One Fire Fighter Killed and Eight Fire Fighters Injured in a Dumpster Explosion at a Foundry—Wisconsin

Executive Summary

In December 2009, a 33 year old male fire fighter died and eight fire fighters, including a lieutenant and a junior fire fighter, were injured in a dumpster explosion at a foundry in Wisconsin. At 1933 hours, dispatch reported a dumpster fire at a foundry in a rural area. Eight minutes later, the initial responding crews and the incident commander (IC) arrived on scene to find a dumpster emitting approximately two-foot high bluish green flames from the open top and having a ten-inch reddish-orange glow in the middle of the dumpster's south side near the bottom. The IC used an attic ladder to examine the contents of the dumpster: aluminum shavings, foundry floor sweepings, and a 55 gallon drum. Approximately 700 gallons of water was put on the fire with no affect. Approximately 100 gallons of foam solution, starting at 1 percent and increased to 3 percent, was then put on the fire, and again there was no noticeable effect. Just over twelve minutes on scene, the contents of the dumpster started sparking then exploded sending shrapnel and barrels into the air. The explosion killed one fire fighter and injured eight other fire fighters, all from the same volunteer department.

Contributing Factors

- Wet extinguishing agent applied to a combustible metal fire.
- Lack of hazardous materials awareness training.
- No documented site pre-plan.
- Insufficient scene size-up and risk assessment.
- Inadequate disposal/storage of materials.

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Key Recommendations

- Ensure that high risk sites such as foundries, mills, processing plants, etc. are pre-planned by conducting a walk through by all possible responding fire departments and that the plan is updated annually.
- Ensure that specialized training is acquired for high risk sites with unique hazards, such as combustible metals.
- Ensure that standard operating guidelines are developed, implemented and enforced.
- Ensure a proper scene size-up and risk assessment when responding to high risk occupancies such as foundries, mills, processing plants, etc.
- Ensure a documented junior fire fighter program that addresses junior fire fighters being outside the hazard zone.

Additionally, manufacturing facilities that use combustible metals should:

- Implement measures such as a limited access disposal site and container labeling to control risks to emergency responders from waste fires.
- Implement a bulk dry extinguishing agent storage and delivery system for the fire department.
- Establish a specially trained fire brigade.

For further information, visit the program Web site at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

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Introduction

On December 29, 2009, a 33 year old male fire fighter died and eight fire fighters, including a lieutenant and a junior fire fighter, were injured in a dumpster explosion at a foundry in Wisconsin. On January 21 - 23, 2010, a general engineer from the National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program conducted an opening meeting with the fire chief and conducted interviews with officers and fire fighters who were at the incident scene. The NIOSH investigator also visited the incident scene and met with the foundry's legal representatives, the Occupational Safety and Health Administration (OSHA) representative, the Wisconsin Department of Commerce's Fire Protection Coordinator, the Wisconsin Department of Natural Resources' Hazardous Waste Specialist, and the county sheriff's office representatives to review issues related to the site. The NIOSH investigator reviewed the officers' and fire fighters' training records, a video captured by the sheriff's patrol car of part of the incident scene, dispatch audio tapes, the county medical examiner's autopsy report and medical records of the injured fire fighters.

Fire Department

The volunteer department involved in this incident had 1 station with approximately 25 volunteer fire fighters and 7 fire apparatus serving a population of about 1,000 residents in a geographic area of approximately 25 square miles. The fire department averages 20 total calls per year.

The fire department had been called to this foundry a few times in the past for the smell of smoke in the building, but there were never any fires. The previous calls ended up being overheated drive belts on electrical motors. The fire department had no documented standard operating guidelines (SOGs).

Training and Experience

The table lists the training and experience of the primary fire fighters involved in the incident.

Fire Fighter	Injured (yes/no)	Training Courses	Years experience
Victim	yes - fatally	Fire Fighter 1, Basic Fire Investigation, Introductory ICS Level 100, Basic Lightweight Building Construction, Basic Wildland Fire Suppression, Managing Company Tactical Operations, and various other administrative and technical courses.	15
FF#1	yes	Various administrative and technical courses.	1
FF#2	yes	Entry Level Fire Fighter 1 and 2, Introduction to ICS 100 through 400, and various other administrative and technical courses.	8.5

FF#3	yes	Fire Fighter 1, various other administrative and technical courses.	7
FF#4	yes	Basic Fire Fighter 1, Advanced ICS, and various other administrative and technical courses.	8
FF#5	yes	Entry Level Fire Fighter 1 and 2, Introduction to ICS 100, Basic Wildland Fire Suppression, and various other administrative and technical courses.	6
FF#6	yes	On the Job Fire Fighter Training	3.5
Jr FF	yes	On the Job Fire Fighter Training	0.3
Lieutenant	yes	Fire Fighter 1, Incident Command System (ICS) Levels 100 through 400, Introduction to NIMS, The Dangers of Light weight Construction, and various other administrative and technical courses.	11
Captain	no	Fire Fighter 1, Entry Level Firefighter Part 1 and 2, Incident Command System (ICS) Levels 100 through 400 and 700, Incident Command, Critical Incident Management Response, Municipal Emergency Response Operations Part 1 and 2, Jaws of Life, and various other administrative and technical courses.	10
2nd Assistant Chief	no	Fire Fighter 1, Entry Level Firefighter Part 1 and 2, Entry Level Fire Officer, Incident Command System (ICS) Levels 100 through 400 and 700, Incident Command, Critical Incident Management Response, Pipeline Emergency Response, Jaws of Life, Wildland Fire Suppression, and various other administrative and technical courses.	9.5
1st Assistant Chief	no	Entry Level Firefighter Part 1 and 2, Entry Level Driver/Operator Part 1 and 2, Incident Command System (ICS) Levels 100 through 400 and 700, Incident Response to Terrorist Bombing Awareness, Recognizing and Identifying Hazardous Materials, Lightweight	29

