Office of Independent Oversight and Performance Assurance
Office of Security and Safety Performance Assurance
U. S. Department of Energy

Independent Oversight Lessons Learned Report

Electrical Safety During Excavations and Penetrations

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SSA

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Abbreviations Used in This Report

CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EM	Office of Environmental Management
GPS	Global Positioning System
KCP	Kansas City Plant
LLNL	Lawrence Livermore National Laboratory
NNSA	National Nuclear Security Administration
OA	Office of Independent Oversight and Performance Assurance
ORNL	Oak Ridge National Laboratory
ORPS	Occurrence Reporting and Processing System
OSHA	Occupational Safety and health Administration
PPE	Personal Protective Equipment
SC	Office of Science
SRS	Savannah River Site

OVERSIGHT

FOREWORD

Since 1984, the Office of Independent Oversight and Performance Assurance (OA), within the Office of Security and Safety Performance Assurance, and its predecessor offices within the U.S. Department of Energy (DOE) have been responsible for evaluating programs of national significance and reporting on their status to the Secretary of Energy, senior Department management, and Congress. This independent internal oversight function is unique in the executive branch of the government and, over the years, has led to notable improvements in safeguards and security; cyber security; environment, safety, and health (ES&H); and emergency management programs. The OA Office of Environment, Safety and Health Evaluations is responsible for evaluating and reporting on ES&H performance throughout the DOE complex.

A number of DOE sites have electrical wiring or utility lines that are not well marked or accurately reflected on site maps and drawings. Previous inspection results and event reports indicate a number of events and near misses during excavation of buried utilities and during penetration of building structures. Therefore, OA identified electrical safety during excavations and penetrations as a focus area—one that warrants increased attention across DOE—during four fiscal year 2004 inspections: Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, the Kansas City Plant, and the Savannah River Site.

As discussed in this lessons learned report, sites have taken significant steps in recent months to increase electrical safety during excavations and penetrations as a result of increased management attention. However, further improvements are needed in the areas of configuration control, utility location surveys, procedure quality, and adherence to established requirements.

1.0 Introduction

This report summarizes the observations, insights, and lessons learned from evaluating the electrical safety during excavations and penetrations during Office of Independent Oversight and Performance Assurance (OA) environment, safety, and health (ES&H) management inspections conducted in 2004. OA, within the Office of Security and Safety Performance Assurance, identified electrical safety during excavations and blind penetrations as a focus area across the U.S. Department of Energy (DOE) complex based on an analysis of past inspections and other performance data, which determined that there have been a number of events and near misses at many DOE sites. In 2004, this focus area was evaluated as part of ES&H inspections at the four sites listed in Table 1. The table also identifies the DOE program office that has primary management responsibility for each site: the National Nuclear Security Administration (NNSA), the Office of Environmental Management (EM), or the Office of Science (SC).

The focus area of electrical safety during excavations and penetrations was selected for 2004 based on a review of previous inspections and operating experience (e.g., occurrence reports) which indicated performance problems in this area. Workers involved in these occurrences were employees of DOE prime contractors and their subcontractors. A DOE Headquarters Operating Experience and Lessons Learned Report in April 2004 noted that excavations that struck buried electrical utilities occurred and were reported once a month, on average, during 2002 and 2003, primarily during construction. Many of the occurrence reports listed inadequate as-built drawings or lack of drawings as a major causal factor. Other causal factors included failure to use locating equipment, and not complying with excavation procedures, (e.g., not hand-digging near buried electrical lines). In some occurrences, survey equipment was used but did not accurately locate buried utilities. Energized electrical lines have also been struck during penetration of floors, walls, and ceilings (i.e., "blind" penetrations). These events have also occurred about once a month during the past three years. Most such events involving blind penetrations occurred while workers used hand tools to drill or cut into facility structures during construction and demolition. Electrical systems that remain energized to support demolition activities (such as lighting circuits) have also presented a particular challenge for this type of work; in a number of cases, the energized systems were not properly marked, locked out, or tested to verify zero energy.

Section 2 of this report discusses OA's observations, including positive attributes and weaknesses. Conclusions are provided in Section 3, and opportunities for improvement derived across the four sites are presented in Section 4.

