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Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation

April 9, 2014

# Volunteer Fire Fighter Electrocuted by Downed Power Line Following Severe Weather – North Carolina

## Executive Summary

On June 13, 2013, a 36-year-old male volunteer fire fighter (the victim) died after being electrocuted as he investigated the source of a small structure fire. The fire department was dispatched to a vehicle fire caused by an energized power line that was downed after severe weather passed through the area. The energized power line fell across the roof of a small metal storage shed, causing the wooden support structure to arc and catch fire. The victim, dressed in street clothing, walked down a rain-soaked gravel and dirt driveway and knelt down to look underneath the building where fire and smoke were emitting, and immediately fell to the ground unconscious. An eye witness reported the victim did not touch the building before he fell to the ground. Rescuers dragged the victim approximately 30 feet away and began performing cardio-pulmonary resuscitation (CPR) and attempted to use an automated external defibrillator (AED). The victim was transported by ambulance to the local hospital where he was pronounced dead.

**Metal storage building that victim was investigating. Note burn marks at bottom.**
***(Photo courtesy of County Fire Marshal)***

## Contributing Factors

- *Energized power line in contact with metal building*
- *Pooling water and runoff from recent rain storm*
- *Victim not wearing any personal protective clothing or non-conductive boots*
- *Lack of situational awareness*
- *Unrecognized electrical hazards – especially on ground gradients and step potential hazards*
- *No other first responders in the immediate area at the time of the incident.*

## Key Recommendations

- *Fire departments should ensure that fire fighters are trained to recognize electrical shock hazards*

# *Volunteer Fire Fighter Electrocuted by Downed Power Line Following Severe Weather – North Carolina*

- *Fire departments should ensure that fire fighters wear the appropriate personal protective clothing and equipment for the hazards anticipated*
- *Fire departments should ensure that fire fighters are trained in situational awareness and to anticipate hidden hazards*
- *Fire departments and authorities having jurisdiction should consider dispatching an ambulance to all confirmed working fires and other emergency incidents.*

**View of metal building with downed power line in contact with roof. Photo taken looking down driveway as seen by approaching fire fighters.**
***(Photo courtesy of County Fire Marshal)***



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

# Volunteer Fire Fighter Electrocuted by Downed Power Line Following Severe Weather – North Carolina

## Introduction

On June 13, 2013, a 36-year-old male volunteer fire fighter (the victim) died after being electrocuted as he investigated the source of a small structure fire. The fire was caused by an energized power line that was downed after severe weather passed through the area. On June 14, 2013, the U.S. Fire Administration notified the National Institute for Occupational Safety and Health (NIOSH) of this incident. On June 26, 2013, a safety engineer and a general engineer with the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to North Carolina to investigate this incident. The NIOSH investigators met with the county fire marshal and the county arson investigator, the county medical examiner, the fire chief, the assistant fire chief and fire fighters who were on scene at the incident. The NIOSH investigators traveled with the fire chief to the incident site and took photographs and measurements. The NIOSH investigators also talked to the owner of an automotive repair garage located adjacent to the incident site. The garage owner was working in the garage at the time that the victim was electrocuted. The NIOSH investigators reviewed the fire department's standard operating procedures and training records. The NIOSH investigators obtained and reviewed a copy of the dispatch audio records and the medical examiner's report. The NIOSH investigators also talked with representatives of the local electrical utility provider.

## Fire Department

This volunteer fire department has 2 stations with 34 members. Thirteen members are certified to North Carolina Fire Fighter II and Fire Fighter III training levels for structural fire fighting operations. The department has an elected Fire Chief, 2 assistant chiefs, 3 captains, 2 fire lieutenants, 1 lieutenant for first responders and 1 lieutenant for traffic control. The fire department meets every Thursday evening for training and business. A business meeting is held every other Thursday evening. The fire department operates a junior fire fighter program to encourage youths in the community to become active in the fire department.

The State of North Carolina requires that fire fighters maintain at least 36 hours of annual training to maintain certification. The fire department enforces this requirement and all fire department sponsored training is mandatory. The Fire Chief can also authorize members to attend off-site training as necessary on a case-by-case basis.

The fire department headquarters facility (Station 1) houses the following equipment:

- Engine 3101 – 1000 gallon baffled tank
- Engine 3103 – pumper / tanker with 1000 gallon baffled tank
- Tanker 3107 – 1500 gallon baffled tanker
- Brush 3109 – Humvee brush truck with 250 gallon baffled tank
- Truck 3114 – rescue vehicle with equipment storage

Station 2 houses an engine with 750 gallon tank and a 1200 gallon tanker.

The fire department serves a population of approximately 1,800 residents in a geographical area of approximately 16 miles. The department responds to 90 – 110 fire calls per year with 6-7 being working structure fires each year. The department also responds to approximately 350 medical calls per year. The fire department provides basic first aid but does not transport medical patients.

The fire department had written policies and procedures that covered subjects such as department safety rules, fire apparatus operations, radio use, structure fire fighting, vehicle fires, motor vehicle accidents, forest fires, hazardous materials operations, and other subjects including a detailed procedure for operating at emergencies at the county airport. The structure fire, vehicle fire, and vehicle accident procedures required the use of full personal protective clothing and equipment. The department did not have a procedure covering the establishment of an incident command system and the radio procedure did not address emergency radio traffic or hazard communications.

The fire department had a standard operating procedure for vehicle fires stating that before entering the danger zone, all fire department personnel shall have complete protection in the form of turnout pants, boots, properly closed coat, helmet, hood, gloves and SCBA. The fire department had a standard operating procedure covering liquid propane (LP) gas leaks but not for downed power lines or other electrical hazards. The structure fire standard operating procedure stated that fire fighters should anticipate hazards including power lines down around structures and live wires inside structures. The vehicle accident SOP stated that all personnel shall anticipate power lines down and hot. The vehicle fire SOP did not include downed power lines among the hazards that fire fighters should anticipate.