		Construction Dangers, Jaws of Life, and various other administrative and technical courses.	
Chief (Incident Commander (IC))	no	Fire Fighter 1; Fire Officer I; Basic Fire Investigation; Introductory and Level 100, 200, and 300 ICS; Introduction to National Incident Management System (NIMS); HazMat I; Basic Lightweight Building Construction; Basic Wildland Fire Suppression; Managing Company Tactical Operations; and, various other administrative and technical courses.	31

Note: Fire Fighter 1 and 2 training met the criteria for National Fire Protection Association (NFPA) 1001, Standard for Fire Fighter Professional Qualifications, Fire Fighter I and Fire Fighter II.

Personal Protective Equipment

At the time of the incident, the victim and FF#4 were in full personal protective equipment (PPE) and had donned their self-contained breathing apparatus (SCBA) with integrated personal alert safety system (PASS). The other injured fire fighters, the lieutenant, and IC were wearing personal protective equipment consisting of turnout coat and pants, a helmet, and boots. Only the officers had portable radios.

Arrival Timeline of Apparatus and Personnel

1933 Hours

Dispatch reported a dumpster fire at a foundry in a rural area.

1941 Hours

Engine #11 (E11) - Chief (Driver and IC), captain, a fire fighter, and FF #1 (*injured*)
Tanker #17 (T17) – 1st Assistant Chief and FF #2 (*injured*)

1942 Hours

Engine #14 (E14) - Lieutenant (Lt) (*injured*), victim, FF #3 (*injured*), and FF #4 (*injured*)
Equipment Truck #15 (ET15) – 2nd Assistant Chief, driver and FF#6 (*injured*)

1945 Hours

Tanker #16 (T16) – FF #5 (*injured*)
Personally owned vehicle (POV) – Jr FF (*injured*)

Notes: 1) The fire department is located approximately 5 miles from the foundry. 2) See Diagram 1 for placement of selected apparatus.

Weather

At the time of the incident, the weather conditions in the area were clear with an approximate temperature of 14 degrees Fahrenheit, 70 percent relative humidity, visibility 10 miles, and south-southwest winds at approximately 10 miles per hour. [1] Prior to the incident, a substantial amount of snow had fallen and the parking lot had been cleared which created a 4-foot snow bank around the parking lot perimeter.

Site Information

The incident occurred at a recycling dumpster on the grounds of a foundry which produced aluminum sand castings from various aluminum alloys. The 70,000 square foot foundry has been in business for over 73 years and currently employs over 100 people. The metal casting facility melts about 375,000 pounds of aluminum each month.

The fire department had walked through the facility 2 years prior to the incident, but there was no documentation and the hazards associated with the outside disposal area were not viewed or considered at that time. Several of the volunteer members had worked at the facility and/or have relatives that work there, thus they felt familiar with the facility.

The dumpster was made of 3/8 to 1/4 inch thick steel and measured approximately 17 feet long by 5 feet wide by 7 feet high. The dumpster contained about a month's worth of aluminum alloy shavings, foundry floor sweepings (consisting of dirt, metal particles, and processing fluids), and several open top 55 gallon drums of slag. *Note: Aluminum alloy slag is a by-product of the foundry's casting process and is produced during the separation of the molten aluminum alloy from impurities while in the aluminum casting furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling.* A representative dumpster and contents similar to the one that exploded are shown in Photo 1 and Photo 2. The dumpster was located in the southwest corner of the foundry's property. Dumpsters of different dimensions and contents were located in the same area, along with a utility pole, a commercial electrical panel box and a fenced-in electrical substation.

Within the previous 2 years, the foundry went from having 3 to 1 shifts per day, which reduced the amount of waste being produced. When the foundry was operating under 3 shifts per day, they kept the 55 gallon drums of slag stacked together and separate from the aluminum alloy shavings and the other metal scrap. After the reduction in shifts, the recycling company requested the foundry add the drums to the dumpster contents after the slag solidified, so the waste could be picked up in one load. Keeping the drums of slag separate from the open air dumpster contents per the previous storage method when 3 shifts were operating would ensure that no contaminates or heat transfer from the slag could mix with the dumpster contents.

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Investigation

The following investigation synopsis details events leading up to the fatal incident. A deputy sheriff patrol car video recording of the south-side of the incident scene and interviews from the on-scene fire

fighters were used to reconstruct the events leading to the incident. The victim was part of a second crew pulling a 1 ¾" hoseline into position when the explosion occurred.

On December 29, 2009, a 33 year old male fire fighter died and eight fire fighters including a lieutenant and a junior fire fighter less than 18 years of age were injured in a dumpster explosion at a foundry in Wisconsin. At 1933 hours, dispatch reported a dumpster fire at a foundry. At 1941 hours, Engine 11 (E11) with the Fire Chief (IC) driving and Tanker 17 (T17) arrived on scene to find a dumpster emitting two-foot high bluish green flames from the open top and having a ten inch reddish-orange glow in the middle of the dumpster's south side near the bottom. The E11 captain manned the pumper while FF#1 and another fire fighter pulled a 1 ¾" hoseline to the west side of the dumpster. The IC called for FF#2 to get the attic ladder from E11 so he could examine the contents of the dumpster. After stepping on the first rung, the IC noticed aluminum shavings, foundry floor sweepings, and a 55 gallon drum in the dumpster. After observing the contents and color of the flames, the IC believed that metal cutting fluids and/or oils were burning. Two foundry employees were on scene and reassured the IC that no magnesium was in the dumpster.

