fighter #1, driver, and another fire fighter), Engine 505 (Captain, driver, and 2 fire fighters), and a police cruiser (1 police officer) to conduct traffic control. Unit 504 was the first to arrive on the scene, at 1059 hours. Unit 504 approached the fireground along the north side of the fireground and positioned the apparatus on the east side of the fireground (see Diagram

1). The Chief sized up the south, east, and north sides of the tank as they arrived on the scene and noticed a grass fire around the fuel tank. The Chief radioed for the other arriving units to pull a handline. The tank was lying on the ground, in an east-west orientation, with the east end of the tank slightly elevated. The grass fire, which consisted of grass and rubbish, was located on the north and south sides of the fuel tank. There was also a small fire, with very little smoke, underneath the east end of the tank (see Photo 1). Engine 502 arrived on the scene following Unit 504, and the driver positioned the apparatus on the northeast corner of the fireground. Engine 505 approached the scene from the south and the driver positioned the apparatus on the southeast corner of the fireground (See Diagram 1). The victim and Fire Fighter #1 pulled a 150-foot, 1 $\frac{3}{4}$ -inch preconnect from Engine 502 and began extinguishing the fire on the north side of the tank. The victim was the nozzle man and Fire Fighter #1 was his backup on the hoseline. The Captain from Engine 505 assisted a fire fighter from Engine 505 in pulling a 150-foot, 1 $\frac{3}{4}$ -inch preconnect from Engine 505. A fire fighter from Engine 502 backed up the fire fighter on the hoseline from Engine 505 and quickly knocked down the fire on the south side of the tank. The Captain, standing on the south side of Tank #1, noticed a civilian (Civilian #1) cutting on Tank #2's support legs with an acetylene torch. The Captain then told Civilian #1 to stop cutting and to move out of the area. *Note: The State Fire Marshal's Office determined that the grass fire was accidental and that the cause of the grass fire was the hot metal fragments produced from the hot work being conducted by Civilian #1 while he was cutting the support legs for Tank #2. The salvage workers had removed the support legs of the 10,000-gallon tank (Tank #1—the tank that exploded) prior to the grass fire. When Tank #1 was pulled to the ground, the drain pipe on the*

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bottom broke off and a diesel-fuel-like substance drained out onto the ground, saturating the grass surrounding Tank #1, and was burned off during the grass fire. The victim and Fire Fighter #1 quickly knocked down the fire on the north side of the tank and underneath the east end of the tank. The fire under the east end of the tank was small, with flames impinging on the hole where the drain pipe had broken off (see Diagram 2 and Photo 1). The Assistant Chief instructed the victim and Fire Fighter #1 to use a fog stream on Tank #1 to cool it down. The Captain, on the south side of Tank #1, instructed his two fire fighters to also spray Tank #1 with water to cool it down (see Photo 2). The fire fighters on the south side of the tank used a straight stream on the tank for approximately 2 minutes. Initially, the water was turning to steam as the fire fighters applied water to the surface of the tank. After a few moments the tank appeared to have cooled down, to the point when the water was no longer turning to steam and was running down the sides of the tank. The Assistant Chief walked over to the tank, placed his hand on its side and noticed that it was cool to the touch. The owner of the garage, which is adjacent to the fireground, informed the Chief that the tank had been out of service and empty for a number of years. After completing fire suppression measures on the north side of the tank, the victim and Fire Fighter #1 repositioned themselves between the east end of the tank and Unit 504. The Captain and fire fighters on the south side of the tank were standing by, awaiting further instructions. While the Chief was standing on the north side of the fireground, Civilian #1 approached him and informed him that he wanted to cut a hole in the end of the tank. *Note: The hole was to be cut in the east end of the tank, allowing the salvage workers to pull a chain through the east end of the tank. The chain would then be used to drag the tank onto a truck to be removed from the site.* The Chief acknowledged him and agreed, and the

