Operating Experience Summary

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Industry Arc Flash Event Results in Serious Burn Injuries

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On March 4, 2009, at the Jubail Project in Riyadh, Saudi Arabia, three workers were removing a 480-volt, molded-case circuit breaker from the bucket of an energized Motor Control Center (MCC) when an electrical arc flash occurred, severely injuring them. All three sustained first- and second-degree burns and were hospitalized following the accident.

The workers had been asked to obtain information about the breaker and tried to remove it to retrieve the information. They did not have an energized electrical work permit, were wearing no PPE other than their hardhats, and wore no arc-rated clothing. (Figure 1-1 shows their hardhats and the breaker on the floor of the utility room post-event.) The face and neck areas of two workers were badly burned, and one of them sustained burns to his hand (Figure 1-2). The third worker suffered scattered burns to his face (likely from molten debris). Figures 1-3 and 1-4 show the burn areas in the utility room where the MCC was located and the proximity of the MCC bucket to the wall. Figure 1-5 shows the inside of the MCC bucket after the event.

An arc flash can release a tremendous amount of concentrated radiant energy at the point of the arcing in a fraction of a second. The result is extremely high temperatures, a tremendous pressure blast, and shrapnel being hurled at velocities in excess of 700 miles per hour. Exposure to an arc flash frequently results in a variety of serious injuries and in some cases death. Workers have been injured even though they were 10 feet or more away from the arc center. Injuries can include damaged hearing and eyesight, as well as severe burns that can require years of skin grafting and rehabilitation.

Figure 1-1. Breaker and hardhats on the utility room floor post-event

Figure 1-2. Arc flash burn to worker's hand

The workers in Riyadh were fortunate that their injuries were not more serious. They were severely burned primarily because they failed to apply fundamental Integrated Safety Management (ISM) principles to the task. When they realized that the requested breaker information could not be obtained without removing the circuit breaker, they should have stopped and modified the work plan and associated hazard analysis.

The designed controls for the identified hazard should have included, as a first option, the necessary actions to establish an electrically safe work condition before allowing a worker inside the arc flash protection boundary. If removing the hazardous energy was not feasible, an energized electrical work permit that clearly described all barriers, including appropriate PPE, should have been developed and discussed with each of the workers. Many of the recent electrical events in DOE workplaces occurred when workers failed to recognize that the work scope or conditions were not bounded by the original work plan and hazard analysis.

Another important consideration when planning work is to minimize exposure to the extent possible. If the job that resulted in injury to the three Riyadh workers had been planned properly, it could have been done by a single worker while the

Figure 1-3. Utility room post-event

Figure 1-4. Burn on wall adjacent to MCC

Figure 1-5. Inside of MCC bucket after breaker was removed

others remained outside the hazardous zone. Applying As Low As Reasonably Achievable (ALARA) is a principle that applies to electrical hazards as well as to radiological hazards.

An event similar to this industry event occurred at the Stanford Linear Accelerator Center (SLAC) on October 11, 2004, when a subcontractor journeyman electrician received serious burns from an electrical arc flash. In that event, the electrician was installing a circuit breaker in an energized 480-volt electrical panel, also without a work permit, and wore a short-sleeved cotton/polyester shirt, leather gloves over voltage-rated gloves, safety glasses, and a hardhat. The arc flash ignited the electrician's clothing and knocked his safety backup, who was standing 2 or 3 feet behind him, to the floor. DOE conducted a Type A Accident Investigation following the accident. (ORPS Report SC-OAK--SU-SLAC-2004-0010)

Among the key deficiencies identified by the Type A Accident Investigation Board were the following.

- A pre-work hazards analysis form was not completed.
- There was no approved energized electrical work permit.
- The worker did not wear the appropriate flame-resistant (FR) clothing or all required PPE.
- No one in the SLAC management chain had been informed that the field supervisor had decided to install the circuit breaker in an energized panel.

The Board concluded that if proper permitting procedures had been followed, the work would not have been done. They also concluded that the severity of the injuries could have been significantly reduced or eliminated if proper FR clothing and PPE were used. The Type A Accident Investigation Report is available at http://www.hss.energy.gov/csa/csp/aip/accidents/typea/Type_A_Electrical_Arc_SLAC_20041011.pdf.

In two recent events at DOE sites, workers did not heed warnings about the potential for an arc flash and worked on or around arc-flash designated electrical equipment without wearing the appropriate PPE. Fortunately no one was injured in either event.

