Operating Experience Summary

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1 Failure to Wear Proper Personal Protective Equipment Results in Arc Flash Injury

On April 14, 2006, at the Brookhaven National Laboratory (BNL), an electrical engineer was injured by an arc flash while closing a fused-disconnect switch in an electrical panel at the Relativistic Heavy Ion Collider (RHIC). The electrical engineer was not wearing appropriate clothing or the PPE required for this operation and received first- and second-degree burns to his face and body. The arc flash resulted from an overvoltage condition caused by a ground fault. (ORPS Report SC--BHSO-BNL-AGS-2006-0002)

On the day of the event, BNL experienced a reduction in electrical power when the regional electrical utility suffered a power dip. This power upset caused problems within the RHIC electrical systems that required troubleshooting. The electrical engineer was called in to help two electronic technicians troubleshoot a high-current ripple problem. Once the problem had been solved, they began restoring electrical power. The electrical engineer was closing four fused-disconnect switches on 480-volt panel PB-1 (Figure 1-1) while the electronic technicians were preparing a 13.8-kV circuit breaker for closure in a nearby panel. The electrical engineer closed switches 4A and 5A at the top of the panel and then closed switch 2A at the bottom of the panel. When he closed switch 3A, he heard a very loud noise and saw sparks and smoke coming from within the panel.

The arc flash created radiant heat energy and molten aluminum, most of which was contained within the panel or vented away from the electrical engineer. However, what was expelled from the front of the panel set his hair on fire and caused first-degree burns on his face, scalp, and chest. He also received first- and second-degree burns on his hands and forearms and a corneal abrasion to his left eye because he was not wearing safety glasses. The electrical engineer's non-flame-resistant shirt and undershirt were slightly burned.

Figure 1-1. Electrical panel PB-1 with switch 3A in the center with signs of arc flash (soot)

The two 400-amp switches (2A and 3A) were coated on the inside with a layer of black soot. The left end of both switches was partially blown out, and adjacent wiring insulation was melted from the heat of the arc flash. The vent panels on the ends of the switches were seared and completely blown off, and the front covers were deformed (Figure 1-2).

A Type B Accident Investigation Board was established to investigate the cause of this accident. The Board believes the arc flash was caused by an overvoltage condition tied to a ground fault on an underground cable, which resulted in the initial arc between the grounded steel frame and phase B bus on the back of switch

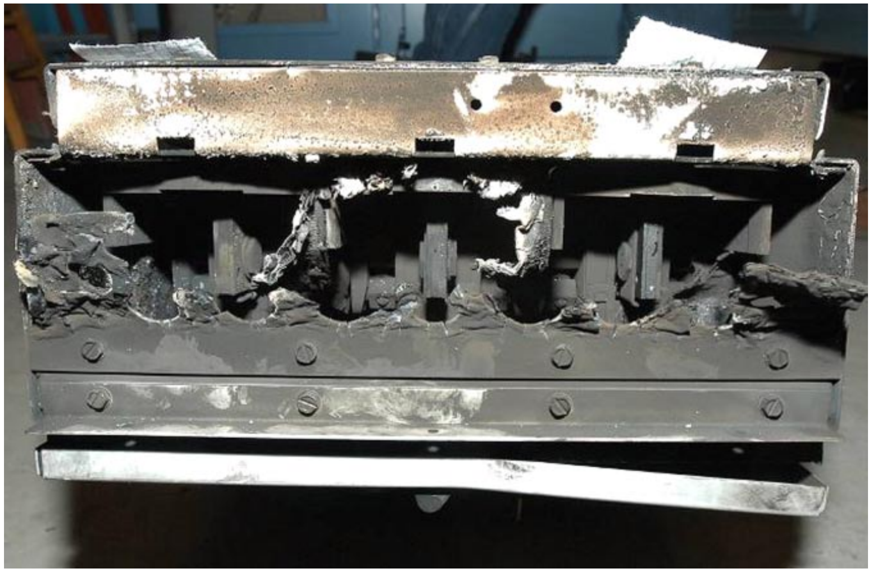

Figure 1-2. Bowed cover on switch 3A

3A. This arc then caused phase-to-phase arcing within switch 3A and the failure of switch 2A. The Board concluded that the accident resulted from a number of deficiencies in the implementation of management systems and processes. The following are examples of these deficiencies.