At 1942 hours, Engine 14 (E14) and Equipment Truck 15 (ET15) arrived on scene. E14 pulled up to the south of E11 and ET15 staged in the east side parking lot. The IC then requested the 1st assistant chief and another fire fighter to set up the dump tank. With a charged hoseline, positioned 20 feet away from the west-side of the dumpster and standing up on a 4-foot snow bank, FF#2 began to flow water using the fog nozzle, and was backed up by FF#1 and another fire fighter. The lieutenant (LT) from E14 took over the fog nozzle after telling FF#2 to put on an air pack. The hoseline crew flowed approximately 700 gallons of water at 50 pounds per square inch (psi) with no affect on the fire, which prompted the IC to call for foam.

At 1945 hours, Tanker 16 (T16) arrived on scene followed by a Jr FF in a privately owned vehicle (POV). The Jr FF reported to the 1st assistant chief and was instructed to go to E14 to get a radio to listen for tool requests. T17 left the scene to refill. The victim and FF#4 were pulling another 1 ¾" hoseline from E11 while FF#2 and FF#3 straightened out the hoseline (see Diagram 1). FF#6 assisted T16 in backing up to the dump tank and was preparing to assist with the tender dumping.

About 100 gallons of foam solution (approximately 6 gallons of Class A/B foam concentrate) from E11's internal foam induction system, starting at 1 percent and increased to 3 percent at 100 psi, was put on the fire and again there was no noticeable effect. At approximately 1953 hours, just as the IC was calling to discontinue foam operations, the contents of the dumpster started sparking, then within seconds, exploded sending shrapnel and barrels into the air. The explosion fatally injured the victim and injured eight other fire fighters (see Diagram 2, Diagram 3, Photo 3, Photo 4, and Photo 5).

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Fire Behavior

Key characteristics of this fire were:

- a metal fire (primarily aluminum alloy shavings) with approximately 2-foot high bluish green flames and a 10 inch reddish-orange glow at the bottom of the steel dumpster;
- approximately 700 gallons of water was put on the fire with no change in fire intensity and the water turning into steam;
- about 100 gallons of Class A/B foam solution was put on the fire with again no change in fire intensity;
- then white sparks began shooting into the air and there was an explosion.

Per the state fire marshal's report, the cause and origin of the fire is listed as undetermined and the cause of the explosion was a result of the fire suppression efforts and the introduction of water and suppressant foam.[2]

After conducting a combustible metal literature review, one speculative theory is that a thermite reaction started from aluminum shavings and particles mixed with metal oxides or silicon oxides (wet sand) which generated enough energy to ignite the aluminum shavings and particles. (*Note: A thermite reaction is a pyrotechnic composition of a metal powder and a metal oxide, which produces an exothermic chemical reaction using aluminum as the reducing agent at high temperature. Thermites can be a diverse class of compositions. The fuels are often aluminium, magnesium, calcium, titanium, zinc, silicon, and boron. The oxidizers can be boron(III) oxide, silicon(IV) oxide, chromium(III) oxide, manganese(IV) oxide, iron(III) oxide, iron(II,III) oxide, copper(II) oxide, and lead(II,III,IV) oxide. The most common thermite is aluminium-iron(III) oxide.)*[3] Once started, the thermite reaction does not need air from the outside to continue burning. The addition of wet extinguishing agent (in this case, water and a foam solution) on the fire most likely generated hydrogen gas, due to the volatile reaction with the aluminum, which exploded.

Factors that may have contributed to the thermite reaction are: the last slag barrel put in the dumpster was still too hot to touch (normally allowed to cool 24 hours but in this case only 1 ½ to 3 hours – initial temperature of the slag (aluminum oxide) is 1425 degrees Fahrenheit when put inside barrel); and the iron (III) oxide (commonly known as rust) in the dumpster and on the slag barrels. *Note: Thermal pattern and iron oxide on slag barrels shown in photo 2.* The melting of the snow laying on top of the dumpster contents may have initially started the generation and/or release of hydrogen gas.

The reaction of small aluminum shavings/particles with any or all of the above mentioned factors has the potential to cause a thermite reaction. Reportedly, the slag barrel was too hot to touch and only cooled for 1 ½ to 3 hours when placed in the dumpster. The temperature of the slag barrel could have been in the 700 to 800 degree Fahrenheit range and may have directly initiated the thermite reaction. In addition to silicon oxides being part of the alloy process, the iron (III) oxide or rust on the slag barrels and on the walls of the steel dumpster provided another means for the most common of

thermite reactions (aluminum-iron (III) oxide) to occur. The thawing or melting snow could have further hydrated the iron oxide and/or silicon oxide which could have enhanced the energy being released when mixed with the aluminum shavings/particles to cause the ignition of the aluminum shavings.

The National Fire Protection Association (NFPA) 484, *Standard for Combustible Metals*, Annex A Explanatory Material, paragraph A.13.3.3.10.3, states that the application of a wet extinguishing agent (particularly water hose streams) accelerates a combustible metal fire and could result in an explosion. In addition, paragraph A.13.3.3.10.1, states water reacting with aluminum can give off highly flammable hydrogen gas.[4,5]

Contributing Factors

Occupational injuries and fatalities are often the result of one or more contributing factors or key events in a larger sequence of events that ultimately result in the injuries or fatality. The NIOSH investigator identified the following items as key contributing factors in this incident that ultimately led to the line of duty death of one fire fighter and to the injuries of eight fire fighters:

- Wet extinguishing agent applied to a combustible metal fire.
- Lack of hazardous materials awareness training.
- No documented site pre-plan.
- Insufficient scene size-up and risk assessment
- Inadequate disposal/storage of materials.