On March 31, 2009, at Brookhaven National Laboratory, a worker failed to use proper arc-flash precautions and wear appropriate PPE when he placed a lockout/tagout on a 440-volt load center breaker. The breaker had been identified as arc-flash category "Dangerous" and was labeled DANGER, ARC FLASH HAZARD, HAZARD/RISK CATEGORY DANGEROUS, ENERGIZED WORK PROHIBITED. The worker who placed the lockout/tagout did not understand that the label meant that the breaker could not be operated in an energized condition. He assumed that the labeling applied only to opening the cabinet and working on or near exposed conductors. There was no injury or electrical shock from this event, but there was a potential for a serious injury. Investigation is ongoing. (ORPS Report EM--BHSO-BNL-BNL-2009-0004)

On November 14, 2008, at the Savannah River Site, a DOE Facility Representative saw a vendor retrieve an instrument from the low voltage area of an electrical panel and look into the open door of another electrical panel. Both 480-volt panels were arc-flash labeled. The vendor was not wearing appropriate PPE in either case. Investigators determined that the apparent cause of this event was that the vendor misunderstood site requirements (i.e., Safe Practices On or Near Electrical Conductors or Live Parts). He was also confused about the arc flash PPE required when opening the 480-volt panel door to gain access to the 24-volt electrical panel, which is interlocked to the 480-volt panel and which is not arc-flash labeled. (ORPS Report EM-SR--SRNS-SIPS-2008-0004; final report issued January 29, 2009)

Choosing and wearing proper PPE are critical as final barriers in preventing injuries from an electrical arc flash. Arc flash clothing is made from materials that have an Arc Thermal Performance Value (ATPV), which is defined as the amount of heat energy (calories/cm^2) the fabric will absorb or deflect. A heat flux of 1.2 cal/cm^2 is considered to be the amount of heat required to produce the onset of a second-degree burn to unprotected skin. National Fire Protection Association (NFPA) Standard 70E, *Standard for Electrical Safety in the Workplace,* requires PPE used for arc flash protection to be worn inside the boundary where an exposure to 1.2 cal/cm^2 would be experienced should an arc flash occur.

All parts of the body that may be exposed to an arc flash should be covered by the appropriate type and quality of PPE. The following is a list of the PPE and clothing that should be worn when working on energized panels.

- V-rated gloves with leather protectors
- V-rated tools
- Non-melting or untreated natural-fiber T-shirt and underwear
- FR pants and shirt (8 calorie/cm^2) or FR coverall over cotton long-sleeved shirt and pants
- Safety glasses and hearing protection
- Double-layer switching hood (with FR face shield)
- Leather work shoes

OSHA regulations in 29 CFR 1910.333(c)(2), "Work on Energized Equipment," state that "only qualified persons may work on electrical circuit parts or equipment that has not been de-energized" and that they "shall be capable of working safely on energized circuits and shall be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools." (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9910)

With regard to PPE, OSHA requirements state the following.

> **1910.335(a)(1)(i)** — Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected for the work to be performed.
>
> **1910.335(a)(1)(v)** — Employees shall wear PPE for the eyes or face wherever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from electrical explosion. (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9912)

In addition, NFPA 70E-2000, *Electrical Safety Requirements for Employee Workplaces*, provides guidance in determining the severity of potential exposure to arc flash and selecting protective equipment. Equations for calculating incident energy and flash protection boundaries are provided in NFPA 70E and in IEEE 1584-2002, *IEEE Guide for Performing Arc-Flash Hazard Calculations*.

The Center of Excellence for Electrical Safety, which was developed by the Energy Facility Contractors Group (EFCOG) Electrical Safety Task Group through a collaborative effort with DOE and the National Nuclear Security Administration, can provide additional information on electrical arc flash. The website is hosted by Los Alamos National Laboratory and can be accessed at http://www.lanl.gov/safety/electrical/.

These events illustrate the dangers associated with an electrical arc flash. Workers should never perform work on energized electrical equipment without an energized electrical work permit that clearly identifies the hazards and appropriate controls. Wearing the correct PPE can reduce the potential for serious burns, and flame-resistant clothing and required PPE should always be worn if there is any chance that an arc flash could occur. Workers must understand that labels indicating that the danger of an arc flash exists are posted to ensure that appropriate precautions are taken when working on equipment so labeled. Pre-job briefings, facility procedures, and training programs should emphasize the danger of electrical arc flash while working on or near energized equipment.