- BNL failed to ensure that ground-fault monitoring detection was operable. This is important because the installed power supply is an ungrounded delta, which can be vulnerable to transients and overvoltages. Ground-fault relays were not included in a preventive maintenance program.
- BNL failed to implement National Fire Protection Association (NFPA) 70, *National Electrical Code* (NEC) 2005 for ground fault protection, which requires detectors for some specific applications of ungrounded electrical systems.
- BNL failed to implement formal work controls for working on ungrounded delta systems that could have a ground fault.
- BNL failed to implement NFPA 70E, *Standard for Electrical Safety in the Workplace*. Arc flash calculations for the building where the incident occurred were not completed. Had they been completed, PPE requirements based on arc flash calculations would have been posted on the electrical panel.
- BNL failed to ensure adequate implementation of the Collider-Accelerator Department Conduct of Operations Program. Pre-job briefings were not held; personnel did not stop work when they observed the electrical engineer not wearing proper PPE; and surveillances of ground-fault conditions were not formalized through approved procedures.

The details of the Board's investigation and Judgments of Need can be found in the Type B Accident Investigation Report, *Arc Flash at Brookhaven National Laboratory*, which is available at http://www.eh.doe.gov/csa/reports/accidents/index.html.

An important issue in this accident was the failure to wear appropriate PPE when approaching and operating the switches on the electrical panel. The danger of exposure to energized circuits when not wearing required PPE was underscored in a recent industry event at a Midwestern commercial nuclear power plant.

On August 26, 2006, an experienced electrician suffered serious flash burns to his hands, arms, face, and torso from a 480-volt arc flash. The arc flash occurred when the electrician decided to test a high-voltage detection device (hot stick) in a spare circuit breaker cubicle (Figure 1-3). His action caused a phase-to-phase short circuit and electrical arc. The electrician was sent to a regional burn center because of his injuries. He did not don the required PPE for accessing the circuit breaker cubicle


Figure 1-3. The damaged spare 480-volt circuit breaker cubicle and hot stick on scorched floor

(i.e., NOMEX® suit, gloves, and face shield). His impromptu decision to test the hot stick was outside the scope of work and was not authorized. (NRC Event Number 42805)

Arc flash events have also occurred at other DOE facilities. The following occurred while personnel were knowingly working on energized equipment.

On December 10, 2005, at the Pantex Plant, an electrical arc flash occurred while an electrician was installing a 12.47-kV fuse in an automatic transfer switch. Investigators believe the arc flash occurred because the fuse holder was misaligned, operated too slowly, or operated with insufficient force. The electrician was not injured because he was wearing a 40-calorie protective suit and using a 6-foot-long hot stick.

Although appropriate PPE was specified, the need to perform the work with the equipment energized was not questioned. A fundamental principle of NFPA 70E is that work on or near energized components must be justified based on safety or system capability and not on operational convenience.

As a corrective action, an Energized Work Permit was implemented that requires a description of need and justification whenever equipment cannot be de-energized. (ORPS Report NA--PS-BWXP-PANTEX-2005-0137)

On December 6, 2005, at the Fernald Environmental Management Project, an electrician received minor burns to the face when an arc flash occurred inside a 480-volt disconnect panel during voltage testing. A faulty multimeter caused a phase-to-phase short circuit. The electricians who were involved in this incident were not wearing flame-retardant clothing, Voltage-rated gloves, face and head protection, or hearing protection specified by NFPA for performing voltage checks. Investigators determined that Fluor Fernald failed to identify current electrical safety program requirements based on NFPA 70E and failed to integrate those requirements into work authorization documents. (ORPS Report EM-OH-FCP-FFI-FEMP-2005-0043)

On October 11, 2004, at the Stanford Linear Accelerator Center, a subcontractor journeyman electrician received serious burns from an electrical arc flash while installing a circuit breaker in an energized 480-volt electrical panel. The electrician's clothing caught fire resulting in burn injuries that required hospitalization. A DOE Type A Accident Investigation Board conducted a formal investigation of the accident and determined that workers did not wear the appropriate flame-resistant clothing and all required PPE. A pre-work hazards analysis was not performed, nor was there an approved electrical hot work permit. (ORPS Report SC-OAK--SU-SLAC-2004-0010; OE Summary 2005-01)

On May 10, 2004, at the Pantex Plant, a warranty service technician received minor flash burns to his eyes from an electrical arc after replacing a failed part in a new chiller system. He was not wearing any PPE and a lockout/tagout was not used. The technician did not incur permanent eye damage. (ORPS Report ALO-AO-BWXP-PANTEX-2004-0046; OES 2004-16)

NFPA 70E 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 IEEE 1584-2002, *IEEE Guide for Performing Arc-Flash Hazard Calculations*.