civilian then proceeded to the east end of the tank with a cutting torch. However, the Chief did not communicate this information to everyone on the fireground. *Note: The Chief later stated that he did not realize or fully understand the request the civilian was making in regards to the methods the civilian would employ when cutting the hole in the tank.* Civilian #1 lit his cutting torch, adjusted the flame, and began cutting near the threaded opening for the 2-inch fill pipe (see Diagram 1 and Diagram 2). The victim and Fire Fighter #1 were kneeling on the ground, facing the east end of the tank while manning the hoseline. The victim was on the nozzle with Fire Fighter #1 backing him up. Civilian #2 (a second fatality) was standing a few feet to the north of the victim and Fire Fighter #1 and was watching his partner (Civilian #1) prepare to cut into the tank (see Diagram 1). When cutting began, there was a loud noise (reported as sounding like a jet engine). After hearing the noise, the Captain and the fire fighters, standing on the south side of the tank, turned and began to run. Tank #1 then swelled and exploded. The east end of the tank (10 feet in diameter and weighing 900 pounds) separated at the seam, at the end of the tank (the end of the tank folded in half, forming into the shape of a "U"), and was blown in an easterly direction. The end of the tank deflected off the front end of Engine 502 before colliding into the side of a storage building (total distance traveled was 114 feet). The tank had turned 180 degrees, with the opened east end of the tank now facing west (see Photos 3 and 4). At the time of the explosion, the victim was in the direct path of the east end of the tank and was killed instantly. Fire Fighter #1 was knocked to the ground by the blast and flying debris and received numerous injuries to his legs. Civilian #1 was knocked to the ground, receiving severe burns to most of his body. Civilian #2's legs were severed at the knees. The driver/operator of Engine 502 was knocked to

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the ground as the end of the tank deflected off the front end of Engine 502. The Assistant Chief, who was standing to the north of the victim, was uninjured. At the time of the explosion, the Chief was walking toward Unit 504, and was just to the south of Fire Fighter #1, when he was knocked to the ground by the blast, but was not injured. There were no other serious injuries reported. The Chief radioed Central Dispatch at 1112 hours for an ambulance. The driver/operator from Engine 505 grabbed the hoseline on the south side of the tank and began to extinguish the spot fires around the tank. The Assistant Chief, Chief, fire fighters, and a city police officer began administering medical treatment to both Civilian #1 and #2 and to Fire Fighter #1. Fire Fighter #1 was transported to a nearby hospital where he received further medical treatment. Civilian #1 was transported to the state's burn treatment center. Civilian #2 was life-flighted to the regional hospital where he was later pronounced dead as a result of the traumatic amputation of his lower extremities. The victim was pronounced dead at the scene.

CAUSE OF DEATH

The cause of the victim's death was listed by the State Medical Examiner as multiple blunt force injuries to the head, neck, torso, and extremities.

RECOMMENDATIONS AND DISCUSSION

Recommendation #1: Fire departments should ensure that, for fires involving potentially dangerous substances, fire fighters utilize and follow the guidelines set forth in the U. S. Department of Transportation's North American Emergency Response Guidebook.^{1,2}

Discussion: If an incident is believed to involve unknown dangerous substances, the user should refer to Guide 111 (pp. 170-171) of the North

American Emergency Response Guidebook (NAERG96), produced by the Department of Transportation (DOT). The guide is primarily used to aid first responders in quickly identifying the specific or generic hazards of the material(s) involved in the incident and protecting themselves and the general public during the initial response phase of the incident. Guide 111 (mixed load/unidentified cargo) lists potential hazards and steps to follow to ensure public safety and the safety of the emergency personnel.

Potential hazards (fire or explosion) specific to this incident were

- explosion from heat, shock, friction, or contamination
- ignition by heat, sparks or flames
- travel of vapors to source of ignition, resulting in flash back
- explosion of containers when heated
- rupture of cylinders, resulting in rocketing.

The emergency response recommendations for fires involving tanks include the following:

- cool containers with flooding quantities of water until well after fire is out
- do not get water inside containers
- withdraw immediately in case of rising sound from venting safety devices or discoloration of tank
- ALWAYS position apparatus and personnel a safe distance away from the tank; sections of the tank can fly in any direction.