Cause of Death/Injuries

According to the medical examiner's autopsy report, the victim died from multiple injuries as a result of blunt force trauma. According to medical records, all of the fire fighters' injuries were due to the explosion resulting in debris impact and/or noise-related injuries. Of the fire fighters injured at the time of the incident, the Lt had lower back and spinal cord injuries; FF #1, FF#5, FF#6 and the Jr FF experienced temporary hearing loss; FF#2 had back pain and temporary hearing loss; FF#3 had a neck sprain and a bump on his head; FF#4 had second degree burns to the left elbow, right flank, and a broken right hand.

Recommendations

Recommendation #1: Fire departments should ensure that high risk sites such as foundries, mills, processing plants, etc. are pre-planned by conducting a walk through by all possible responding fire departments and that the plan is updated annually.

Discussion: National Fire Protection Association (NFPA) 1620 *Standard for Pre-Incident Planning, 2010 Edition*, states that the pre-incident plan should be the foundation for decision making during an emergency situation and provides important data that will assist the IC in developing appropriate strategies and tactics for managing the incident. This standard also states that the primary purpose of a

pre-incident plan is to help responding personnel effectively manage emergencies with available resources. Pre-incident planning involves evaluating the protection systems, building construction, contents, and operating procedures that can impact emergency operations. Section 8.1 states "The pre-incident plan shall identify and document any special hazards recognized by the authority having jurisdiction that present extraordinary life safety challenges, operations challenges, or other challenges to emergency responders."[6] A pre-incident plan identifies deviations from normal operations and can be complex and formal, or simply a notation about a particular problem such as the presence of flammable liquids, explosive hazards, common attic, drop ceilings, roofing materials, modifications to structural building components, or structural damage from a previous fire.[7,8]

In addition, NFPA 1620 outlines the steps involved in developing, maintaining, and using a pre-incident plan by breaking the incident down into pre-, during- and post-incident phases. In the pre-incident phase, for example, it covers factors such as physical elements and site considerations, occupant considerations, protection systems and water supplies, hydrant locations, and special hazard considerations. The pre-incident plan should be documented, shared with other departments who provide mutual aid, and if possible, entered into the dispatcher's computer so that the information is readily available if an incident is reported at the noted address.

In this incident, the fire department had walked through the facility 2 years prior to the incident but there was no documentation and the hazards associated with the outside disposal area were not indentified or considered at that time. Several of the fire fighters had worked at the facility and/or have relatives that work there, thus they felt familiar with the facility.

Recommendation #2: Fire departments should ensure that specialized training is acquired for high risk sites with unique hazards, such as combustible metals.

Discussion: Fire departments often respond to complex or unique hazards which require specialized/advanced knowledge and/or training in dealing with that hazard. Combustible metal fires present unique and dangerous hazards to fire fighters which are not commonly encountered in conventional fire fighting operations. The temperatures encountered in a combustible metal fire far exceed those of a structure fire.[5]

The National Fire Protection Association (NFPA) 484, *Standard for Combustible Metals*, states that it is extremely important to conduct a good size-up by identifying the combustible metals involved, the physical state of the metals (e.g., shavings, chips, fine dust, etc.), the location relative to other combustible materials, and the quantity of the product involved. NFPA 484, A.13.3.3.10.3, states that the application of a wet extinguishing agent (particularly water hose streams) accelerates a combustible metal fire and could result in an explosion.[4] This is due to the water reacting with aluminum to give off highly flammable hydrogen gas. This conversion of water into hydrogen has a heat value (British Thermal Units per pound (Btu/lb)) of about 2.8 times that of gasoline, assuming 100 percent conversion of the hydrogen in the water. This equates to flowing 42.8 gallons per minute (gpm) of gasoline on the fire for every 100 gpm of water. Thus, in lieu of using a wet extinguishing agent, primarily water, it is recommended that a bulk dry extinguishing agent be used such as dry sand, dry soda ash, or dry sodium chloride. If no bulk dry agents are available, the best approach may be to

isolate the material as much as possible, protect exposures, and allow the fire to burn out naturally.[5] Proper training is a must to properly identify and handle these unique fires. Manufacturers and fire departments with combustible metals in their jurisdiction should review Chapter 13 of the National Fire Protection Association (NFPA) 484: Standard on Combustible Metals.[4]

Recommendation #3: Fire departments should ensure that standard operating guidelines are developed, implemented and enforced.

Discussion: Written SOGs enable individual fire department members an opportunity to read and maintain a level of assumed understanding of operational procedures. Conversely, fire departments can suffer when there is an absence of well developed SOGs. The NIOSH Alert, *Preventing Injuries and Deaths of Fire Fighters* identifies the need to establish and follow fire fighting policies and procedures.[9] Guidelines and procedures should be developed based on recognized standards and best practices, trained upon by all potential responding personnel, and fully implemented and enforced to be effective. The following NFPA Standards identify the need for written documentation to guide fire fighting operations:

NFPA 1500 *Fire Department Occupational Safety and Health Program* states that fire departments shall prepare and maintain policies and standard operating procedures that document the organizational structure, membership, roles and responsibilities, expected functions, and training requirements, including the following....(4) The procedures that will be employed to initiate and manage operations at the scene of an emergency incident. In particular, NFPA 1500, 4.2.3.1, states a risk management plan should include risk identification of actual and potential hazards.[10]

NFPA 1561 *Standard on Emergency Services Incident Management System* states that standard operating procedures (SOPs) shall include the requirements for implementation of the incident management system and shall describe the options available for application according to the needs of each particular situation.[11]

Recommendation #4: Fire departments should ensure a proper scene size-up and risk assessment when responding to high risk occupancies such as foundries, mills, processing plants, etc.