NFPA 70E, section 130.3, *Flash Hazard Analysis*, states the following:

> A flash hazard analysis shall be performed to protect personnel from arc flash injury. This analysis shall determine the Flash Protection Boundary and the necessary PPE to work within that boundary. The analysis shall determine the incident energy exposure to the worker (in calories/cm^2) and shall be based on the working distance of the worker's face and chest areas from a potential arc source for the specific task. The default Flash Protection Boundary for systems rated at 600 volts or less shall be 4 feet. The following approach boundaries are identified in NFPA 70E.
>
> - *Limited Approach Boundary* is the distance from an exposed energized part within which a shock hazard exists.
> - *Restricted Approach Boundary* is the distance from an exposed energized part within which there is an increased risk of shock, due to electrical arc-over combined with inadvertent movement, for personnel working in close proximity to the energized part.
> - *Prohibited Approach Boundary* is the distance from an exposed energized part within which work is considered the same as making contact with the energized part.
> - *Flash Approach Boundary* is the distance from exposed energized parts within which a person could receive a second-degree burn if an electrical arc flash were to occur.

Only a qualified person should be permitted to work within the Limited Approach Boundary of exposed energized parts operating at 50 volts or more. They must be trained to distinguish exposed energized parts from other parts of electrical equipment, to determine nominal voltage of exposed energized parts, to know approach distances and corresponding voltages, and to determine the degree and extent of hazards and the PPE and job planning necessary to perform the task safely.

Section 110.16, *Flash Protection*, of National Electric Code, requires posting switchboards, motor control centers, panelboards, and industrial control panels with markings to

Electrical Hazards

- **Electrical Shock and Burns** – Contact with electrical energy can result in nerve and tissue damage, severe burns, and electrocution as current flows through the body.
- **Arc Flash Burns** – An arc flash can heat the air to temperatures as high as 35,000 °F, vaporizing metal and causing severe skin burns from direct heat exposure and by igniting clothing.
- **Arc Blast** – The heating of air and vaporization of metal creates a pressure wave that can damage hearing, cause a concussion, and produce other injuries from flying metal debris or worker falls.

warn personnel of arc-flash dangers. An example warning label is shown in Figure 1-4.

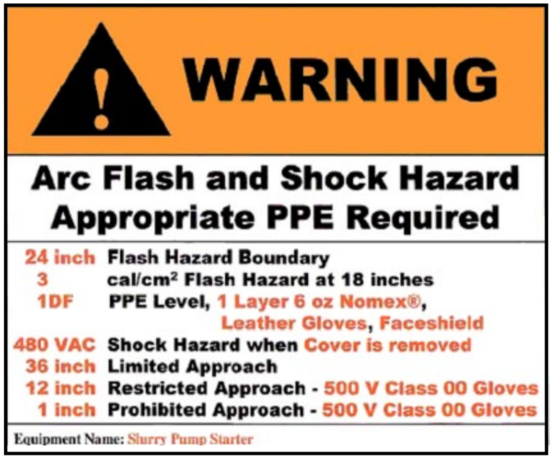

Figure 1-4. Example of arc flash warning label

In addition to flash hazard analysis, personnel training, and selection of PPE, justification to work on energized components should be performed. NFPA 70 E, section 130.1, *Justification for Work*, states that energized parts to which a worker might be exposed shall be put into an electrically safe work condition, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is not feasible because of equipment design or operational limitations.

These electrical arc-flash events underscore the importance of implementing the guidance in NFPA 70E for arc-flash protection. Electrical safety engineers should perform flash hazard analyses and ensure that these calculations are controlled. Information on approach distances and required PPE should be posted on electrical equipment. Facility managers should make sure that the need to work on energized circuits has been reviewed and justified and that the use of required PPE is strictly enforced.