KEYWORDS: Arc flash, burns, injury, PPE, industry event

ISM CORE FUNCTIONS: Analyze the Hazards, Develop and Implement Hazard Controls, Perform Work within Controls

2 Vehicle Accidents and Fatalities Reinforce the Need for Safe Driving

According to the Bureau of Labor Statistics, *National Census of Fatal Occupational Injuries in 2006*, fatal highway incidents were the most frequent type of fatal work-related events in 2006. Such accidents account for nearly one out of four (25 percent) of all fatal work injuries. (http://www.bls.gov/news.release/archives/cfoi_08092007.pdf)

Seven work-related fatalities have been reported to DOE since 2006, and four of those fatalities (57 percent) resulted from a vehicle accident that involved a DOE or contractor employee. The vehicle fatalities are discussed below.

On July 1, 2008, a Western Area Power Administration employee, who was a passenger in a government vehicle traveling along a county gravel road, was fatally injured. The driver was following a government equipment truck, and gravel dust produced by the lead vehicle obscured the truck from his vision. He hit the left rear end of the truck when it stopped at a stop sign, and the force of the collision caused fatal injuries to the passenger. Figure 2-1 shows the damage to the passenger side of the vehicle. The truck also sustained damage (Figure 2-2). The Type A Accident Investigation Report is available at http://www.hss.energy.gov/csa/csp/aip/accidents/typea/WAPA_July108_Final_Fatal_Rpt.pdf.

On January 22, 2008, at Oak Ridge National Laboratory, a contractor employee driving to an offsite meeting in his personal car hit a patch of black ice and was killed when his car left the road and impacted a tree. Rapidly changing temperatures and light rain contributed to this accident. (ORPS Report SC-ORO--ORNL-X10BOPLANT-2008-0001)

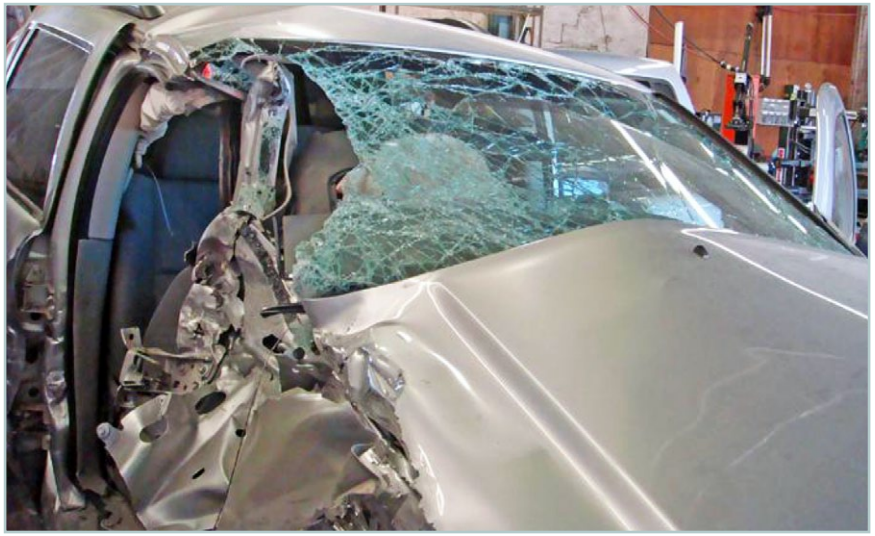

Figure 2-1. Damage to passenger side of vehicle

Figure 2-2. Damage to rear of truck

Another fatality occurred in 2007 and involved a Sandia National Laboratory employee riding a motorcycle. On March 27, 2007, the employee was on his way to the airport for a business trip and was "splitting lanes" (i.e., driving between two lanes of moving traffic) at a slightly faster speed than the traffic in the lanes. Apparently, the motorcycle came in contact with the front tires of a semi-tractor trailer truck in a traffic lane and tipped over. The employee was thrown under the truck, run over by its rear wheels, and killed. The California Highway Patrol investigator concluded that the employee was driving too fast for conditions. (ORPS Report NA--SS-SNL-CASITE-2007-0002; final report issued June 12, 2007)

A Lawrence Livermore National Laboratory (LLNL) employee driving a government-owned pickup truck offsite lost his life on July 24, 2006. Police investigators believe that he fell asleep at the wheel, crossed the center line, and hit an oncoming tractor trailer head on. (ORPS Report NA--LSO-LLNL-LLNL-2006-0035; final report issued November 13, 2006)

In addition to the fatalities, more than a dozen vehicle accidents, both injury and non-injury, have been reported to the ORPS database just in the past year, including the following.