Discussion: Per NFPA 1620, the foundry would be classified as an *Industrial Occupancy* and is defined as "an occupancy in which products are manufactured or in which processing, assembling, mixing, packaging, finishing, decorating, or repair operations are conducted.[6] When responding to a high-risk occupancy such as a foundry, the first arriving officer or incident commander must conduct a proper scene size-up of the incident including a risk assessment in terms of life safety for responders and occupants. Size-up is defined as an ongoing process of evaluating the situation to determine what has happened, what is happening, and what is likely to happen. A sufficient scene size-up should include:

- ✓ Type of Occupancy
- ✓ Access

- ✓ Building Construction
- ✓ Environmental Conditions
- ✓ Location of the Fire
- ✓ Resources Responding
- ✓ Water Supply
- ✓ Special Hazards/Risks
- ✓ Time of Day
- ✓ Color of Smoke
- ✓ Utilities
- ✓ Built-in Fire Protection
- ✓ Pre-Incident Planning

Based upon the type of occupancy and what is burning, the IC needs to contact and establish communications with the occupant/facility representative regarding the situation. A relationship with the occupant/facility representative should initially take place during a pre-incident planning visit. NFPA 1, *Fire Code* states that an occupant/facility shall designate and train a liaison representative for the fire department. A liaison shall assist in pre-incident planning and emergency response procedures which identify the location of hazardous materials.[12] If there is no life safety hazard (danger to civilians/occupants) and the fire does not extend or threaten other parts of the facility, the IC should stage all resources until an incident action plan is developed. Once what is burning is properly identified, the appropriate extinguishing agent should be used. If the responding fire departments do not have the resources needed to safely attack the fire (e.g. a bulk dry extinguishing agent for combustible metal fires) and the fire is not threatening lives, the contents should just be allowed to burn out while protecting exposures.

NFPA 1500 states in Chapter 8 – Emergency Operations, that risk management principles must be routinely employed by supervisory personnel at all levels of the incident management system to define the limits of acceptable and unacceptable positions and functions for all members at the incident scene. The risk to fire department members is the most important factor considered by the Incident Commander in determining the strategy that will be employed in each situation.[10]

Recommendation #5: Fire departments should ensure a documented junior fire fighter program that addresses junior fire fighters being outside the hazard zone.

Discussion: The involvement of junior fire fighters (teenagers less than 18 years of age) in the fire service was established early in the fire service's history. Particularly, volunteer departments have welcomed teenage personnel, often alongside of other family members serving in the department. A positive lifelong connection can be achieved when starting young people out within a fire department. However, being that they are under 18 years of age creates certain responsibilities for the fire department.

Many state and federal laws govern work-related activities of youths, which protect the health/safety and educational opportunities of young people. The Fair Labor Standards Act (FLSA), the primary law addressing child labor, exempts volunteer activities, however, the U.S. Department of Labor

advocates voluntary compliance with FLSA requirements for work-like volunteer activities. In addition, OSHA (Federal) has jurisdiction over volunteers in an employer-employee relationship.[13] In this case, OSHA had no jurisdiction because the employer-employee relationship did not exist.

A fire department establishing a program for junior fire fighters should document what the allowable duties are for junior fire fighters in a department's SOGs. The National Volunteer Fire Council (NVFC) has published a *Junior Firefighter Program Handbook* that addresses the steps of starting and maintaining a program, including sample documents from currently existing programs for reference.[14] The International Association of Fire Chiefs (IAFC) has published *Opening New Doors: Guidelines and Best Practices for a Successful Youth Fire Service Program.*[15] If a junior fire fighter would have been near the same location of the victim, death or severe injury could have resulted. Thus, at no time should a junior fire fighter ever be potentially in harms way.

In this case, the junior fire fighter was aware of his duties and was not directly involved in fire suppression. Due to the limited area around the incident, the hazard zone encompassed where the apparatus were staged. However the junior fighter could have been more safely utilized at the station assisting in the tanker refilling, away from the hazard zone. The temporary hearing loss incurred was a result of the limited area around the incident and the unexpected intensity of an explosion.

Recommendation #6: Fire departments should* ensure *all fire fighters who may operate in or near a hazard zone, prior to approaching, have donned the full complement of personal protective equipment, i.e., self-contained breathing apparatus and turn-out gear.

Discussion: Although there is no evidence that the use of personal protective equipment (PPE) would have prevented this fatality or these injuries, this recommendation is provided as a good safety practice. Properties of burning metals cover a wide range. Even when the exact metal is known, metal fires should never be approached without proper protective equipment. Additionally, PPE may not protect wearers from injuries due to contact with molten materials as this hazard exceeds design criteria of PPE and wearers must be aware of PPE limitations. The toxicity of certain metals is also an important factor in fire suppression. Some metals (particularly heavy metals) can be fatal if they enter the bloodstream or their smoke fumes are inhaled.[16]

At any dumpster fire, fire fighters should be fully protected and on-air prior to approach; approach can be at a distance where cooling and control can start well before approaching the dumpster. Fire fighters should remember that there is nothing worth saving in a dumpster fire as the contents are always unknown. The dumpster may contain class A combustibles, discarded hazardous materials, or propane tanks. A dumpster fire is literally a potential bomb and should be treated in that way.

In this incident, only two fire fighters on scene were wearing their full complement of PPE.

Recommendation #7: Manufacturing facilities that use combustible metals should implement measures such as a limited access disposal site and container labeling to control risks to emergency responders from waste fires.