Appropriate NFPA 70E Definitions

- **Flame-Resistant (FR)** — The property of a material whereby combustion is prevented, terminated, or inhibited following the application of a flaming or non-flaming source of ignition, with or without subsequent removal of the ignition source.
- **Flash Hazard Analysis** — A study investigating a worker's potential exposure to arc-flash energy, conducted for the purpose of injury prevention and the determination of safe work practices and the appropriate levels of PPE.
- **Flash Suit** — A complete system of FR clothing and equipment that covers the entire body, except for the hands and feet. This includes pants, jacket, and beekeeper-type hood fitted with face shield.
- **Qualified Person** — One who has the skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training on the hazards involved.

KEYWORDS: *Arc flash, injury, electrical safety, personal protective equipment, NFPA 70E, flame retardant, flash boundary*

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

Pipefitter Burned When Soldering Torch Fails

2

On June 9, 2006, at the Los Alamos National Laboratory (LANL), a pipefitter working for the support services subcontractor (KSL) received first- and second-degree burns when his acetylene torch failed and flames engulfed his left hand. The pipefitter was soldering sections of copper pipe when the accident occurred, and was not wearing flame-retardant gloves. (ORPS Report NA--LASO-LANL-TA55-2006-0012; final report filed September 6, 2006)

An integrated work document (IWD) had been prepared for removing old piping and installing new piping underneath a glovebox. Two pipefitters attended a pre-job briefing and discussed the task. Their PPE included one pair of anti-C coveralls, two pairs of booties, and one pair of surgeon's gloves. The IWD included a spark and flame permit that required a fire watch. One of the pipefitters performed this function while the other one soldered the pipe connections. The pipefitter used an air-acetylene torch package that consisted of a TurboTorch®, a small bottle of acetylene with a regulator, and a section of gas hose (Figure 2-1). A closeup of the torch head is shown in Figure 2-2.

The pipefitter held the torch in his left hand and the solder in his right hand as he worked in the small, difficult-to-work-in space beneath the glovebox. As the work progressed, the fire watch heard a "pop." He then heard the pipefitter say that his hand was on fire and that flames coming from beneath the hose had ignited the base of the torch. The fire watch immediately kinked the hose to cut off the gas to the torch and turned off the regulator at the tank.

Figure 2-1. Acetylene bottle, regulator, hose, and torch head

Figure 2-2. Torch head and hose connection to the acetylene bottle

When the pipefitter pulled off his surgeon's gloves, he saw that the left glove was blackened, but had not failed (Figure 2-3), and the right glove was not significantly marked. Investigators believe the burns on the thumb, middle, and little finger of the pipefitter's left hand were caused by sweat in the glove that was turned to steam by the heat of the flames.

KSL management appointed a team to investigate the incident. They determined that the incident was caused by a loose hose connection on the torch head that allowed acetylene gas to escape and ignite (Figure 2-4). The hose connection did not have an engineered locking device to ensure the integrity of the connection.

The TurboTorch manufacturer's instructions required performing a leak test and tightening any loose connections, but those instructions were not included in the KSL work instructions.

Because the torch lacked an engineered locking device at the hose connection, the manufacturer-recommended controls were inadequate to prevent recurrence of this type of failure.

Figure 2-3. Pipefitter's blackened left glove

Figure 2-4. Closeup of hose connection at torch valve torch

The KSL general manager directed that all torches of this design (i.e., single-hose, air-acetylene) be removed from service. Two-hose oxyacetylene or disposable propane bottle torches will be used instead.

The KSL team also determined that the PPE used for the job was inadequate in that only surgeon's gloves were being worn for radiological protection, rather than leather or flame-retardant gloves, which would provide thermal protection. Although LANL's implementing requirement for PPE required the use of gloves to protect against potential tissue burns, KSL's procedure for gas welding and cutting did not include a requirement for leather or flame-retardant gloves during soldering. KSL will modify their procedure to include this requirement.

KSL will also modify their procedure for preparation and control of KSL work instructions to ensure that appropriate manufacturer's requirements, LANL and regulatory requirements, and specific equipment and tools are included in the development of work instruction procedures. In addition, KSL has decided to switch from copper piping to stainless steel piping, which is joined by orbital welding, thus eliminating the need for high-temperature brazing.