- On March 26, 2009, at LLNL, a truck driver backed out of a delivery dock area and struck a DOE rental car that was passing behind the truck. The truck had traveled only about 2½ feet before hitting the car, breaking the passenger window and mirror, and damaging the passenger door. The truck driver shut off the engine, engaged the parking brake, exited the vehicle, and lent assistance to the occupants of the rental car. There were no injuries either to the truck driver or to the occupants of the car. Investigation is ongoing. (ORPS Report NA--LSO-LLNL-LLNL-2009-0017)
- On November 12, 2008, at the Remote Sensing Laboratory–Andrews, two employees driving a 1-ton truck towing a 20-foot trailer were involved in a single-vehicle accident. They were driving on a public highway when a crosswind blew the truck and trailer over as the truck topped a hill. Both employees had minor injuries and were transported to a local hospital. The trailer had minor damage; the truck was not drivable. (ORPS Report NA--NVSO-NST-RSL-2008-0003)
- On July 31, 2008, at Pantex, a mechanic traveling on a state road on government business dozed off momentarily, then overcorrected when he realized he had veered off the roadway, resulting in a skid and 180 degree rotation. The vehicle skidded into a ditch and hit a power pole. The driver and a passenger were treated for minor injuries at the accident scene. (ORPS Report NA--PS-BWP-PANTEX-2008-0089)
- On July 29, 2008, at the Nevada Test Site, an employee driving a government-issued automobile between work locations looked down to adjust her window and accidentally drove onto the right shoulder of the road. She inadvertently hit the accelerator instead of the brake causing her to overcorrect, and the car fishtailed, crossed the center line, slid onto the opposite shoulder of the road, and flipped over, landing on its roof. The employee was wearing her seatbelt and was able to exit the vehicle through a back side window with only minor scrapes on her elbow, leg, and foot. (ORPS Report NA--NVSO-NST-NTS-2008-0014)
- On July 29, 2008, at Argonne National Laboratory–East, an employee driving to an offsite meeting in a government-issued van applied the brakes but the van did not respond. The driver could not find the emergency brake, so he turned left onto the median to avoid a car stopped for a traffic light.

The rear of the van struck a tree and the front passenger side of the van struck a second tree before the van came to a stop. The employee was not injured. Investigators later found no problem with the braking system and determined that the brakes had been properly inspected and maintained. (ORPS Report SC--ASO-ANLE-ANLEPHY-2008-0001)

There are five common contributors to vehicle accidents: hazardous weather; fatigue; speeding; aggressive driving; and drunk driving. Two of the DOE accidents, including the fatality at Oak Ridge, occurred while driving in hazardous weather conditions (i.e., icy conditions, crosswinds) and the motorcycle accident was also attributed to driving too fast for conditions.

When driving in hazardous conditions, whether it is work-related or personal travel, it is important to take additional safety precautions, including the following.

Driving in Snow/Ice —Do not brake or accelerate hard; instead, use the pedals gently and slowly. Braking hard can cause the tires to lock up and result in a skid. Slow down, increase the distance between other cars, try to take bends without braking to reduce the chance of sliding and losing control, and steer into the skid. Always be cautious when temperatures are low and there is moisture on the road, and be especially careful on bridges where the road surface may be icy, even if nearby roadways are ice free.

Driving in Rain — Like snow, rain can impair visibility, especially on the highway when there is a lot of spray from cars. A good practice in these conditions is to slow down and maintain a safe distance from other vehicles. One particular hazard that comes with driving in the rain is hydroplaning and losing control of the vehicle, so it is important to avoid fast accelerations and braking or sudden steering corrections.

Driving in Wind — High winds are more problematic for drivers of trucks, buses, recreational vehicles, and campers or when towing a trailer. Slow down and steer carefully, especially when moving from a protected area to an unprotected area or when encountering larger vehicles (e.g., tractor-trailer trucks). Wind is often accompanied by heavy rain or winter precipitation, so it is also important to watch for slippery areas.

A number of DOE vehicle accidents were attributed to driving while distracted or drowsy. According to research by the National Highway Traffic Safety Administration (NHTSA), driver inattention (i.e., distractions or drowsiness) is the leading factor in most crashes and near-crashes. Nearly 80 percent of crashes and 65 percent of near-crashes involved some form of driver inattention 3 seconds before the event. An NHTSA analysis that focused on types of driver inattention and the associated risks included the following key findings.

- Drowsiness is a significant problem that increases a driver's risk of a crash or near-crash by at least a factor of four.
- Reaching for a moving object increased the risk of a crash or near-crash by 9 times; looking at an external object by 3.7 times; reading by 3 times; applying makeup by 3 times; dialing a hand-held device (typically a cell phone) by almost 3 times; and talking or listening on a hand-held device by 1.3 times.