Discussion: Manufacturing facilities should have a standard operating procedure (SOP) for the disposal of their manufacturing waste. This SOP should include adequate labeling of containers and storage areas for these wastes. It should also identify unique hazards if the public were to come in contact with the waste or if fire fighters or other emergency responders were to respond to an emergency. NFPA 704, *Identification of the Hazards of Materials for Emergency Response*, states all buildings or areas storing, using, or handling hazardous materials be marked by use of a standardized placarding system. The placarding system identifies hazard categories for health, flammability, reactivity and special hazards, including water reactivity and oxidizers.[17] This SOP should be reviewed annually for any changes in the materials being stored for waste. In addition, to help prevent uncontrolled dumping of unknown materials into the dumpster, a secured area may be necessary.

Within the previous 2 years, the foundry went from having 3 to 1 shifts per day, which reduced the amount of waste being produced. When the foundry was operating under 3 shifts per day, they kept the 55 gallon drums of slag stacked together and separate from the aluminum alloy shavings and the other metal scrap. After the reduction in shifts, the recycling company requested the foundry add the drums to the dumpster after the slag solidified so the waste could be picked up in one load. A safer procedure might be to keep the drums of slag separate from the open air dumpster contents per the previous storage method when 3 shifts were operating. NFPA 484, section 13.2.7.3.2, states that open storage of metal chips and dust particles that are readily ignitable should be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.[4]

In this incident, there was no labeling on the dumpster that identified the contents. The Wisconsin Department of Natural Resources determined that no hazardous waste regulations were violated.

Recommendation #8: Manufacturing facilities that use combustible metals should implement a bulk dry extinguishing agent storage and delivery system for the fire department.

Discussion: Fire departments do not routinely have bulk dry extinguishing agents on hand or a method to implement their use. The National Fire Protection Association (NFPA) 484, *Standard for Combustible Metals*, Annex A Explanatory Material, paragraph A.13.3.3.10.3, states that facilities that use combustible metals should provide these dry extinguishing agents in areas near where the combustible metals are used and stored, including scrap. These bulk dry extinguishing agents must be kept free of moisture wherever they are stored. A delivery system to apply the dry extinguishing agents should be onsite, such as a front end loader and/or dump truck, and it should be available to the fire department at all times. *Note: Automatic sprinkler protection systems for areas where combustible metals are used or stored are not recommended.*[4]

Recommendation #9: Manufacturing facilities that use combustible metals should establish a specially trained fire brigade.

Discussion: A specially trained fire brigade that is knowledgeable in the permissible methods of fighting incipient fires within the areas that utilize or contain the combustible metals can be a very effective means of fire protection. Only specially trained personnel should be permitted to engage in fire control activities; all other personnel should be evacuated. Upon arrival of the local fire department, all fire control activities should be by a unified incident command that includes knowledgeable plant personnel.[4]

References

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Investigator Information

This incident was investigated by Matt Bowyer, General Engineer, with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Division of Safety Research. The report was authored by Matt Bowyer. Expert technical reviews were conducted by Deputy Chief William Goldfeder, Loveland-Symmes Fire Department and editor of FirefighterCloseCalls.com and by Murrey E. Loflin, Director, West Virginia University Fire Service Extension. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division. An external chemical opinion on thermite reaction was given by Professor Alan Stolzenberg, Department of Chemistry, West Virginia University. Additional external comments were provided by the Occupational Safety and Health Administration's local area office and the foundry's legal representative and their task force manager.

One Volunteer Fire Fighter Killed and Eight Fire Fighters Injured in a Dumpster Explosion at a Foundry—Wisconsin