Table 1. Sites Inspected by OA During 2004

Safety Management Inspection Site	Headquarters Program Office(s)
Savannah River Site (SRS)	EM/NNSA
Kansas City Plant (KCP)	NNSA
Oak Ridge National Laboratory (ORNL)	SC
Lawrence Livermore National Laboratory (LLNL)	NNSA

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2.0 Results

DOE and NNSA Headquarters and field organizations have taken significant steps to improve electrical safety across the complex. However, a number of challenges need to be addressed to further enhance electrical safety during excavations and penetrations. Because site-specific deficiencies and opportunities for improvement have already been communicated to the sites as part of OA's inspection reports, the improvement items in this report focus on potential enhancements of DOE performance across the complex. However, where appropriate, OA refers to positive attributes at specific sites so that interested parties can obtain additional information about innovative approaches and noteworthy practices (e.g., by referring to the applicable ES&H inspection report or by contacting the site).

Positive Attributes

DOE and NNSA Headquarters have provided direction that has led to improved electrical safety during excavations and penetrations. In April 2004, the Deputy Secretary of Energy declared May 2004 as Electrical Safety Month and chartered an Electrical Safety Advisory Group to address electrical safety risks across the DOE complex. Supporting these initiatives, a draft revision of the DOE Electrical Safety Handbook includes safety guidance for excavations and penetrations in the vicinity of buried and embedded electric utilities. In addition, an electrical safety performance improvement program was established that includes tracking and trending performance in electrical safety, developing plans to strive for improvement, providing a quarterly status report to the Deputy Secretary, and identifying sites that have excellent performance records and "Best Practices." DOE and NNSA contractors have responded by developing and implementing initiatives to improve electrical safety. Although the Headquarters directives do not specifically address electrical safety during excavations and penetrations, most site improvement plans include steps to improve safety in these areas—for example, purchasing better instrumentation for locating buried utilities, developing better procedures and permit processes, and providing training for individuals assigned to locate utilities.

Each site inspected by OA has established processes for ensuring that electrical hazards are identified before excavations or penetrations begin. Hazard identification includes establishing the location of electric utilities that are buried underground or imbedded in the floors, walls, and ceilings of structures. The location of buried utilities is determined based on review of drawings and the results of surveys made with specialized location instrumentation. Once identified, the locations are marked on the ground with paint, flags, or other markers. Controls, such as lockout/tagout, personal protective equipment (PPE), and hand digging, are then established to reduce the risk of electric shock during digging. Similar processes are used to reduce the risk of shock during penetration of masonry floors, walls, and ceilings. Penetrations in hollow drywall are typically made by cutting small holes in the drywall to allow visual identification of electric utilities inside the walls before more extensive drilling or sawing begins. Controls for blind penetrations typically include lockout/tagout and PPE.

The DOE/NNSA management focus on electrical safety management, combined with continuing events involving electric shock and near-misses during excavations and penetrations, has resulted in heightened awareness of electrical safety risks associated with this work. This awareness has prompted a number of programmatic improvements at all of the sites visited by OA in 2004. New programs have been established for locating buried utilities, instrumentation has been upgraded, training has been improved, and administrative processes have been strengthened. Examples of program improvements and effective practices at one or more sites include:

- Each site inspected by OA has established a formal process for identifying electrical hazards before performing excavations or penetrations.

These processes require that utility location activities be completed and documented on excavation/penetration permit forms, and that these permits be approved by authorizing individuals before work begins.

- Each site visited by OA requires the use of non-destructive digging techniques within a specified distance of buried utilities. For example, at some sites, workers use vacuum excavation equipment to remove soil that had been loosened with air or water jets. At LLNL, vacuum excavation equipment is used routinely to dig "pot holes" as an exploratory technique when the exact location of utilities is not known.
- LLNL is placing electronic marker balls with utilities before backfilling excavations. Each marker ball has an electronic system that can be excited by an above-ground instrument. When excited, the ball transmits a digital code that is used to positively identify the marked utility, its position, and its depth. Straight utility runs are marked at 100-foot intervals, and all turns and junctions are marked.
- LLNL has also established a comprehensive training and qualification program for individuals who use utility locator instrumentation. Trainees participate in six months of on-the-job training, which includes working with qualified site locator personnel. After six months, they are sent to an industry locator training course, which includes 40 hours of classroom training on the theory and operation of utility locator instruments, and a series of practical exercises. At the end of the course, each locator must successfully complete a final practical exercise in order to be certified as a utility locator. Individuals are not authorized to work independently until they have completed this course.
- ORNL plans to use global positioning system (GPS) equipment to identify the location of underground utilities with greater precision.