## Training and Experience

In the State of North Carolina, fire fighters are required to receive 36 hours of training each year, and each Fire Chief is responsible for setting departmental training requirements. At this fire department, all department-sponsored training is mandatory and fire fighters must maintain at least 36 hours of training per year to meet state requirements. An assistant chief is responsible for overseeing the training and record keeping functions.

The victim had been a member of the fire department for approximately 1.5 years. Department records showed the victim had received training on subjects such as fire department organization, forcible entry, foam fire streams, orientation and safety, driver operator, fire scene safety, self-contained breathing apparatus (SCBA) and equipment maintenance and other topics. The victim had received some certification training but was not yet Firefighter I certified. Department records showed the victim had received 114 hours of training at the department in 2012 and 42 hours in 2013. Records indicated that at least two 3-hour training classes covered electrical safety.

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## Structure and Electrical Service

The incident occurred on a sloping hillside directly behind a commercial automotive repair garage that fronted a two-lane paved county highway (see Diagram 1 and Photo 1).

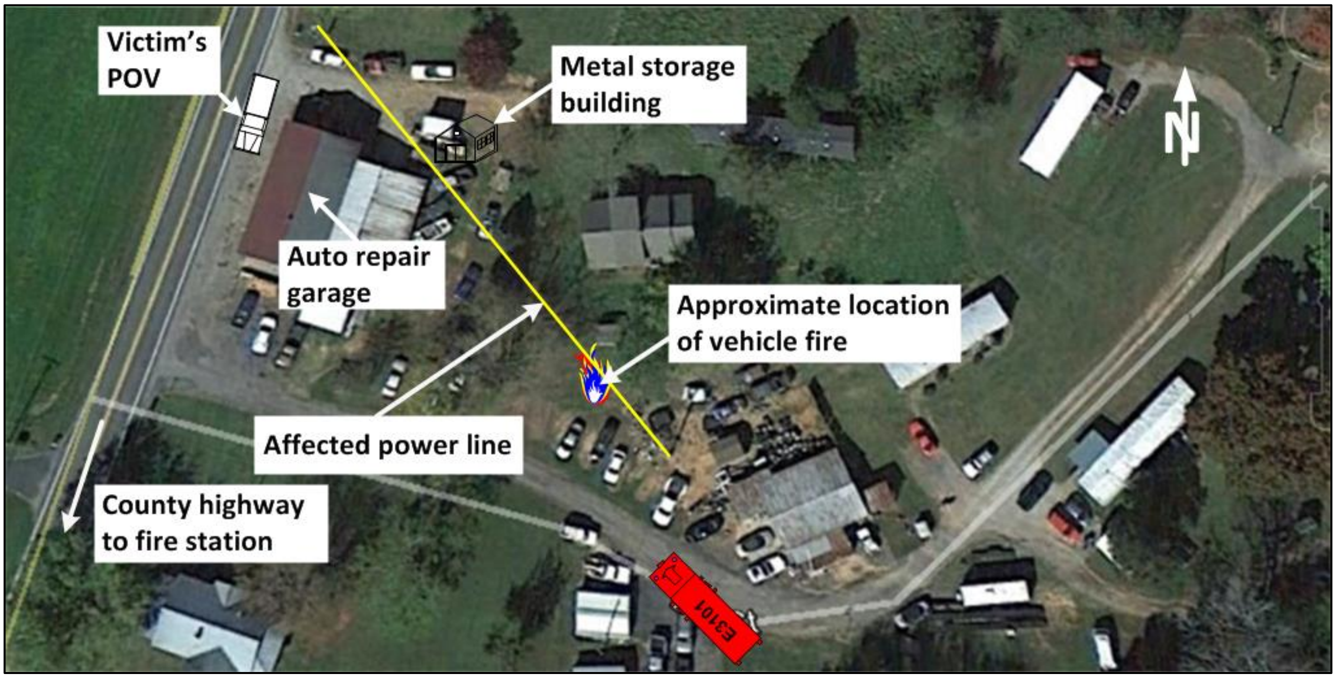


**Diagram 1. Overhead view of incident site. Diagram adapted from Google Earth satellite image dated 10/20/2012. Note that the metal storage building was not present at the time the image was collected.**

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**Photo 1. Incident scene looking up gravel and dirt driveway toward county highway. Automotive repair garage is seen in the background. Repaired power lines can been seen at top of photo over the metal storage building.**
***(Photo NIOSH)***

After responding to a report of downed power lines with a vehicle on fire, by-standers notified the arriving fire department members that a structure was on fire. Fire and smoke was observed coming from underneath a 12 foot by 16 foot metal storage building. The un-grounded building was supported by concrete blocks and 4-inch by 4-inch wooden posts (see Photo 2).

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**Photo 2. Close-up of metal storage building showing the support structure and location where electrical current went to ground, causing wooden supports to catch fire.**
***(Photo NIOSH)***

A rain storm with high winds passed through the area just prior to the incident, causing a large branch on a maple tree to break off and pull down an electrical service line, reported to be carrying 7200 volts of alternating current (AC). The downed wire came into contact with an automobile below the broken tree branch and the metal storage building above the broken tree branch (see Photo 3 and Photo 4).

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**Photo 3. Tree branch resting on powerlines downhill from the incident site near metal storage building. The automobile fire was further down the hill and below the tree.**
***(Photo Courtesy of County Fire Marshal)***

The incident scene was spread across a large area on a sloping hillside that included several structures, a number of parked vehicles, trees and other obstacles that restricted visibility (see Diagram 1). The incident scene included two extremely hazardous areas – the burning vehicle in contact with an arcing downed power line and the downed power line in contact with the metal storage building that ignited the wooden support members under the building.

