Electrical Safety Information

6 August 2007 Everett A. Lipman

1 Electrical Hazards

Your body is somewhat conductive, with resistance varying depending on the points across which you measure and how well electrical contact is made. From arm to arm or arm to leg, R is between about 1 kΩ and 4 MΩ depending on whether your skin is wet or dry, contact area, etc. If your skin is punctured, R can be as low as 100 Ω.
Current thresholds (all are approximate, high frequency is different):

- 1 mA — threshold of perception
- 5 mA — noticeable shock, involuntary movement
- 6–30 mA — GFCI (see below) opens circuit within $< 200\ I_t/I$ ms
- 10 mA — pain, loss of muscular control, may not be able to let go
- 30 mA — possible ventricular fibrillation
- 50 mA — probable ventricular fibrillation
- 100 mA — respiratory arrest, fibrillation, death becoming likely
- 1 A — nerve damage, burns, death likely
- 15 A — circuit breaker opens circuit

Example: US Navy 9 V battery death

Types of Electrical Hazard:

- Shock-induced ventricular fibrillation
- Respiratory arrest
- Nerve damage
- Shock-induced mechanical injury
- Burns

- Arc flash
- Arc ignition

Causes of Electrical Hazards:

- Arc conduction: ≈ 1000 V/mm
- Unintended contact (examples: drilling, downed power lines)
- Capacitive discharge
- Inductive current interruption
- Defeated interlock
- Low-V, High-I heating (example: burns from watch band)

2 What comes out of the wall?

- 120 VAC RMS, 170 V amplitude, 340 V p-p
- Most outlets rated for 15 A (14 AWG), some for 20 A (12 AWG)
- 240 VAC RMS split phase
- Much of the rest of the world is on 240 V
- Three phase
- NEMA 5-15 plug/socket — left eye (small) live
- Wire color codes:
  - black: live (think funeral)
  - green: ground
  - white: neutral
  - gray: neutral
  - red: live (split single phase, three phase)
  - blue: live (three phase)
  - brown, orange, yellow: live (alternative three phase)
- European color codes:
  - brown: live

  - green/yellow stripe: ground
  - blue: neutral
- **Never bet your safety on color codes!**

3 Safety Measures

- Case grounding
- Double insulation (no single-failure shock hazard, usually labeled)
- Residual current devices (GFCI)
- Hand in pocket

4 Demonstration Equipment

- Clamp meter
- Transparent clamp meter cord
- Power supply
- 2.2 Ω, 25 W resistor
- Appliance with polarized plug
- Outlet tester
- Power entry module
- Strain relief

5 Further Reading

- `http://www.cdc.gov/Niosh/injury/traumaelface.html`
- `http://www.cdc.gov/Niosh/face/stateface/ne/03ne022.html`
- `http://www.hanford.gov/rl/?page=508`

Remain conscious of electrical hazards, and never work with dangerous electricity when you are tired!

November 17, 2003
Investigation: # 03NE022

Farmer Electrocuted Exiting Grain Bin

SUMMARY

A 43-year-old farmer was killed when he was electrocuted while exiting a metal grain bin. The victim had been scooping shelled corn into a portable electric auger, which moved the corn outside to another auger powered by a power-take-off (PTO) shaft from a tractor, dumping it into a grain truck. A loose wire inside the portable auger's electric motor caused the metal auger housing which laid across the bin's access door frame to become energized. When the victim grabbed hold of the frame and stepped backward out of the bin, his foot made contact with the ground, creating a completed circuit, causing the electrocution. The victim was pronounced dead at the scene.

The Nebraska Workforce Development, Department of Labor's Investigator concluded that to help prevent future similar occurrences, farmers should:

- **Ensure all electrical wiring and fixtures, both permanent and temporary are in good repair.**
- **Ensure that all electrical wiring and fixtures (outlets, extension cords, pull boxes) are of the type best suited for the environment in which they will be used.**
- **Ensure that adequate means of grounding are provided for all structures and equipment.**
- **Consider installing either permanent or portable Ground Fault Circuit Interrupters (GFCIs).**

PROGRAM OBJECTIVE

The goal of the Fatality Assessment and Control Evaluation (FACE) workplace investigation is to prevent future work-related deaths or injuries, by a study of the working environment, the worker, the task the worker was performing, the tools the worker was using, and the role of management in controlling how these factors interact.

This report is generated and distributed **solely** for the purpose of providing current, relevant

education to employers, their employees and the community on methods to prevent occupational fatalities and injuries.

INTRODUCTION

On July 7, 2003, at approximately 3:00 p.m., a 43-year-old farmer died after he was electrocuted while exiting a metal grain bin. The Nebraska Department of Labor was notified of the fatality the next day by the local news media. The Nebraska FACE Investigator met with the investigating County law enforcement officials on July 9, 2003, and reviewed photographs taken at the site. A meeting with the victim's wife, father and investigating officers was conducted July 22, 2003 along with a site visit at the mishap location.