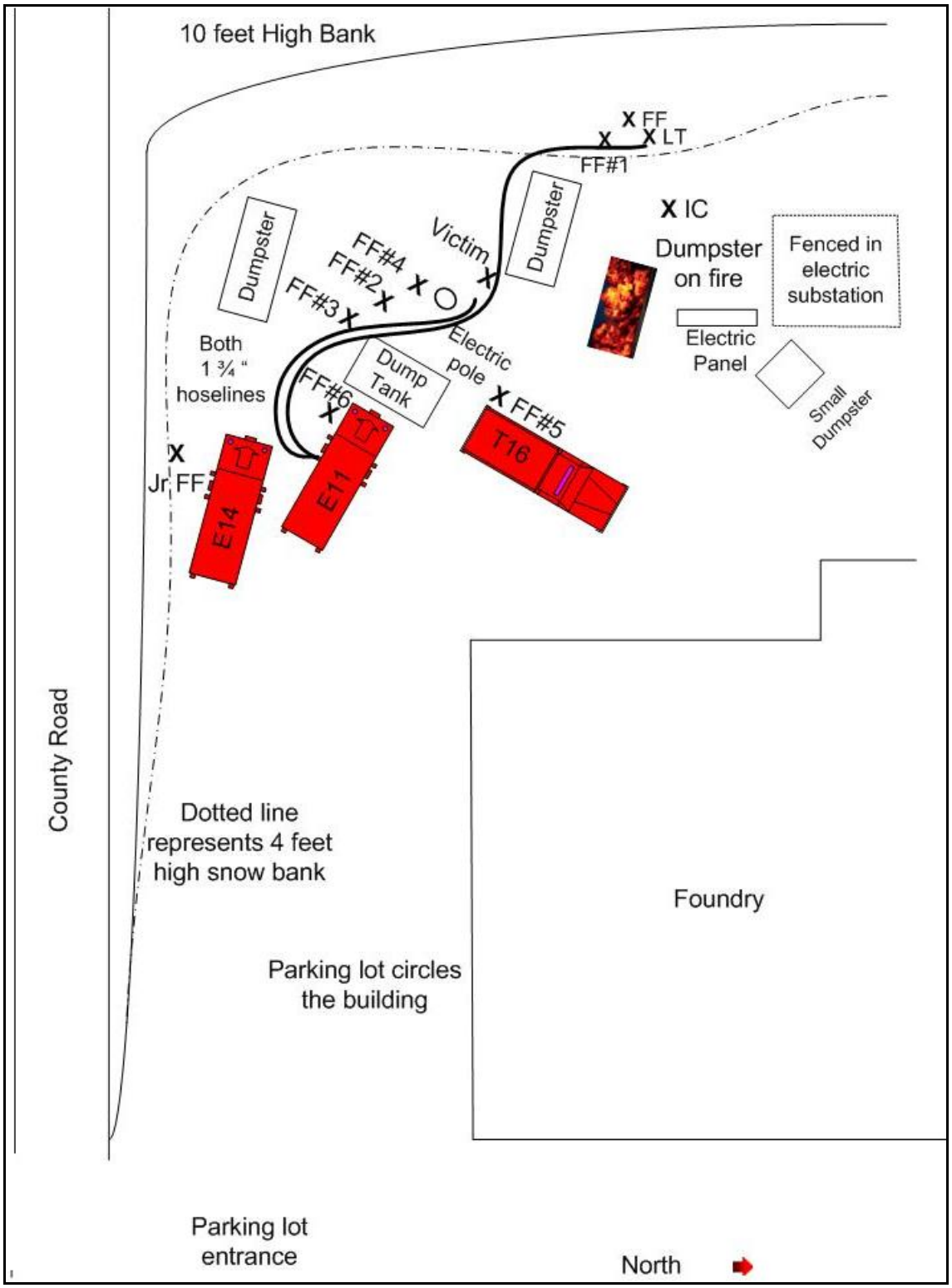

Diagram 1. Approximate locations of key apparatus and personnel just prior to the explosion.

One Volunteer Fire Fighter Killed and Eight Fire Fighters Injured in a Dumpster Explosion at a Foundry—Wisconsin

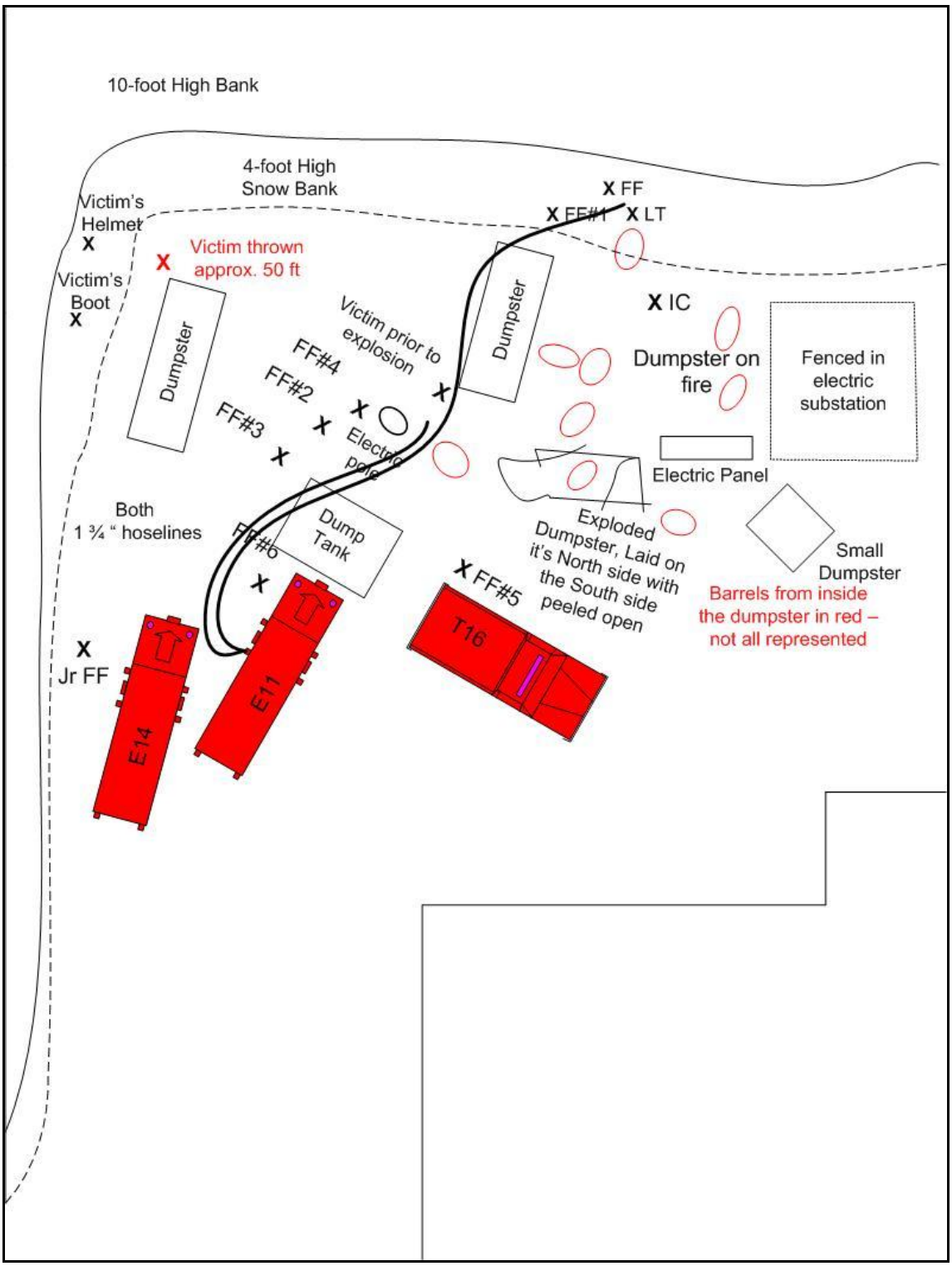

Diagram 2. Approximate location of dumpster and victim after the explosion.