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**Photo 4. Close-up showing tree branch on power lines.**
***(Photo courtesy of County Fire Marshal)***

# Electrical Shock Hazards

The severity of injury from electrical shock depends on the amount of electrical current and the length of time the current passes through the body. For example, 1/10 of an ampere (0.1 amp or 100 milliamps) of electricity going through the body for just 2 seconds is enough to cause death. The amount of internal current a person can withstand and still be able to control the muscles of the arm and hand can be less than 10 milliamperes (milliamps or mA). Currents above 10 mA can paralyze or "freeze" muscles. When this "freezing" happens, a person is no longer able to release a tool, wire, or other object. In fact, the electrified object may be held even more tightly, resulting in longer exposure to the shocking current. For this reason, hand-held tools that give a shock can be very dangerous. If you can't let go of the tool, current continues through your body for a longer time, which can lead to respiratory paralysis because the muscles that control breathing cannot move. You stop breathing for a period of time. People have stopped breathing when shocked with currents from voltages as low as 49 volts. Usually, it takes about 30 mA of current to cause respiratory paralysis.[1]

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Currents greater than 75 mA cause ventricular fibrillation – a very rapid, ineffective heartbeat. This condition will cause death within a few minutes unless a special device called a defibrillator is used to save the victim by restoring a normal heartbeat. Heart paralysis occurs at 4 amps, which means the heart does not pump at all. Tissue is burned with currents greater than 5 amps.[1]

Table One shows what usually happens for a range of currents lasting one second at typical household voltages. Longer exposure times increase the danger to the shock victim. For example, a current of 100 mA applied for 3 seconds is as dangerous as a current of 900 mA applied for 0.03 seconds (a fraction of a second). The muscle structure of the person also makes a difference. People with less muscle tissue are typically affected at lower current levels. Even low voltages can be extremely dangerous because the degree of injury depends not only on the amount of current but also on the length of time the body is in contact with the circuit. *Note: LOW VOLTAGE DOES NOT MEAN LOW HAZARD!*[1]

**Table One**
**Effects of Electrical Current in the Human Body**

| | |
|---|---|
| Below 1 milliampere | Generally not perceptible |
| 1 milliampere | Faint tingle |
| 5 milliamperes | Slight shock felt; not painful but disturbing. Average individual can let go. Strong involuntary reactions can lead to other injuries |
| 6-25 milliamperes (women)<br>9-30 milliamperes (men) | Painful shock, loss of muscle control. The freezing current or "let-go" range. Individuals cannot let go, but can be thrown away from the current if extensor muscles are stimulated.* |
| 50-150 milliamperes | Extreme pain, respiratory arrest (breathing stops), severe muscle contractions. Death is possible. |
| 1,000 – 4,300 milliamperes | Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur; death likely. |
| 10,000 milliamperes | Cardiac arrest and severe burns occur. Death is probable. |
| 15,000 milliamperes | Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit! |

*If the extensor muscles are excited by shock, the person may be thrown away from the power source. The lowest overcurrent at which a typical fuse or circuit breaker will open is 15,000 milliamps (15 amps)

Sometimes high voltages lead to additional injuries. High voltages can cause violent muscular contractions. You may lose your balance and fall, which can cause injury or even death. High voltages can also cause severe burns. At 600 volts, the current through the body may be as great as 4 amps, causing damage to internal organs such as the heart. In addition, internal blood vessels may clot. Nerves in the area of the contact point may be damaged. Muscle contractions may cause bone fractures from either the contractions themselves or from falls.[1]

A severe shock can cause much more damage to the body than is visible. A person may suffer internal bleeding and destruction of tissues, nerves, and muscles. Sometimes the hidden injuries caused by electrical shock result in a delayed death. Shock is often only the beginning of a chain of events. Even if the electrical current is too small to cause injury, your reaction to the shock may cause you to fall, resulting in bruises, broken bones, or even death.[1]

The length of time of the shock greatly affects the amount of injury. If the shock is short in duration, it may only be painful. A longer shock (lasting a few seconds) could be fatal if the level of current is high enough to cause the heart to go into ventricular fibrillation. This is not much current when you realize that a small power drill uses 30 times as much current as what will kill. At relatively high currents, death is certain if the shock is long enough. However, if the shock is short and the heart has not been damaged, a normal heartbeat may resume if contact with the electrical current is eliminated. (This type of recovery is rare.)[1]

The amount of current passing through the body also affects the severity of an electrical shock. Greater voltages produce greater currents. So, there is greater danger from higher voltages. Resistance hinders current. The lower the resistance (or impedance in AC circuits), the greater the current flow will be. Dry skin may have a resistance of 100,000 ohms or more. Wet skin may have a resistance of only 1,000 ohms. Wet working conditions or broken skin will drastically reduce resistance. The low resistance of wet skin allows current to pass into the body more easily and give a greater shock. When more force is applied to the contact point (such as a tight grip or falling onto the current source) or when the contact area is larger, the resistance is lower, causing stronger shocks.[1]

The path of the electrical current through the body also affects the severity of the shock. Currents through the heart or nervous system are most dangerous. If you contact a live wire with your head, your nervous system may be damaged. Contacting a live electrical part with one hand—while you are grounded at the other side of your body—will cause electrical current to pass across your chest, possibly injuring your heart and lungs.[1] For additional information on electrical safety, see the NIOSH publication *Electrical Safety – Safety and Health for Electrical Trades Student Manual* [DHHS/NIOSH Publication Number 2009-113] available by contacting 1-800-CDC-INFO (1-800-232-4636) and the NIOSH Electrical Safety topic webpage http://www.cdc.gov/niosh/topics/electrical/ .

Figure 1 describes a scenario where electrical current can enter a fire fighter's body causing shock if the fire fighter is too close to a downed power line. When electrical current flows into the ground, it establishes an electrical field around the point where the current enters the ground. This electrical field is known as the ground gradient. The electrical field dissipates (gets weaker) rapidly as the distance from the point of entry with the ground increases. Therefore, there is a difference in the potential voltages at any two points within the gradient. This potential difference is known as "step potential." The difference in potential between the points where the fire fighter's feet make contact with the ground can cause electrical current to flow through the fire fighter's body. Step potential can be reduced or eliminated by wearing the appropriate non-conductive footwear, keeping the feet together or shuffling the feet in small sliding motions. The presence of water or moist damp conditions can increase the size of the ground gradient.