INVESTIGATION

Victim: The victim was a 43-year-old male in apparent good health. He was a self-employed farmer, raising hogs, cattle and row crops. There were no other employees. He had been farming his entire life and had lived at the incident site since he was approximately 7 years old. The victim was alone at the time of the accident.

Training: Unknown.

Equipment: The exact age and brand of the portable electric auger could not be determined. The victim's spouse stated that it had been in use on the farm for at least 15 years, and had received a new motor during that period. The incident bin and another alongside (capacities unknown) were built approximately 35 years ago. Entrance was gained through a square service door located approximately 3 feet above ground level.

Electrical Power Source: Power for the auger (110 volts) originated from a power pole (see picture # 1) located near the house. This pole and pull box were installed during the late 1940s. Knockout plug holes had not been covered, allowing birds to build inside the box (see picture #2).

The wiring runs approximately 88 feet underground through metal conduit to another pull box located between the two grain bins (see pictures #3 & 8). This box contained a 30 amp screw-in type fuse (see picture #3). A duplex metal outlet box had been attached to the bottom of the pull box. It was wired using the same 10-gauge wiring.

A black flexible electrical cord was then plugged into the outlet box. The male end of this cord was the older two-pronged style with no ground prong (see picture # 4). The female end of the flex cord had another metal duplex outlet box attached (see picture #5).

The portable auger was wired with a flexible two-wire cord (see picture # 6), connected internally to the motor. The male end was the two-pronged older style.

The victim would activate the portable auger by plugging its 2-prong male end into the black flex cord's receptacle box. Nowhere along the entire system from the power pole to the bin were there any grounding methods used, nor were there any ground fault circuit interrupters (GFCIs) installed.

Weather: [1]The temperature at the time of the incident was approximately 90 degrees, with 72 percent humidity, making the outside temperature feel like approximately 106 degrees. The temperatures inside the bin would have been significantly higher. Law enforcement personnel stated that upon their arrival the victim's clothing was completely soaked with perspiration.

ANALYSIS:

The victim started work that morning doing normal chores and was finished by 7:00 a.m. He then ran several errands. After returning home during the morning, he started loading and hauling corn from the incident bin. At approximately 2 p.m. he went into his house, staying inside until approximately 2:30 p.m. He then went back outside and started the tractor and portable auger to finish off the truck's load.

Approximately 30-45 minutes later the victim's 11-year-old daughter went outside and saw the victim lying across the bin opening. She went over and touched the victim, receiving a shock also. She immediately ran inside and told her 13-year-old brother, then dialed 911. The 911 operator notified local rescue personnel, and also the electric company they believed responsible for service at the site.

The victim's son rushed outside and turned off the tractor then unplugged the portable auger. He attempted to remove his father from the bin but was unsuccessful. Local emergency personnel responded within approximately 15 minutes. They understood that the auger had been unplugged and checked the victim for vital signs. Once it was determined the victim was dead they backed away, not knowing if anything else nearby may be energized.

The power company crew arrived on site a few minutes later. When they saw the farmstead they determined that the electrical "service" was not theirs. Rescue personnel met them at the site entrance. The power company personnel stated that if there was an emergency they could disconnect the power to the entire farmstead at the road, but if it was a non-emergency they would rather call the owning agency since their meters and associated equipment were different. Rescue personnel advised them that it was not an emergency situation. There was also concern for the nearby hog barn ventilation systems and the houses air conditioner if total power was cut. The power crew called the owning Power Company, but remained on site

to offer assistance if necessary.

The owning power company personnel arrived within 5 minutes. They shut off the power at the pull box between the bins by pulling down on the handle. The crew leader stated that the 30 amp installed fuse had not blown, thereby allowing continual power to pass to the victim prior to his son unplugging the auger. Rescue personnel removed the victim from the bin.

Several days afterwards the victim's father and brother dismantled the portable auger's electric motor. They stated that there was a bare wire touching the inside case, which had caused the motor to become energized. They repaired the bare wire, and also installed a new flexible cord with the ground wire attached to the motor housing plate (see picture #7). The old pull box between the bins was replaced with a newer breaker style box. A ground wire was run from the new box directly into the ground underneath in an attempt to establish a ground. The servicing electrical company was going to be contacted to inspect the grounding system. The victim's spouse stated that once the bins were emptied, they would be torn down.

Note: The local volunteer rescue squad has now received training from both power companies that offer service in their area of responsibility that includes removing the meters to disrupt power if necessary.

SYNOPSIS

Faulty equipment, non-grounded electrical conductors and a victim soaked in sweat combined to create a scenario that proved deadly. Unfortunately these conditions are all too common in the rural agricultural environment. Proper grounding and/or the installation of GFCIs on all buildings and equipment should prevent this type of accident from happening to others.

CAUSE OF DEATH

According to the death certificate, the cause of death was: Electrocution

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Ensure all electrical wiring and fixtures, both permanent and temporary are in good repair.