One Volunteer Fire Fighter Killed and Eight Fire Fighters Injured in a Dumpster Explosion at a Foundry—Wisconsin

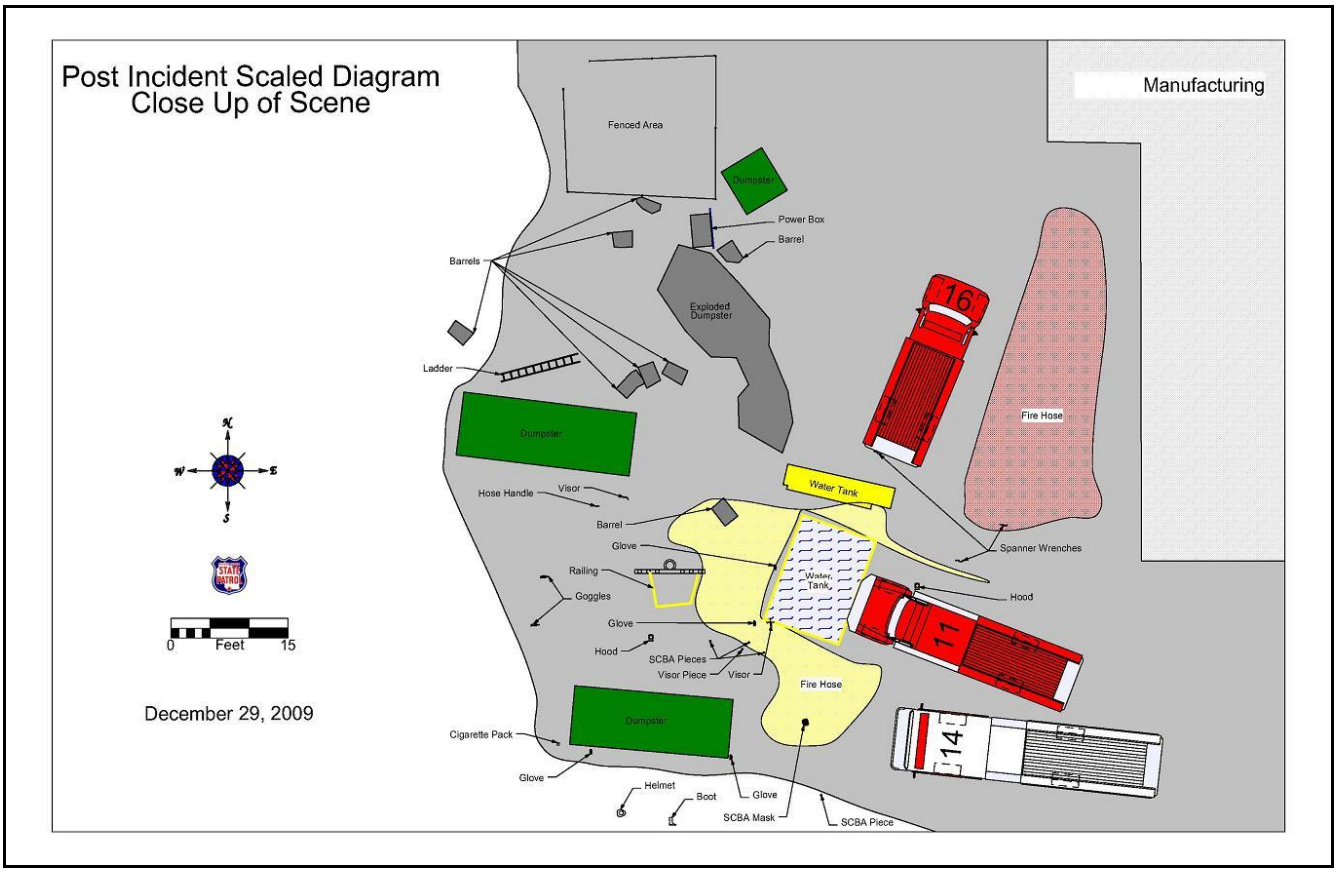

Diagram 3. Post incident scaled close-up of the scene.
(*Courtesy of the Sheriff's Department*)

One Volunteer Fire Fighter Killed and Eight Fire Fighters Injured in a Dumpster Explosion at a Foundry—Wisconsin

Photo 1. A dumpster similar in size and shape to the one that exploded. (*NIOSH photo*)

One Volunteer Fire Fighter Killed and Eight Fire Fighters Injured in a Dumpster Explosion at a Foundry—Wisconsin

Photo 2. Dumpster contents similar to the contents of the dumpster that exploded. Note thermal pattern and iron oxide (rust) on slag barrels.
(*NIOSH photo*)

One Volunteer Fire Fighter Killed and Eight Fire Fighters Injured in a Dumpster Explosion at a Foundry—Wisconsin

Photo 3. Barrel that was blown from the dumpster and believed to have impacted the lieutenant who had been standing at that spot on the snow bank with the 1 ¾" hoseline. (*NIOSH photo*)

One Volunteer Fire Fighter Killed and Eight Fire Fighters Injured in a Dumpster Explosion at a Foundry—Wisconsin

Photo 4. Exploded dumpster and its' remaining contents. (*NIOSH photo*)

One Volunteer Fire Fighter Killed and Eight Fire Fighters Injured in a Dumpster Explosion at a Foundry—Wisconsin

Photo 5. Bottom of the dumpster showing the origin of the fire in the dumpster.

(*NIOSH photo*)