There are a number of steps that fire fighters can take to protect their safety and health when exposed to electrical hazards:

- Treat all downed power lines as if they are energized, even if no sparking, arcing or jumping of the power line is observed.
- Keep a safe distance from downed power lines – at least a minimum of 10 feet and if possible keep back at least the distance of the span between two power poles or power line supports.
- Wear the appropriate personal protective clothing and footwear rated for electrical work.
- Do not attempt to move or cut downed wires. Contact the local electrical utility provider for assistance. Only electric utility employees have the training and equipment needed to safely handle power lines.
- Avoid walking or standing in pooled water when downed power lines are present.
- If you notice tingling or the sensation of electrical shock in your feet, move away slowly in a shuffling motion, keeping both feet in contact with the ground at all times to avoid the hazard of "Step Potential". This is important because electric current will radiate out from the area like ripples in a pool of water. Anyone who stands or walks through the area is in danger of being seriously injured or electrocuted, and the risk is even greater when you take large steps, because your feet may be in two different voltage zones, providing another path through which current can flow through your body.
- When fighting fires near downed power lines, do not use straight stream nozzles. Never apply water directly to electrical equipment that is burning or arcing. Since water is a good conductor of electricity, the current may flow back through hose stream to the nozzle and cause a serious injury. Use a high pressure fog nozzle to break up water stream and prevent electrical current from flowing through the hose stream.

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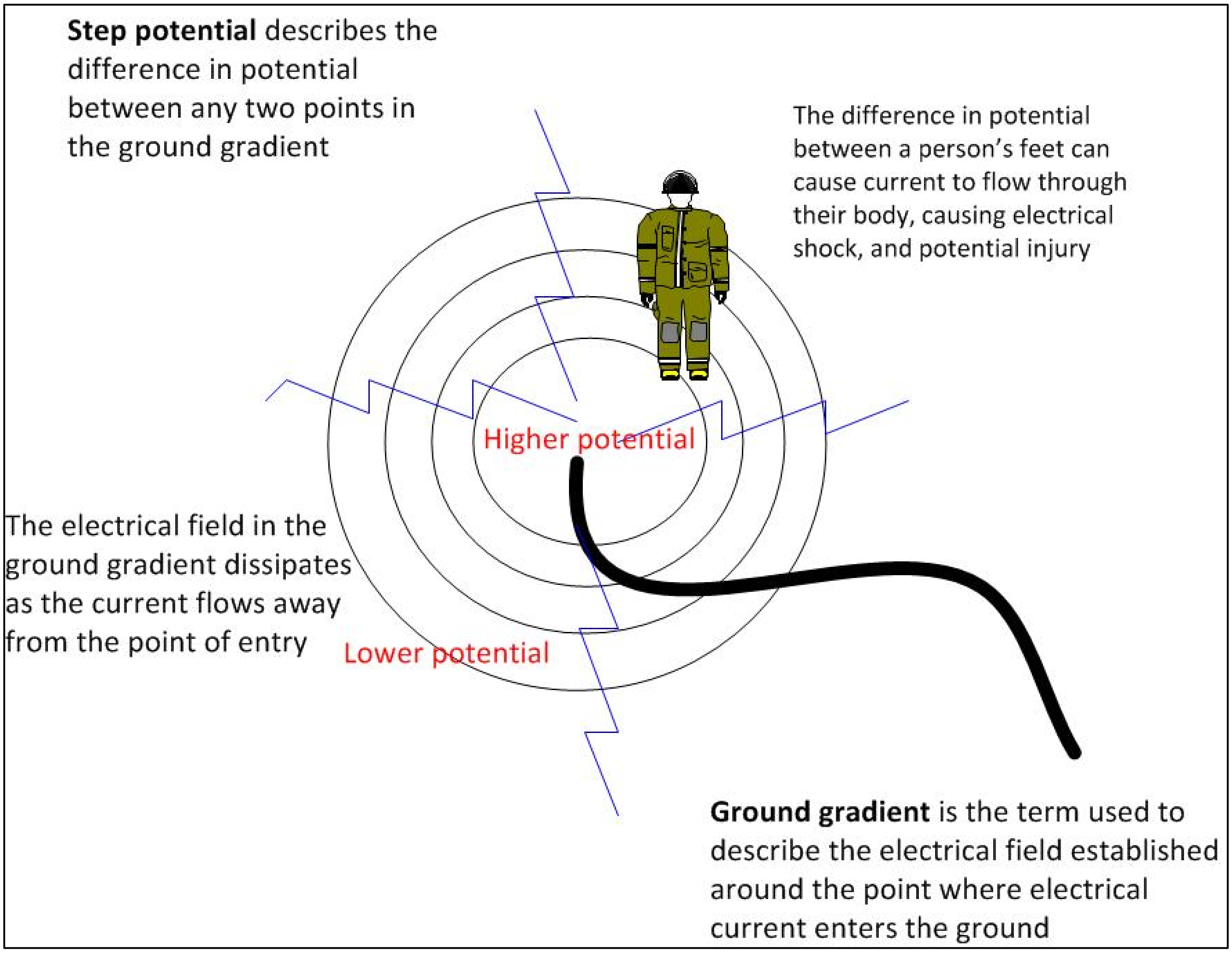


**Figure 1**
**The electrical field established around a downed power line. The electrical field is stronger and the ground gradient higher near the point the electrical current enters the ground.**

# Timeline

The timeline for this incident is limited to the initial response of units to a reported vehicle fire with downed power lines on June 13, 2013. The times are approximate and were obtained from review of the dispatch audio and event records, witness interviews, and other available information. In some cases the times may be rounded to the nearest minute, and some events may not have been included. The timeline is not intended, nor should it be used, as a formal record of events.

- **1508.53 Hours**
  911 call reporting a vehicle fire due to downed power lines.

- **1510.49 Hours**
  Local volunteer fire department dispatched to vehicle fire with downed power lines.