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The emergency response recommendation to ensure public safety, for fires involving tanks include the following:

- call the appropriate emergency response telephone numbers listed on the back cover of the *North American Emergency Response Guidebook*
- keep unauthorized personnel away
- stay upwind
- keep out of low areas, such as ditches, culverts, or any depression in the surrounding terrain.

This incident involved a fire in proximity to a large fuel tank, which requires the evacuation and isolation of the incident site for a minimal distance of $\frac{1}{2}$ mile in all directions.

Fire fighters arriving at the scene stated that there were no placards or warning signs on or near the tank. Photos of the tank at the scene of the incident did not reveal any information contrary to the fire fighters' reports that there were no placards or warning signs.

Recommendation #2: Fire departments should develop, implement, and enforce standard operating procedures (SOPs) that address fire fighter safety regarding emergency operations for hazardous substance releases.^{3,4}

Discussion: Standard operating procedures (SOPs) regarding operations to be conducted at the scene of a hazardous substance release would provide fire fighters with the department's most commonly accepted order of fireground priorities.

At the time of the incident, the department did not have written or established SOPs regarding hazardous-substance-release incidents.

Recommendation #3: Fire departments should ensure that emergency response personnel adhere to the procedures outlined in 29 CFR 1910.120(q)2—Emergency response to hazardous substance releases.⁵

Discussion: Fire departments should comply with OSHA safety standard 29 CFR 1910.120(q)2 which would provide additional guidelines to a fire department's standard operating procedures (SOPs). Standard 29 CFR 1910.120(q)2 contains procedures for dealing with emergency responses. These procedures include (1) emergency response plan, (2) elements of an emergency response plan, (3) procedures for handling emergency response, (4) skilled support personnel, (5) specialist employees, (6) training, (7) trainers, (8) refresher training, (9) medical surveillance and consultation, (10) chemical protective clothing, and (11) post-emergency response operations.

Additionally, owners of aboveground storage tanks should

Recommendation #4: Register all tanks, existing or new, with the State Fire Marshal.⁶

Discussion: Code of Iowa Chapter 100 and Iowa Administrative Code Chapter 5, Section 661-5.307(1) both require the registration of aboveground storage tanks (AST) exceeding 1,100 gallons. All tanks, existing or new, shall be reported to the Fire Marshal Division for registration. Tank #1 (10,000 gal) and Tank #2 (15,000 gal) were never approved, inspected, or registered with the State Fire Marshal's Division of Registration, according to AST files on hand. The tank was subject to

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out-of-service notification according to Chapter 5, Section 661-5.307 (101).

Recommendation #5: Ensure that aboveground tanks are in compliance with NFPA 30 2-3.6 “Emergency Relief Venting for Fire Exposure for Aboveground Tanks.”^{6,7}

Discussion: Except as provided in NFPA 30 2-3.6.2, “every aboveground storage tank shall have some form of construction or device that will relieve excessive internal pressure caused by exposure fires.” Under 2-3.6.4, “where entire dependence for emergency relief is placed upon pressure-relieving devices, the total venting capacity of both normal and emergency vents shall be enough to prevent rupture of the shell or heads of a horizontal tank.”

The State Fire Marshal’s office found that Tank #1’s venting capacity consisted of two 3-inch vent openings that had both been sealed by a 2½-inch reduced caps. The 2½-inch reduced caps made the tank vapor tight. The pressure valve installed on Tank #1 was 6 inches in width. Pressure venting for a 10,000-gallon tank (Tank #1) requires valves 8 inches in width. Thus, the vapors were unable to escape the tank and venting did not occur. The emergency pressure valve acting alone did vent, but did not prevent the rupture of the tank due to the flame from the torch coming in contact with trapped vapors.