Discussion: The pull box located near the house had several of the knock-out plugs missing, which allowed birds to fill it full of nesting materials. If an attempt had been made to shut the

box off at this location, chances are good that the actions would have been blocked due to the extreme amount of materials inside. The pull box located between the bins also had knockouts removed. The duplex box attached to the bottom was missing one of the receptacles and also the cover plate. Both the black flexible extension cord from the pull box, and also the cord hard wired into the electrical auger motor had numerous areas where the external insulation had cracked and been taped over with black electrical tape. Black electrical tape does not have the same insulating properties as the original insulation. There were also areas on the motor wire where the internal insulation surrounding the copper wiring was exposed. The male end of the black extension cord was missing the protective insulation wafer that fits over the two prongs.

Suggestion: Remove equipment from service that has damaged electrical cords, missing ground prongs, and/or missing or cracked insulation.

Recommendation #2: Ensure that all electrical wiring and fixtures (outlets, extension cords, pull boxes) are of the type best suited for the environment in which they will be used.

Discussion: Both cord male ends were the old two-prong style. The black cord's male end was missing the protective insulating wafer. Neither of the duplex outlets attached to the pull-boxes had protective covers. The duplex outlet box attached to the black extension cord was made for indoor use only and should never be used outdoors. Any time a fixture that is intended for inside use is used outside there is a high probability that moisture will enter the fixture through the manufactured cutouts, holes, etc. Fixtures intended for outside use do not have these openings and are made to withstand extreme environments.

Recommendation #3: Ensure that adequate means of grounding are provided for all structures and equipment.

Discussion: At the time of construction, there were no federal, state or local requirements for grounding grain bins or installed electrical service beyond the service entrance. Since the incident, the breaker box between the bins has been grounded by inserting the ground wire into the ground. To check if this is a proper ground, the servicing power company should be contacted to conduct a test to ensure its adequacy.

Recommendation #4: Consider installing either permanent or portable Ground Fault Circuit Interrupters (GFCI).

Discussion: Ground Fault Circuit Interrupters differ from fuses. The idea behind a fuse is to protect a building or item from an electrical fire. If the hot wire were to accidentally touch the

neutral wire for any reason , an incredible amount of current will flow through the circuit and start heating it up The fuse heats up faster than the wire and burns out stopping further flow of energy before the energy flow can start a fire.

A GFCI is much more subtle. When you look at a normal 120-volt outlet in the United States, there are two vertical slots and then a round hole centered below them. The left slot is slightly larger than the right. The left slot is called "neutral," the right slot is called "hot" and the hole below them is called "ground." If the auger motor is working properly, all electricity that it uses will flow from hot to neutral. An outlet with a GFCI is designed to continuously monitor the amount of current flowing from hot to neutral. A GFCI outlet looks slightly different from a regular outlet in that it has a reset button and the vertical slots have a horizontal half-slot. If there is any imbalance (power leaking to a fault), it trips the circuit. It is able to sense a mismatch as small as 4 or 5 milliamps, and it can react as quickly as one-thirtieth of a second. The GFCI can sense the current flowing through a human because not all of the current is flowing from hot to neutral as it expects -- some of it is flowing through a person's body to ground. As soon as the GFCI senses that, it trips the circuit and cuts off the electricity.

REFERENCES

1. National Weather Service, Valley Nebraska office

ATTACHMENTS

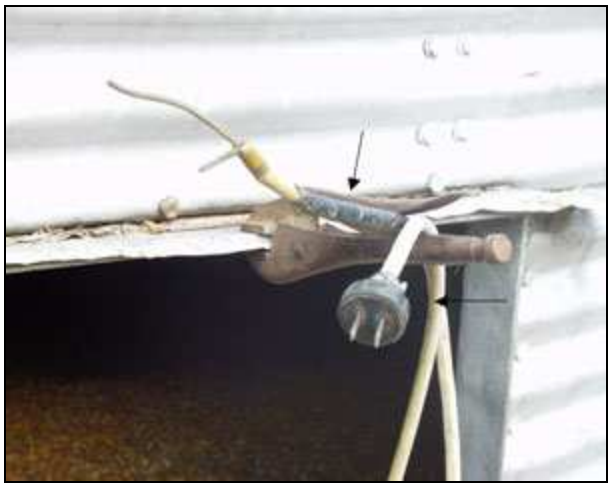
**Picture #1: Pull box with conduit running to
grain bins.**

**Picture #2: Pull box between house and corn
bins with nesting materials.**

**Picture #3: Pull box that was between bins,
removed after incident.**

Picture #4: Black extension cord male end.

Picture #5: Black extension cord female end.



Picture #6: Portable auger motor cord.

Picture #7: Portable auger motor housing opened with new ground wire.

Picture #8: Pull box between bins day of incident with protective covering.

To contact Nebraska State FACE program personnel regarding State-based FACE reports, please use information listed on the Contact Sheet on the NIOSH FACE web site Please contact In-house FACE program personnel regarding In-house FACE reports and to gain assistance when State-FACE program personnel cannot be reached.

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