- **1515 Hours (approximate)**
  Engine 3101 enroute (Assistant Chief and fire fighter 1)

- **1518 Hours (approximate)**
  Tanker 3107 enroute (fire fighter 2)

- **1520 Hours (approximate)**
  Assistant Chief upgrades dispatch to include structure fire

- **1524.28 Hours**
  Fire fighter 2 radios “fire fighter down” and requests ambulance.

- **1529.41 Hours**
  Ambulance on-scene.

- **1549.49 Hours**
  Victim transported.

- **1600.06 Hours**
  Victim at hospital.

## Personal Protective Equipment

At the time of the incident, the victim was wearing blue jeans, a tee shirt and lightweight boots similar to station duty boots (see Photo 5 and Photo 6). The victim was carrying a portable radio which was found on the ground after the victim was transported to the hospital. The fire department had a standard operating procedure for vehicle fires stating that before entering the danger zone, all fire department personnel shall have complete protection in the form of turnout pants, boots, properly closed coat, helmet, hood, gloves and SCBA. It was reported that the victim’s fire fighting turnout clothing was found in his personally-owned-vehicle (POV) after the incident. The right boot was examined by the NIOSH Investigators at the County Fire Marshal’s office. The left boot was not available for examination. Small burn marks were noted near the toe of the right boot (see Photo 7 and Photo 8). There was no evidence the boots were rated for electrical work.

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**Photo 5 (left) and Photo 6 (right). Photos show right boot worn by victim at time of incident. Note mud on boot, indicating boot was worn in a wet, muddy area**
***(NIOSH photos.)***

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**Photo 7 (left) and Photo 8 (right – enlarged). Right boot worn by victim. Note hole near toe – probable exit hole where current exited body. This area of boot corresponds with burn injuries identified in coroner's report.**
***(NIOSH photos.)***

## Weather Conditions

High winds with light rain and thunder passed through the area just prior to the incident. Wind speeds were measured from 17.3 miles per hour (mph) to 21.9 mph. At approximately 1515 hours, a wind gust of 49.5 mph from the north/north-west was reported .[2] Humidity was approximately 50 percent and barometric pressure was approximately 29.8 inches. The temperature was approximately 60.8°F. The incident occurred on a gravel and dirt driveway approximately 30 feet wide that sloped downhill. Emergency responders reported the driveway was soaked with rain at the time of the incident. The weather and rain-soaked ground were considered contributing factors in this incident.

## Investigation

On June 13, 2013, a 36-year-old male volunteer fire fighter (the victim) died after being electrocuted as he investigated the source of a small structure fire. Wind from a storm passing through the area blew part of a maple tree across 7200 volt alternating current electrical service lines. An energized power line fell, contacting a parked automobile below the tree. The power line arced when it contacted the vehicle, causing the automobile to catch fire. The downed power line also came in contact with a small metal storage building located behind an automotive repair garage.

At approximately, 1508 hours, the county 911 dispatch center received a report of an automobile fire caused by a downed power line. The local volunteer fire department was dispatched at approximately 1510 hours. The county 911 dispatch center received multiple reports of downed power lines in the area following the storm but the fire department involved in this incident was not dispatched on any other calls. A civilian county resident also died as the result of a falling tree and downed power lines at a nearby location.

Fire fighters responding to Station 1 found that all electrical power in the immediate area was off. The fire fighters had to manually open the bay doors in order to respond. At approximately 1515 hours, an assistant fire chief and a fire fighter responded on Engine 3101. They responded to the incident scene, just a few miles away, traveling north and turning onto a narrow gravel street that sloped steeply downhill just south of the automotive repair garage. They observed a car on fire with downed power lines in contact with the car. They observed blue-colored electrical arcs coming from the power line so they did not approach the burning vehicle. As they were sizing up the scene from inside the engine cab, bystanders began to yell out that a nearby structure was on fire. The fire fighter (fire fighter 1) exited the engine and went to investigate the location of the structure fire. He walked uphill, following the street and then walked past the front of the repair garage to where he could see smoke and fire coming from underneath the metal storage building. He walked back to report his observations to the assistant chief. At approximately 15:20 hours, the assistant chief radioed dispatch to upgrade the incident to include a structure fire and then turned the engine around.

The victim responded to the incident scene in his personally-owned vehicle (POV) driving south. As he approached the incident scene, a civilian who lived nearby flagged him down and reported that a structure was on fire. The victim, dressed in street clothes (blue jeans, shirt and lightweight duty boots) exited his vehicle and went to investigate the location of the structure fire. He did not check in with incident command. He followed a gravel driveway downhill past the repair garage. A bystander reported that the victim approached the metal building and knelt down to look under the building. The bystander reported that after kneeling down, the fire fighter fell over onto the ground. The bystander did not see the victim touch or make contact with the building. It was reported that the surrounding area was soaked with rainwater and runoff was flowing down the driveway at the time of the incident. It was also reported that the force of the electrical current dislodged the victim's left boot, which was picked up after he was transported.

At approximately 1518 hours, a fire fighter (fire fighter 2) left Station 1 driving Tanker 3107. Arriving on-scene, he observed Engine 3101 staged in the street below the automotive repair garage. He also observed a civilian frantically trying to get his attention so he drove past the garage and parked in a narrow gravel driveway. He observed someone lying on the ground near a metal storage building that had smoke coming from under the building. Fire fighter 2 went to investigate and quickly observed that the person lying on the ground was a member of the fire department. The victim was lying on his right side in close proximity to the metal building but not in contact with it. The victim's left shoe was off and lying on the ground nearby. Fire fighter 2 attempted to check the victim's carotid pulse and felt an electrical shock when he touched the victim's neck. At approximately 1524 hours, fire fighter 2 quickly radioed dispatch for an ambulance, reporting that a fire fighter was down, and then began to administer medical attention.