The following event is another example of failing to incorporate the manufacturer's recommendation for equipment use into facility operations.

On May 20, 1999, at the Hanford Site, a flashback occurred while D&D workers were using a cutting torch fueled by unleaded gas and oxygen rather than acetylene. The flash caused the oxygen hose to burst and burn in half, producing a "road flare"-size flame. Following the event, a field engineer reviewed the torch manufacturer's manual and found a recommendation that addressed installing a flashback arrester on the oxygen line at the torch. As a corrective action, a flashback arrester was installed before permitting the torch to be used again. (ORPS Report EM-RL--BHI-IFSM-1999-0004)

Acetylene (C_2H_2) is used almost universally as a gas for welding and cutting. Even though it is very common, acetylene is extremely dangerous. When mixed with pure oxygen in a torch, the flame can reach 5,700°F. Acetylene is chemically unstable, which makes it very sensitive to excess pressure, excess temperature, mechanical shock, or static electricity. It is very easy to ignite and burns at a very fast rate, so it is very important to ensure all fittings are tight and have been leak-tested.

The following events highlight the importance of taking these necessary precautions.

- On March 31, 2005, at the Savannah River Site, a small flame was observed on an acetylene bottle regulator as an operator was using the oxyacetylene torch to cut metal. A fire watch immediately extinguished the flame. The operator failed to perform a required leak test on the oxy-acetylene system before use. Investigators later determined that the regulator was defective. (ORPS Report EM-SR--WSRC-FDP-2005-0005)
- On April 6, 2004, at the Idaho National Laboratory, a worker felt heat through his glove and noticed a small flame as he attempted to close the isolation valve on an acetylene bottle following oxy-acetylene cutting. The flame originated between the valve stem and the packing nut (Figure 2-5). Investigators identified several other oxy-acetylene torch systems that leaked either at the valve-stem packing nut or at the regulator threads. The gas-bottle vendor stated that occasional packing-nut leaks on acetylene bottles can be expected. Investigators recommended testing the systems for leaks. (ORPS Report NE-ID--BBWI-SMC-2004-0003)

Figure 2-5. Fire originated between the isolation valve and packing nut

Performing an inspection of equipment before use is always a good practice, whether directed by a procedure or work instruction or not. The few minutes taken to verify safe equipment operability can prevent worker injuries and help to ensure smooth job performance.

These events underscore the need to check fittings and connections for leaks on acetylene and other compressed-gas cylinders. Acetylene leaks, no matter how small, can have serious consequences. When performing any type of hot work, it is essential that workers use properly rated PPE to protect them from thermal injuries. It is also very important to review manufacturers' recommendations and incorporate their instructions for equipment use into procedures, work packages, and worker training.

KEYWORDS: *Torch, burns, soldering, acetylene, personal protective equipment, gloves, procedures, manufacturer's information*

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

Before You Drill — Check the Other Side of the Wall

3

On August 28, 2006, at the Idaho National Laboratory, a maintenance worker accidentally drilled into a pressurized fire extinguisher, releasing its contents. The worker was drilling into a wall and did not realize that a recessed fire extinguisher cabinet was located on the other side of the wall. The maintenance worker was not injured. (ORPS Report NE-ID--BEA-CFA-2006-0006; final report filed August 30, 2006)

The worker drilled an inspection hole through the 5/8-inch sheetrock wall, then used a flashlight to look for any obstructions. When he saw no obstruction, he started drilling holes for thermostat wires and the 1/4-inch diameter center guide using a 1-inch hole saw. As the worker began to drill the holes for the center guide, he penetrated the fire extinguisher, which released its contents into the cabinet and into the room where it was located. Figure 3-1 shows the hole that was drilled through the sheetrock into the back of the recessed fire extinguisher cabinet, and Figure 3-2 shows the hole in the fire extinguisher.

Investigators determined that the team leader and workers walked down the area before work began. The workers had a building drawing that indicated which rooms required a thermostat, but the workers received no direction on exact locations where the thermostats should be hung. Instead, they were given latitude to mount the thermostats wherever it was convenient to do so.