Weaknesses

Observations by OA during recent safety inspections, along with continuing events involving inadvertent contact with buried and embedded electric utilities during excavations and penetrations, indicate the need for additional improvements. Specific areas where improvements are needed include configuration control, utility location surveys, procedures and processes, and adherence to established requirements. These areas are discussed in the following paragraphs.

Excavation Event That Resulted in Cutting a Buried Electrical Line

Configuration control programs at most sites do not include current and accurate drawings. The use of outdated and inaccurate drawings is a common factor in many excavation/penetration events reported in the DOE Occurrence Reporting and Processing System (ORPS). Site personnel acknowledged that drawings were out-of-date at each site visited by OA. While each site has drawings that show buried and embedded electrical utilities, these drawings have not been consistently kept up to date with as-built conditions and modifications, and thus the drawings cannot be regarded as fully reliable. Most sites lack an effective process for updating drawings when utilities are identified in locations other than those shown on drawings, and none have plans for reconstitution of sitewide drawings.

The effectiveness of utility location surveys is reduced because of weaknesses in personnel training and selection and use of equipment. Lack of reliable drawings has caused field organizations to rely heavily on instrument surveys to identify the location of buried and embedded utilities. Thus, proper use of survey instrumentation is important for ensuring electrical safety during excavations and penetrations. OA's observations of surveys and discussions with the individuals performing the surveys indicate that survey instruments are not always used in accordance with instrument capabilities or vendor recommendations. Examples of such inconsistencies include:

- Surveying an area where nine-inch-deep holes were to be drilled using an instrument capable of detection to a depth of only four inches
- Not using the metal detection mode when surveying for unidentified utilities

- Not using a semicircular scanning pattern as recommended by the instrument vendor
- Exceeding the recommended distance between the instrument transmitter and receiver.

Only one of the sites OA visited has established a training and qualification program for utility locators. Most sites provide little formal training to these individuals, and most have not established written procedures for use of survey equipment. In addition, some sites have not benchmarked their survey instrumentation to confirm that it performs as expected under site-specific conditions. Benchmarking is important because local soil conditions can significantly impact instrument capability.

Procedures and processes are not sufficiently rigorous. The OA review identified inconsistencies in the quality of excavation/penetration permits. Workers performing excavations and penetrations rely on these permits as a source of information about required controls. The permit processes also serve as mechanisms for specifying or referencing safety controls. Incomplete and unclear entries were identified that could result in the failure to establish appropriate controls. For example, penetration controls that were specified in upper-tier documents, such as requirements for use of drill stops to restrict penetration depth and requirements to review drawings prior to making penetrations, were not specified or referenced in some permits.

Buried Electrical Line Cut

In addition, responsibilities for locating utilities and using penetration permits are not always clearly specified. For example, the split of responsibilities between construction subcontractors and site organizations for locating utilities and using site permits is not always clearly addressed in contracts or procedures. The process at one site does not include adequate provisions for documenting the completion of location surveys, which could lead excavators to mistakenly interpret the absence of markings to mean that a survey had identified no utility when, in fact, no survey was done. Some permitting processes are complex, and instructions for completing permit forms are not clearly defined. This complexity is particularly evident when both excavations and penetrations are covered by the same procedure and form.

In some cases, procedures exempt some excavations and penetrations from the permitting process but do not provide an adequate justification or technical basis. For example, at one site, excavations up to 12 inches in depth were excluded, even though burial depth was not consistently addressed in construction specifications and electrical utilities had been found at less than 12 inches depth. Similarly, fastener penetrations less than two inches in depth were excluded, even though several recent events involved electrical utilities embedded at less than two inches.

A number of non-electrical occupational safety deficiencies associated with excavations were identified during this review. These deficiencies included entry into excavations by unauthorized individuals, inadequate fall protection at the edge of an excavation, excavated materials placed too close to the edge of an excavation, an exclusion rope too close to an excavation, and workers' failure to wear high-visibility vests while surveying in traffic.

Management has not ensured strict adherence to requirements. Non-compliance with established procedures is frequently cited as a cause of reported excavation events. Although OA observed only a few examples of failure to follow permitting procedures during the reviews performed in 2004, procedure violations had previously caused electric utility strikes at each site visited. Site-specific excavation procedures are written by prime contractors, and many excavation work activities are performed by subcontractors. Therefore, effective flowdown of these procedural requirements to subcontractors is important for ensuring safety; however, expectations for subcontractor compliance with site-specific excavation procedures are not fully addressed in some subcontracts. Training is another mechanism for conveying electrical safety expectations for excavations, but some sites provide little training in this area.