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Fire fighter 1 was walking back to Engine 3101 when he saw Tanker 3107 arrive on-scene and drive past the repair garage. Moments later, he heard fire fighter 2 radio that a fire fighter was down, so he quickly ran back past the garage in the direction of Tanker 3107. He arrived at the location of the metal storage building and observed Fire fighter 2 attending to the victim. Fire Fighter 2 yelled for Fire fighter 1 to get an automated external defibrillator (AED) from Engine 3101. Fire fighter 1 quickly ran back to Engine 3101 and retrieved an AED. The assistant chief heard fire fighter 2 radio dispatch that a fire fighter was down so he walked up the hill to find the other fire fighters. Fire fighter 2 and the garage owner, who had come to investigate and was standing nearby, pulled the victim across the gravel driveway for a distance of approximately 30 feet away from the metal building. Fire fighter 2 began to aid the victim. A third fire fighter (fire fighter 3) arrived in his POV and assisted fire fighter 2 in performing CPR. Both fire fighter 2 and 3 reported feeling electrical shocks while performing CPR on the victim. When Fire fighter 1 arrived with the AED, it was quickly connected to the victim. The AED display indicated "*Advise no shock*." A 60 hertz interference message was also displayed. The three fire fighters continued to perform CPR for approximately 20 minutes until an ambulance arrived. Additional fire fighters continued to arrive on-scene including the Fire Chief. The victim was transported to the local regional medical center where he was pronounced dead. NIOSH investigators contacted the local electrical utility company but were unable to confirm the voltage in the service line at the time of the incident.

## 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 injury or fatality. NIOSH investigators identified the following items as key contributing factors in this incident that ultimately led to the fatalities:

- Energized power line in contact with metal building
- Pooling water and runoff from recent rain storm
- Victim not wearing any personal protective clothing or non-conductive boots
- Lack of situational awareness
- Unrecognized electrical hazards – especially on ground gradients and step potential hazards
- No other first responders in the immediate area at the time of the incident.

## Cause of Death

According to the official autopsy report, the medical examiner listed the victim's cause of death as due to high voltage electrocution.

## Recommendations

***Recommendation #1: Fire departments should ensure that fire fighters are trained to recognize electrical shock hazards.***

Discussion: According to the *Essentials of Fire Fighting and Fire Department Operations*, fire fighters should be familiar with electrical transmission systems and their hazards to avoid injuries to themselves and to protect electrical equipment. While electrocution is usually associated with high-voltage equipment, conventional residential current is sufficient to deliver a fatal shock.[3] The factors that affect the seriousness of electrical shock include the following:

- Path of electricity through the body
- Degree of skin resistance (wet skin = low resistance; dry skin = high resistance)
- Length of exposure
- Available current – amperage flow
- Available voltage – electromotive force
- Frequency – alternating current (AC) or direct current (DC).[3]

Electrical shock can lead to the following:

- Cardiac arrest
- Ventricular fibrillation
- Respiratory arrest
- Involuntary muscle contractions
- Paralysis
- Surface or internal burns
- Damage to joints
- Ultraviolet arc burns to the eyes.

The integrity of electrical systems is based on their being properly grounded, insulated, and circuit-protected. Fire fighters need to be aware of the basic concepts of electricity and electrical system integrity in order to protect lives and stop potential losses. A disruption of any of the components of an electrical system can pose a danger to fire fighters and to civilians in need of rescue. The best way to learn about electrical hazards is to contact your local power company. Many power companies provide seminars and workshop training for the local fire departments in their areas.[4-6]

Electricity is always trying to seek the path of least resistance to ground. Incidents involving electrical transmission equipment and downed power lines are especially dangerous to fire fighters. In these cases, electricity may be seeking ground through vehicles, fences, and other conductors. A victim in an energized vehicle is like a bird sitting on an overhead power line. As long as the bird (or the victim) does not contact the ground, no electrocution can take place. Anything or anyone who touches the vehicle and the ground at the same time creates a path for the electricity to seek ground and risk electrocution. Fire fighters attempting to approach downed power lines or compromised electrical equipment may feel a tingling sensation in their feet, legs or body. This is a danger sign known as ground gradient. Ground gradient is electrical energy that has established a path to ground through the earth and is energizing the earth around the point where the electrical current enters the earth. A downed power line can energize the ground in concentric rings of decreasing energy of up to 30 feet or more, depending upon the voltage of the electrical source and environmental conditions such as rain or snow. A fire fighter who feels a tingling in their boots must back away in a shuffling motion keeping both feet in contact with the ground at all times. In some cases, the electrical system can still be intact and pose a hazard to fire fighters, particularly when aerial apparatus and aluminum ground ladders are used near energized power lines and electrical equipment. Although it rarely happens, electricity can "jump" conductors, if a conductor comes close to the exposed wire or power connection.[4] Fire departments should train all fire fighters on the potential hazards associated with ground gradients and step potentials.

Fire fighters working at structure fires, motor vehicle accidents, wildland fire operations and any emergency where contact with electrical energy is a possibility need to be aware of the following electrical shock hazards:

- Electrical current can flow through the ground and extend outward for several feet, depending upon the conditions (i.e. ground gradient)
- Contact with downed power lines that are still energized – treat all downed power lines as energized
- Overhead power lines that fall onto and energize conductive equipment and materials located on the ground
- Smoke that becomes electrically charged and conducts electrical current
- Solid stream water applications on or around energized power lines or equipment.[4]

See page 6, "Electrical Shock Hazards" for additional information on the effects of electrical current on the human body.

In this incident, the victim approached the metal storage building to investigate the source of smoke and flames coming from underneath the building. The victim may not have been aware of the downed power line in contact with the roof of the metal building. An eye witness reported that the victim knelt down as if to look under the building but did not appear to touch the building when he suddenly fell to the ground. He was found lying approximately three feet from the front of the building when other fire fighters came to render aid. The first fire fighter to reach the victim reported that he felt an electrical shock when he touched the victim's neck to check for a carotid pulse. Rescuers dragged the victim approximately 30 feet away from the building and began to administer cardio-pulmonary resuscitation (CPR). The fire fighters administering CPR reported feeling electrical shocks as they attended to the victim. Rescuers need to protect themselves whenever the risk of additional injuries is present by moving farther away and making sure clothing and personal protective equipment is rated for electrical work. While rescuers took measures by moving the victim some distance from the electrical source, (in this case over 30 feet) fire fighters reported continuing to feel electrical shock during their resuscitation efforts, which indicated the potential for additional injuries was still present.