The NHTSA study, as well as other information on vehicle safety, including motorcycle safety, can be accessed at http://www.nhtsa.gov/portal/site/nhtsa/menuitem.9fa154a4d39f02e770f6df1020008a0c/.

The National Safety Council (NSC) has also recently completed a study on driver distractions, focusing primarily on the use of cell phones and text messaging while driving. A fact sheet compiled by NSC based on this study is available at http://www.nsc.org/resources/issues/factsheet.aspx.

An Office of Health, Safety and Security (HSS) *Safety Share* issued on January 15, 2009, discusses common accident scenarios and lists driving practices that enhance safety. Some good practices include wearing a seatbelt; avoiding distractions such as using a cell phone, eating, drinking, or adjusting in-car controls; and controlling potential aggressive driving issues by driving at times when highways tend to be less crowded and planning routes before driving. The *Safety Share* is available at http://www.hss.energy.gov/csa/csp/feosh/docs/Safe_Driving_Practices.pdf.

In addition, HSS is currently reviewing vehicle accidents that involve the Department's ProForce and gathering data specifically related to these events. The results of that review will be available upon completion of the study.

Although it is important for drivers to be well prepared to operate a vehicle before traveling on roadways, maintaining a vehicle is also an important element of vehicle safety. Ensuring that brakes are in good working order is clearly essential, but it is also important that items such as headlights, windshield wipers, and power steering are checked on a regular basis and properly maintained. A list of basic system checks and maintenance requirements developed by the American Safety Council is posted online and can be accessed at http://www.safemotorist.com/articles/vehicle_maintenance.aspx.

These events illustrate some of the conditions that can lead to vehicle accidents resulting in serious injuries or even fatalities. It is essential to be aware of hazardous driving conditions and to take appropriate safety precautions. It is also important to stay focused on driving safely and pay attention to the road ahead, avoiding any distractions that may prevent a quick reaction when necessary. Driving when drowsy can result in falling asleep at the wheel and may result in an accident that causes injuries or a fatality. In addition, proper vehicle maintenance is required to ensure that the vehicle is in safe operating condition.

General Safe Driving Tips

- Be cautious at intersections. Intersections can be risky because there are a lot of distractions: turning cars, pedestrians, and red-light runners.
- Keep your eyes on the road. Talking on a cell phone or reading a map can distract you and lead to an accident. Keep in mind that a distracted driver might also be near you. Drive cautiously.
- Be alert near parked cars. Someone could open a car door or pull out in front of you.
- Don't drive while sleep deprived. Sleep is not a matter of willpower, but a biological need. If you become drowsy, pull off the road and get some rest.

— From http://auto.erieinsurance.com/Safety-tips-road.aspx

KEYWORDS: Vehicle accident, fatality, injury, inattention, drowsiness, ice, crosswind

ISM CORE FUNCTIONS: Analyze the Hazards, Perform Work within Controls

The Office of Health, Safety and Security (HSS), Office of Analysis publishes the *Operating Experience Summary* to promote safety throughout the Department of Energy (DOE) complex by encouraging the exchange of lessons-learned information among DOE facilities.

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Commonly Used Acronyms and Initialisms

Agencies/Organizations	
ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
CPSC	Consumer Product Safety Commission
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
INPO	Institute for Nuclear Power Operations
NIOSH	National Institute for Occupational Safety and Health
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration

Units of Measure	
AC	alternating current
DC	direct current
mg	milligram (1/1000th of a gram)
kg	kilogram (1000 grams)
psi (a)(d)(g)	pounds per square inch (absolute) (differential) (gauge)
RAD	Radiation Absorbed Dose
REM	Roentgen Equivalent Man
TWA	Time Weighted Average
v/kv	volt/kilovolt

Job Titles/Positions	
RCT	Radiological Control Technician

Authorization Basis/Documents	
JHA	Job Hazards Analysis
JSA	Job Safety Analysis
NOV	Notice of Violation
SAR	Safety Analysis Report
TSR	Technical Safety Requirement
USQ	Unreviewed Safety Question

Regulations/Acts	
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
D&D	Decontamination and Decommissioning
DD&D	Decontamination, Decommissioning, and Dismantlement
RCRA	Resource Conservation and Recovery Act
TSCA	Toxic Substances Control Act

Miscellaneous	
ALARA	As low as reasonably achievable
HEPA	High Efficiency Particulate Air
HVAC	Heating, Ventilation, and Air Conditioning
ISM	Integrated Safety Management
MSDS	Material Safety Data Sheet
ORPS	Occurrence Reporting and Processing System
PPE	Personal Protective Equipment
QA/QC	Quality Assurance/Quality Control
SME	Subject Matter Expert