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3.0 Conclusions

Sites have taken significant steps in recent months to improve electrical safety during excavations and penetrations. Continuing improved performance should result from the focus of senior management attention on electrical safety; corporate support from the Office of Environment, Safety and Health; and improvement initiatives by site organizations. However, a number of challenges remain that warrant increased attention. Out-of-date drawings are a significant challenge to reliable identification of utility locations. The ideal solution would be to develop as-built drawings for all sites, but the cost of this effort is unlikely to be justifiable, given budget limitations and competing priorities. Even though drawings of buried and embedded utilities will probably never be fully accurate, they will remain an important element in the identification of utility locations, and steps should be taken to make them as accurate as possible. Electrical surveys for buried and embedded electric utilities will also remain important to safety. While sites have made progress in obtaining and using state-of-the art survey instrumentation, improved procedures and training are needed to ensure the effectiveness of electrical surveys. Excavation and penetration procedures and permitting processes have been strengthened in recent months, but additional improvements are needed to ensure that responsibilities are clearly assigned and that applicable requirements flow down to the individuals who perform the work.

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4.0 Opportunities for Improvement

Opportunities for improvement in the areas of DOE/NNSA direction and oversight, configuration control, utility location surveys, procedures and processes, and adherence to requirements are listed below.

DOE/NNSA

1. **At the Headquarters Office of Environment, Safety and Health, as part of the overall effort to improve electrical safety, monitor occurrence report data on unplanned electrical intrusions and provide a periodic status report on overall trends and outliers to senior DOE management, program offices, and site offices for further action as appropriate**.

2. **At DOE/NNSA program offices, because of the number of incidents and the potential for serious injury, direct site offices to conduct assessments of electrical safety during excavations and blind penetrations, including review of the lessons learned and opportunities for improvement in this report**.

3. **At the site office level, sustain and strengthen line management oversight attention on electrical safety for excavations and penetrations, including increased observations of work activities for assessment of procedural compliance.**

Site Contractors

1. **Improve configuration control by better documenting the locations of underground utilities.** Specific actions to consider include:

   - Establish processes to revise site drawings or maintain databases that describe the location of newly installed or reconfigured buried or embedded utilities.
   - Establish processes to revise site drawings to reflect as-found conditions when electric utilities are discovered in locations other than those shown on the drawings.

2. **Enhance utility location surveys in the areas of instrumentation and personnel training.** Specific actions to consider include:

   - Mark areas where excavations and penetrations are planned using paint or markers to facilitate more thorough searches by utility location personnel. Mark underground utilities in the vicinity of the excavation in accordance with American Public Works Association guidelines.
   - Test survey instruments under all site conditions to ensure that they will perform as expected.
   - Establish training and qualification programs for individuals who perform electric utility location surveys. Incorporate the use of mockups to improve proficiency of using equipment for various conditions.
   - Consider the use of GPS and marker balls to facilitate identification of utilities.

3. **Enhance procedures and processes to ensure requirements are clearly identified and communicated.** Specific actions to consider include:

   - Develop written procedures for identifying the location of buried and embedded electric utilities. Consider including guidance in the following areas: equipment to be utilized; recommended settings and limitations; scanning methodology (speed, direction, etc.); equipment checks; and safety warnings and controls (e.g., appropriate controls for scanning in roadways). Validate these procedures to ensure their effectiveness in identifying electrical utilities under site-specific conditions.

- Consider developing and using an excavation checklist to ensure that excavations are initially performed correctly and are maintained in a safe condition while work is being performed.

- Ensure that Occupational Safety and Health Administration (OSHA) requirements and penetration controls specified in upper-tier site documents are specified or referenced on excavation and penetration permits.

- Ensure that adequate technical bases exist for program exclusions or exemptions.

4. **Ensure that individuals strictly adhere to requirements.** Specific actions to consider include:

- Train individuals who perform excavations and penetrations, including subcontractors, on site-specific procedures.

- Ensure that expectations for subcontractor compliance with site-specific excavation and penetration procedures are included in subcontracts. Clearly convey responsibilities and expectations to subcontractors for compliance with these procedures, and hold them accountable for non-compliance.

- Consider using checklists to verify compliance with safety requirements associated with excavations.

- Audit program compliance with OSHA requirements (29 CFR 1910.335, 1926.416, and 1926.651), site procedures, and vendor recommendations. Include observations of utility location surveys.