The autopsy report noted burn injuries on both of the victim's feet and the left forearm that likely marked the flow path of the electrical current. The victim was dressed in street clothes, lightweight boots, and the ground was reported to be saturated from the recent heavy rainstorm.

***Recommendation #2: Fire departments should ensure that fire fighters wear the appropriate personal protective clothing and equipment.***

Discussion: Fire departments should ensure that fire department personnel should wear the appropriate clothing that is referenced in the fire departments SOG's and if relevant, required by state laws. Additionally, the fire department should provide each member with the appropriate protective clothing and protective equipment to provide protection from the hazards to which the member is or is likely to be exposed. Such protective clothing and protective equipment shall be suitable for the tasks that the member is expected to perform.[7] The National Fire Protection Association (NFPA) 1971 *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting* (2013 Edition), Chapter 7.10.10 states that fire fighter footwear shall be tested for resistance to electricity as specified in Section 8.31, Electrical Insulation Test 2, and shall have no current leakage in excess of 3.0 milli-amps (mA).[8] Note that NFPA 8.31 Electrical Insulation Test 2 is conducted in accordance with Section 9 of the ASTM F2412 Standard Test Method for Foot Protection.[9]

Footwear meeting the NFPA and ANSI test criteria will be labeled accordingly. Footwear will be marked "**EH**" if approved for electrical work. The ANSI approval stamp alone does not necessarily mean the footwear offers protection from electrical hazards. Note that footwear made of leather must be kept dry to protect you from electrical hazards, even if marked "**EH**"[1]

In this incident, the victim was wearing street clothes and lightweight boots that were not rated for electrical work. The ground was reported to be saturated with rainwater at the time of the incident. It was reported that the victim's structural fire fighting personal protective clothing and equipment were found in his personal vehicle after the incident. The use of the appropriate personal protective clothing and footwear may have provided better protection to the victim, possibly resulting in a different outcome.

***Recommendation #3: Fire departments should ensure that all fire fighters are trained in and recognize the importance of situational awareness.***

Discussion: The book *Essentials of Fire Fighting and Fire Department Operations* defines situational awareness as an awareness of the immediate surroundings.[3] On the fireground, every fire fighter should be trained to be constantly alert for changing and unsafe conditions. This applies not only to the conditions found within a burning structure, but to the exterior fireground as well. Fire fighters may encounter a wide variety of surface features that they must walk across while performing fireground tasks. For example, surfaces may be wet, slippery, ice-covered, uneven, and may be vegetation-covered or include debris from the burning structure. Downed power lines, broken or leaking natural gas meters and distribution lines, unstable structures and other environmental factors are just some of the hazards that may be present of the fireground.

In this incident, the victim arrived on scene, was flagged down by a civilian who told him that a building was on fire, and immediately went to investigate the source of smoke and fire emitting from underneath a small metal storage building. He did not check in with incident command. It is unknown whether the victim was aware of the downed power line. It was reported by bystanders that the victim did not appear to touch the storage building prior to falling to the ground.

***Recommendation #4: Fire departments should establish, implement and enforce standard operating procedures / guidelines (SOPs / SOGs) that address the communication and acknowledgement of urgent or priority safety messages for hazardous situations that present an imminent threat to the safety of fire fighters.***

Discussion: Communication is one of the most important safety behaviors on every emergency scene. At times it may be necessary to broadcast urgent or priority safety messages over the radio. Fire departments should develop and enforce procedures and guidelines that address the efficient and effective communication of hazardous situations to everyone at the emergency scene. One example of such a procedure is that when an emergency communication is necessary, the person transmitting the message should make the urgency clear to the dispatch center. Dispatch should give an attention tone if one is available within the system, advise all other units to stand by, and tell the caller to proceed with the emergency message. An emergency message that broadcasts details of a safety hazard should be repeated several times. After the communication is complete, the dispatch center should notify all units to resume normal radio communication.[3]

All safety hazards should be communicated to everyone on the incident scene as soon as they are discovered. This communication should include confirmation with an acknowledgement that the recipients have received and understand the communication. During this incident, the first arriving crew observed a vehicle on fire and blue-colored electrical arcs coming from the downed power line in contact with the vehicle. The crew made the determination to size up the scene from a distance and stayed inside the apparatus cab until bystanders began yelling that a structure was on fire. The incident scene was spread across a large area on a sloping hillside that included several structures, a number of parked vehicles, trees and other obstacles that restricted visibility. The incident scene included two extremely hazardous areas – the burning vehicle in contact with an arcing downed power line and the downed power line in contact with the metal storage building that ignited the wooden support members under the building. A hazard communication in the form of a priority or urgent radio message broadcast over the fireground channel might have been enough to warn all emergency responders that electrical wires were down and extreme caution was needed.

***Recommendation #5: Fire departments should establish, implement and enforce standard operating procedures / guidelines (SOPs / SOGs) that address fire fighters responding to emergencies in their personally-own vehicle (POV) that include reporting to the incident commander, wearing the appropriate personal protective equipment (PPE) and adhering to the established accountability system .***

Discussion: Fire fighters are often required to respond to emergency scenes in their personally-owned vehicle (POV) or other than first line apparatus. This is especially true in the volunteer fire service where responders frequently respond from home, work and other locations instead of from the fire station. Fire departments should ensure that all fire fighters follow established procedures and guidelines for responding to an incident scene when not responding as part of a crew on a fire department vehicle. The first thing the fire fighter should do upon arriving on-scene is to report to the incident commander for assignment. The incident commander is responsible for the overall operation of the emergency response, including the safety and accountability of all fire fighting personnel at the scene. Reporting to the incident commander for an assignment reduces the likelihood of freelancing and helps to ensure the incident commander maintains accountability. Many fire departments allow fire fighters to carry their turnout gear in their POVs. Reporting to the incident commander with full turnout gear helps ensure the fire fighter is immediately ready to carry out an assignment and can do so in a safe manner. In this incident, the victim arrived on-scene in his personally-owned vehicle. The victim was immediately flagged down by a civilian who urgently stated that a structure was on fire. The victim immediately went to investigate without reporting to command or donning his turnout gear. It is unknown how much the victim was able to size-up the immediate area or whether he was aware of the downed power line. A bystander reported that the victim approached the metal building and knelt down to look underneath the building. The bystander did not see the victim touch or make contact with the building. In this incident, reporting to incident command for an assignment may have resulted in a different outcome. The incident commander was unaware that the victim was on-scene until fire fighter 2 radioed that a fire fighter was down.