The procedure used by the workers permitted removal of a section of wall surface material (i.e., plasterboard or drywall) to inspect for wires or piping in the interior of the wall or to install a receptacle when cutting would not penetrate significantly beyond the interior surface of the wall surface material. Investigators learned that the worker who drilled into the fire extinguisher did not walk around the wall to see what was on the other side because he did not intend to drill completely through the wall.

Figure 3-1. Hole drilled through back of fire extinguisher cabinet

Figure 3-2. Hole in fire extinguisher

This event would not have occurred if the worker had simply checked the other side of the wall before drilling. However, the procedure that was used for this work has been changed as a result of the event, and exploratory penetrations must now be performed with a non-powered tool. The revised procedure also does not permit workers to use a power tool before they have made absolutely certain that there is no interference inside the wall.

When performing similar drilling tasks, workers and their supervisors should remember that recess-mounted panels, unlike surface-mounted panels, reduce the margin for error when drilling into the wall from the other side. Workers must also remember that the depth of the recess must be accounted for when drilling.

As the following similar events show, inattention to detail and inadequate procedures can have potentially serious consequences.

On October 14, 2003, at Lawrence Livermore National Laboratory, a carpenter mounting a key box set penetrated a 480/277-volt panel on the other side of the wall, resulting in arcing in the panel and between the screw head and the box. The carpenter was mounting the key box set directly below existing boxes and when some anchors did not "bottom-out" on the sheet rock, he thought it was because there were metal studs in the wall. Since he ran out of 2-inch sheet rock screws, he decided to use 3-inch screws, and one of them penetrated the panel box and contacted the bus bar. The screw disintegrated, but the carpenter did not receive an electrical shock. (ORPS Report DP-OAK--LLNL-LLNL-2003-0036)

Investigators determined that no special procedure or permit was required for the job and that the contractor made no effort to check the other side of the wall for any potential obstructions. The worker, who had worked in the facility for many years, did not consider that there might be a recessed breaker box in the next room because he had never encountered one during previous, similar tasks.

In an event at Argonne National Laboratory in 2002, a contractor furniture installer inadvertently drilled three screws into the back of a recessed electrical breaker on the other side of the wall. Procedures were in place to conduct the task safely, and the work planning checklist specifically identified a potential safety hazard of the work as "mounting to walls with utilities (electrical conduit)," but neither the furniture installer nor the person monitoring his work verified that there were no obstructions in the adjacent room. Investigators determined that human error (inattention to detail) was the direct cause of this event. (ORPS Report SC-CH-AA-ANLE-ANLEAPS-2002-0002)

Prevent Events

Walk down the work site and perform the following checks.

- Identify equipment you will be working on.
- Ensure that equipment requiring isolation is clearly marked.
- Verify that drawings reflect as-built conditions.
- Identify any safety hazards or issues that may not be immediately apparent (e.g., check the other side of the wall before work begins).

Drilling into electrical components is far more common across the DOE complex than drilling into a fire extinguisher, but both types of events can stem from similar problems. An analysis performed for an August 2004, Lessons Learned Report on Electrical Safety at DOE found that about three-quarters of the electrical work occurrences were caused by personnel errors (e.g., procedure violations or inattention to detail) or work control weaknesses. The report presented measures to prevent such occurrences, including walking down the work site to (1) identify equipment to be worked on; (2) ensure that equipment to be isolated is clearly marked; (3) verify or modify drawing to reflect as-built conditions; and (4) identify any additional hazards or safety issues. Although the maintenance workers and their team leader at Idaho National Laboratory performed a walkdown, it was not thorough enough to identify the safety hazard presented by the fire extinguisher on the other side of the wall.

OSHA regulations in 29 CFR 1926.416(a)(3) state that before work is begun the employer shall ascertain by inquiry or direct observation or by instruments whether any part of an energized electric power circuit, exposed or concealed, is so located that the performance of work may bring any person, tool, or machine into physical or electrical contact with the electrical power circuit. However, workers also must take responsibility for their own safety by performing an independent check of the area in which they intend to perform work tasks that are potentially hazardous.

These events illustrate the importance of taking responsibility for one's own safety, as well as the necessity of developing procedures that adequately address work performance. Even when a task appears to be uncomplicated and easily performed, workers must check for any unseen hazards before they begin a work task. Supervisors and managers must also ensure that all work is adequately planned, that all hazards are identified, and that appropriate controls are in place before work begins. The simplest "skill of the craft" task can present serious hazards and may require additional, task-specific procedures to ensure worker safety.