Recommendation #6: Ensure that unsupervised, isolated aboveground tanks are secured and marked in such a manner as to identify the fire hazards of the tank and its contents to the general public.⁷

Discussion: Unsupervised, isolated aboveground storage tanks shall be secured and marked with placards or labels in such a manner so as to identify

the fire hazards of the tank and its contents to the general public. The area in which the tank is located should be protected by fencing or some form of barricade to deter tampering or trespassing. The State Fire Marshal’s Office found that the tank was not properly labeled. The tanks were not secured or protected from tampering or trespassing. No placards or signs were visible in photographs taken of Tank #1 and Tank #2 at the incident scene.

Additionally, persons conducting welding or cutting should

Recommendation #7: Consider all tanks hazardous unless they have been tested and found safe, cleaned, or rendered inert.^{8,9}

Discussion: Welding and cutting on tanks containing hazardous materials may cause, and has caused, explosions or fires resulting in death and serious injuries. Any tank can contain or may have contained a combustible material. Three aspects of minimizing risks associated with combustibles are (1) containment, (2) ventilation, and (3) purging.

The civilian salvage workers involved with dismantling the aboveground tanks failed to render the tanks vapor free while they were cutting the supports of the two tanks. When the supports for Tank #1 were cut, the tank was allowed to fall freely onto the ground, which in turn broke off the drain pipe (labeled as F on Diagram 2). This allowed flammable liquid (gasoline and a heavy petroleum distillate [kerosene] were detected in samples taken from Tank #1 by the State Fire Marshal’s Office) to drain from the tank and saturate the grass and debris surrounding the tank. Cutting was continued on and around the storage tank with the hot pieces of metal from the steel frame

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smoldering in the grass (source of ignition for grass fire).

Recommendation #8: Prohibit welding or cutting operations in the presence of explosive atmospheres.¹⁰

Discussion: NFPA 51B states that cutting or welding shall not be permitted in the presence of explosive atmospheres (e.g., mixtures of flammable gases, vapors, liquids, or dusts with air) or explosive atmospheres that can develop inside uncleared or improperly prepared drums, tanks, or other containers and equipment that have previously contained such materials or that can develop in areas with an accumulation of combustible dusts. The civilian salvage workers involved with dismantling the aboveground tanks continued cutting operations in the presence of flammable liquids (gasoline and a heavy petroleum distillate [kerosene]) after the flammable liquids drained from Tank #1. Civilian #1 proceeded to cut into Tank #1 after the tank had been exposed to the heat produced by the grass fire. Tank #1 was not cleaned or prepared for cutting prior to Civilian #1 cutting into the east end of the tank. Fire was present under the east end of Tank #1 during fire fighting operations. Flames were impinging on the opening for the drain pipe. When flame impingement occurs on a tank that has little liquid inside it, then there is nothing to absorb the heat but the metal itself. Tank #1 was constructed of steel. A total of 16 minutes had elapsed from the time Central Dispatch was notified of the fire (1056 hours) until the Chief called requesting an ambulance (1112 hours). The amount of time that Tank #1 was exposed to fire prior to the call to Central Dispatch is unknown. Steel does not tolerate high heat well so when temperatures reach above 400°F, the integrity of the tank is quickly jeopardized (NFPA statistics show that pressure tanks can

fail from flame impingement within the first 15 to 20 minutes of the first flame exposure).

REFERENCES

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Fire Protection Association, pp. 3-175.

9. National Fire Protection Association 327 2-3, 1993 Edition, Cleaning or Safeguarding Small Tanks and Containers Without Entry, Quincy, MA.

10. National Fire Protection Association 51B: 3-1.1 (c), 1994 Edition, Fire Prevention in Use of Cutting and Welding Processes, Quincy, MA.

INVESTIGATOR INFORMATION

This incident was investigated by Mark McFall and Kimberly Cortez, Safety and Occupational Health Specialists, Division of Safety Research, NIOSH.