***Recommendation #6: Fire departments and authorities having jurisdiction should consider dispatching an ambulance to all confirmed working fires and other emergency incidents.***

Discussion: During this incident, an ambulance was called to the scene after fire fighters realized that a fire fighter was down. Having an ambulance dispatched and available at an emergency incident provides additional resources on-hand in the event that medical attention is needed. The first fire fighter to observe the victim lying on the ground radioed dispatch for an ambulance. Fire fighters performed cardio-pulmonary resuscitation (CPR) on the victim for approximately 20 minutes until an ambulance arrived. Dispatching emergency medical services personal to all confirmed working fires and emergency incidents represents a good safety and health practice.

## References

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3. IFSTA [2008]. Essentials of Fire Fighting and Fire Department Operations, 5th Edition. International Fire Service Training Association. Fire Protection Publications; Oklahoma State University, Stillwater Oklahoma.

4. Dodson David W. [2007]. Fire Department Incident Safety Officer, 2nd Edition. Thomson Delmar Learning. Clifton Park, NY.

5. Duke Energy [2013]. Contractors & First Responders Safety. Duke Energy website. http://www.duke-energy.com/safety/contractors-and-first-responders.asp. Date accessed: July 23, 2013.

6. Duke Energy [2013]. First Responder Beware: Electrical and Natural Gas Safety webpage. http://www.dukesafety.com/firstresponders/. Date accessed: July 23, 2013.

7. NFPA [2013]. NFPA 1500 *Standard on fire department occupational safety and health program*. 2013 ed. Quincy, MA: National Fire Protection Association.

8. NFPA [2013]. NFPA 1971 *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*. 2013 ed. Quincy, MA: National Fire Protection Association.

9. ASTM [2011]. ASTM 2412 *Standard Test Method for Foot Protection, Section 9*. Conshohocken, PA. ASTM International.

## Investigator Information

This incident was investigated by Timothy Merinar, Safety Engineer, and Matt Bowyer, General Engineer, with the Fire Fighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, WV. An expert technical review was provided by David Dodson, Response Solutions, LLC. A technical review was also provided by the National Fire Protection Association, Public Fire Protection Division.

***Volunteer Fire Fighter Electrocuted by Downed Power Line Following Severe Weather – North Carolina***

## Additional Information

Many power companies provide training and safety information and materials to fire departments and emergency responders in their local areas. Fire departments should contact the power company in their immediate area for additional information. The following websites contain examples of the types of training and safety information available to first responders. *Note that the following list contains examples and is not a complete list of the safety and health information available to emergency responders concerning electrical safety hazards through a simple internet web search*:

http://www.dukesafety.com/firstresponders/

https://www.firstenergycorp.com/content/fecorp/newsroom/news_releases/jcp-l-holds-new-emergency-responder-electrical-safety-training-.html

http://www.we-energies.com/firstresponders/cart/firstresponder_042710.pdf

http://www.alliantenergy.com/SafetyAndReliability/GasSafety/EmergencyResponders/index.htm

http://www.tkolb.net/tra_sch/Gas_Elec_PECOBook.pdf

The National Fallen Firefighters Foundation (NFFF) sponsors the Everyone Goes Home® program intended to prevent firefighter line of duty deaths and injuries. Part of the mission of the Everyone Goes Home® Firefighter Life Safety Initiatives Program is to provide the resources necessary to enable fire departments to implement the 16 Firefighter Life Safety Initiatives. The implementation of the initiatives is essential to elimination of preventable line-of-duty injuries and deaths. As part of this effort, the NFFF has developed a number of safety training videos based upon the NFFF 16 Life Safety Initiatives (http://www.lifesafetyinitiatives.com/ ). A video titled *Electrical Safety - Keeping Our First Responders Safe* can be found at:

http://www.everyonegoeshome.com/kits/volume3/7/

The following NIOSH Fire Fighter Fatality Investigation and Prevention Program reports contain information on shock and electrocution hazards encountered by fire fighters:

Career Fire Captain Electrocuted After Contacting Overhead Powerline From the Platform of an Elevating Platform Fire Apparatus – Pennsylvania
http://www.cdc.gov/niosh/fire/reports/face200801.html

Career Captain Electrocuted at the Scene of a Residential Structure Fire - California
http://www.cdc.gov/niosh/fire/reports/face200507.html

Volunteer Fire Fighter Dies After Coming into Contact With a Downed Power Line - Arkansas
http://www.cdc.gov/niosh/fire/reports/face9946.html

Downed Power Line Claims the Life of One Volunteer Fire Fighter and Critically Injures Two Fellow Fire Fighters - Missouri
http://www.cdc.gov/niosh/fire/reports/face9937.html

Electrical Panel Explosion Claims the Life of a Career Assistant Fire Chief, an Electrician, and Seriously Injures an Assistant Building Engineer–Illinois
http://www.cdc.gov/niosh/fire/reports/face9928.html

Volunteer Fire Fighter Electrocuted While Fighting a Grass Fire - California
http://www.cdc.gov/niosh/fire/reports/face9926.html

The Occupational Safety and Health Administration (OSHA) has developed guidelines for helping employers develop action plans to address emergency incidents. These guidelines are intended to help employers, workers, and businesses develop a well-thought out emergency action plan to serve as a guide when immediate action is necessary. This publication can be found at:

https://www.osha.gov/Publications/osha3088.pdf

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