KEYWORDS: *Drill, penetration, cut, saw, wall, hidden, walk down, safety check*

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

A Lesson from the Past: Lack of Work Activity Coordination Sank U.S. Submarine In Shipyard

4

All construction projects, whether large or small, require some form of central control in order to schedule and coordinate multiple tasks to complete them on schedule and safely. Many of these work activities must be performed simultaneously and controlled such that any interference between tasks will not impact worker safety. Lessons learned from past incidents and accidents are still applicable today, as illustrated by the following industry event, which occurred 37 years ago.

On May 19, 1969, at the Mare Island Naval Shipyard in the San Francisco Bay Area, the nuclear-powered attack submarine *Guitarro* (SSN-665) sank in 35 feet of water (while tied up next to the dock) when the forward part of the ship suffered uncontrolled flooding (Figure 4-1).

The submarine was under construction and being fitted out at dockside when it sunk. Shipyard workers re-floated the submarine 3 days later and moved it into a drydock for repairs. There was no loss of life; however, damage was extensive and the commissioning of the ship (Figure 4-2) was delayed 33 months at a cost of approximately $35 million. An Armed Services Investigating Subcommittee was appointed following the incident. Subcommittee members determined that both inadequate coordination of construction activities and inadequate assignment of specific responsibilities contributed to the accidental sinking of the submarine. More detailed information on the accident investigation is available at http://www.history.navy.mil/library/special/guitarro.htm.

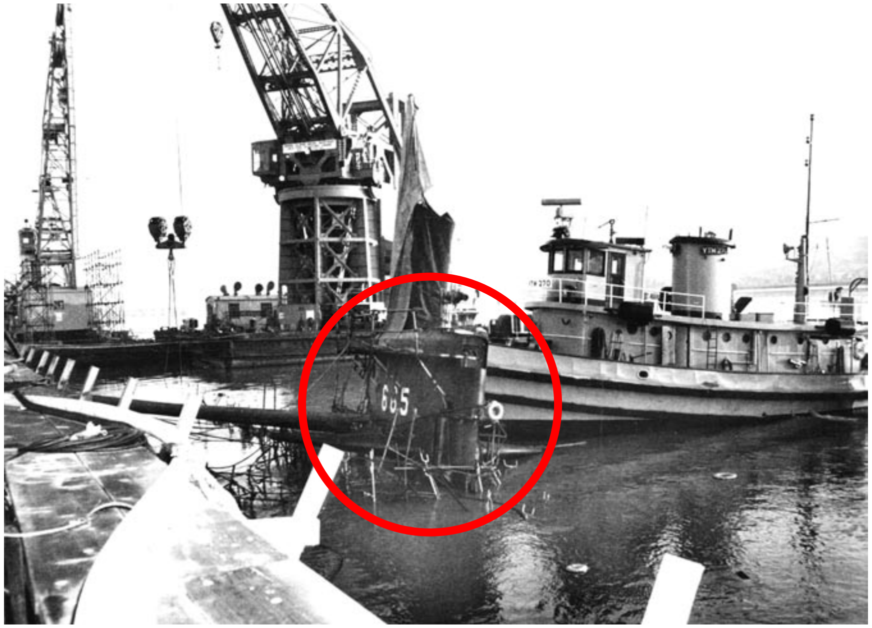

Figure 4-1. USS Guitarro resting on the river bottom as a tugboat prevents it from capsizing. All that is visible above the water is the ship's sail (circled).

During the afternoon and evening of the accident, two separate groups of civilian construction workers, a nuclear group and a non-nuclear group, were independently working on the ship. The nuclear group was performing instrument calibrations, which required them to add approximately 5 tons of water to tanks located aft of the ship's pivot point. At the same time the non-nuclear group was attempting to bring the ship to trim (i.e., level fore and aft) by adding water to tanks forward of the ship's pivot point. As the nuclear group continued to add water to tanks at the rear of the ship, the non-nuclear group would add water to ballast tanks in the front of the ship to maintain trim.