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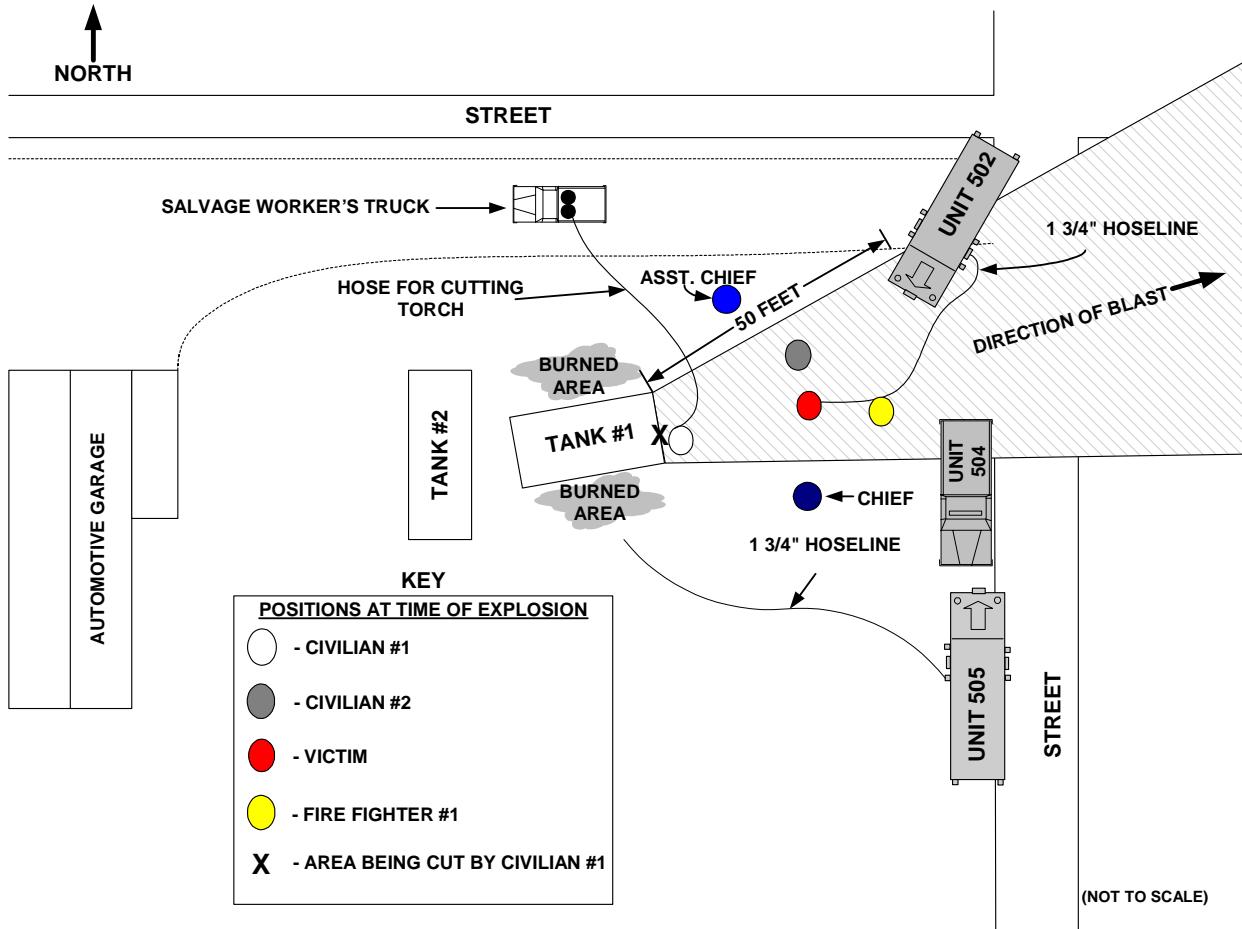
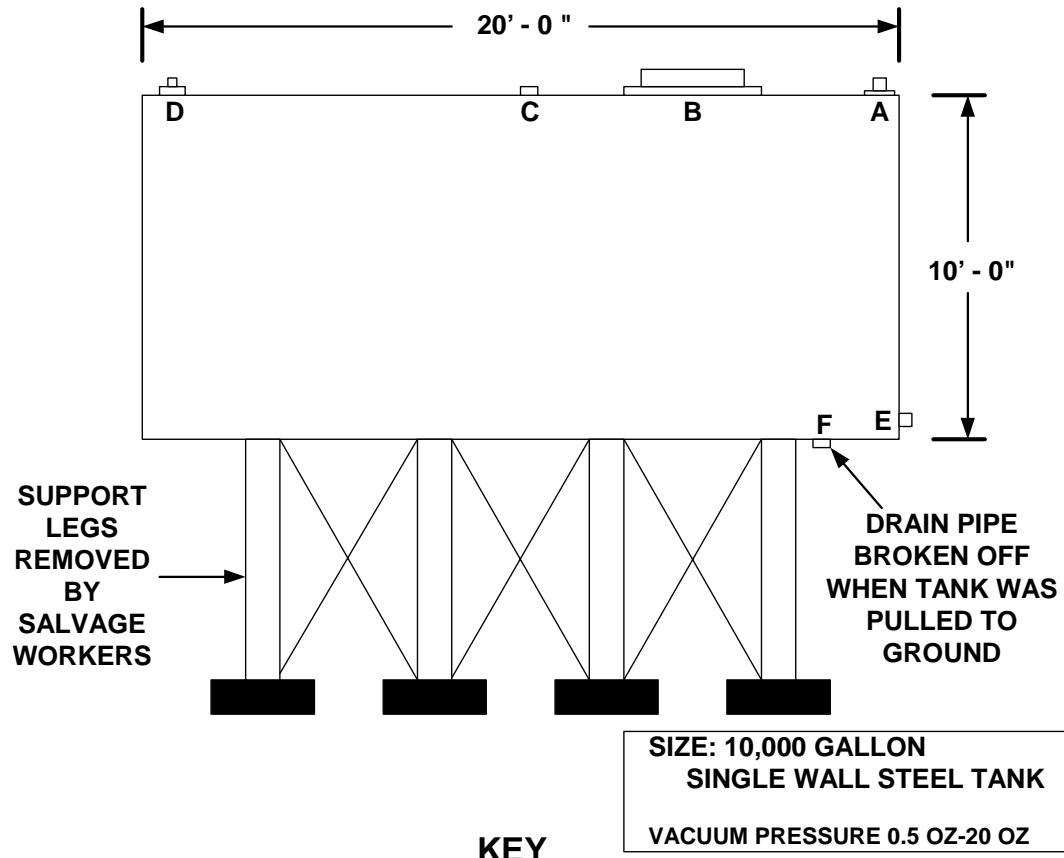