A security watch on the submarine became concerned that the ship was riding low in the bow and that wave action from passing boats caused water to enter an open manhole used to access the sonar dome in the nose of the submarine. The security watch told the non-nuclear group about his concern but failed to notify his superiors as required by regulations. His warnings were ignored by the non-nuclear group, who only stopped adding water to the forward ballast tanks when it was time to take their lunch break. While they were at lunch, the nuclear group completed their calibrations and began to empty the aft tanks. This caused the stern of the ship to become more buoyant and rise and the bow to sink even further because of the water that had been added to forward ballast tanks. A half-hour later, the submarine took a sharp downward angle

Figure 4-2. USS Guitarro at commissioning. Notice the ship's normal trim and waterline.

as massive flooding occurred through open hatches. Workers attempted to close watertight doors and hatches to isolate compartments, but were unsuccessful because cables and lines had been routed through openings, allowing the submarine to fill with water and sink in the river along side the dock.

As investigators would learn, the submarine's Achilles heel in this accident was the unprotected open manhole for the sonar dome, which is located close to the ship's waterline. When the bolted cover plate is removed, the opening is normally protected by a 3½-foot-tall cofferdam, and is designed to prevent water from entering the sonar dome. Investigators discovered that in March workers had removed the manhole cover and cofferdam to facilitate replacement of faulty sonar transducers inside the dome. The cover plate was later located on the dock, and the cofferdam was found in a warehouse.

Neither the Ship Superintendent nor General Foreman (who were responsible for the safety of the ship) realized that the manhole had been unprotected for 2 months. In addition, neither work group knew what the other was doing, nor were they aware of each other's presence on the submarine. At that time, construction work on nuclear submarines was divided into nuclear construction and non-nuclear construction. Each group maintained its own separation of responsibilities; however, there needed to be constant communication to ensure operations were coordinated and scheduled effectively and efficiently. After reviewing all the facts, investigators concluded that a lack of centralized control and responsibility for all construction resulted in the ship's sinking.

At DOE, the coordination of work activities is very important, whether the work involves a large construction project or normal facility operations and maintenance. A key element of coordination is adequate communication of work activities across organizations. This should include not only those organizations that are performing work, but also those organizations that might be impacted by the work of others. Communication of scheduled work tasks can be accomplished by publishing them in a Plan of the Day/Plan of the Week, by general area announcements, and through work planning meetings and pre-job briefings. A form of central control is necessary to ensure that every organization performing work is working to an approved plan and that potential safety impacts are anticipated and prevented. Simply put, work must be coordinated in a way that the right hand knows what the left hand is doing, particularly during demolition.

Since the beginning of 2006, 25 final occurrence reports for which the cause code "work planning not coordinated with all departments involved in task" was identified as a causal factor have been entered into the ORPS database. The following is an example of this type of event.

On August 7, 2006, at Hanford, a subcontractor for the Washington Closure Hanford (WCH) Regulatory and Environmental Management organization uncovered four energized electrical wires, and broke one with a bucket, while excavating a test pit to conduct confirmatory sampling in a waste-side drain field scheduled for demolition near Building 331. The electrical wires were buried underneath wood to indicate their presence. Work was stopped, and two electricians traced the wires back to a circuit breaker box and locked and tagged out all four circuits. (ORPS Report EM-RL--WCH-GENAREAS-2006-0003; final report filed October 12, 2006)

During the investigation, one of the concerns was that WCH did not involve the 331 Building Manager when planning the excavation. The 331 Building Manager stated that he knew there were electrical lines running through the drain field and would have provided the approximate location to WCH if he had known about the excavation. It was also learned that the backhoe operator was not familiar with the Hanford practice of placing wood over direct-buried cables and believed the wood was debris from old concrete forms when he saw it in his bucket. The practice of placing metal tape on wood and placing the wood over the cables had been done in the 1980s and 1990s. This important information would have been well understood if work planning had been coordinated and communicated among all organizations.

Excellence in job performance and workplace safety cannot be achieved without accurate and timely communication among work organizations. The use of a centralized control, which has overall work authority, is also important to ensure that any interference between work tasks is minimized and will not impact worker safety.

KEYWORDS: *Coordination, work control, communication, safety, multiple tasks*

ISM CORE FUNCTIONS: *Analyze the Hazards, Develop and Implement Hazard Controls, 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 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
SELLS	Society for Effective Lessons Learned

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