Diagram 1. Aerial View of Incident Site



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- A** = 3-INCH VENT OPENING REDUCED TO A SEALED 2 1/4-INCH PIPE CAP
- B** = EMERGENCY VALVE WITH 6-INCH VALVE AND FLAME ARRESTER PLATE (VALVE AND FLAME ARRESTER PLATE WAS BLOWN OFF AND RECOVERED)
- C** = 1-INCH STEEL TAPE FUEL GAUGE (DISCONNECTED AT TIME OF INCIDENT)
- D** = 3-INCH VENT OPENING REDUCED TO A SEALED 2 1/4-INCH PIPE CAP
- E** = 2-INCH FILL PIPE THREADED CONNECTION (FILL PIPE REMOVED PRIOR TO INCIDENT)
- F** = 1-INCH WATER DRAIN UNDER TANK

Diagram 2. Profile of Fuel Tank #1



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Photo courtesy of the Madisonian.

Photo 1. Photo of Tank #1 Prior to Explosion

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Photo courtesy of the Madisonian.

***Photo 2. Fire Fighters on the South Side of Tank #1, Prior to the
Explosion, Applying Water to Tank's Surface to Cool It Down***

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Photo courtesy of the Madisonian.

Photo 3. Burning Fuel Tank Immediately After Explosion



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Photo courtesy of the Madisonian.

Photo 4. Incident Site Immediately After Explosion Occurred.

Note: Tank #1 turned 180 degrees on its axis.