# Electrical Safety Action Plan

**Stanford Linear Accelerator Center (SLAC)**
**July 23, 2004**

## 1. INTRODUCTION AND SUMMARY

### 1.1. Introduction

This report is in response to the May 24, 2004 memo to DOE Office of Science labs entitled "Department of Energy Electrical Safety Month" from Milton D. Johnson, Chief Operating Officer and the subsequent June 10, 2004 memo from John Muhlestein, DOE Stanford Site Office Manager, both of which requested an Electrical Safety Action Plan (ESAP).

The Electrical Safety Review Team (ESRT) was formed by the SLAC Director via a June 24, 2004 memo to SLAC senior managers to develop an ESAP. The ESAP contained herein first reviews lessons learned, as applied to operations at SLAC, focusing on the areas of concern identified by DOE: 1) personnel errors; 2) work control problems; 3) configuration management weaknesses; 4) electrical intrusion events and 5) vehicles. Suggestions are made ("Recommended Actions") for either maintaining or further improving safety performance in each of the five areas. The plan also addresses how SLAC will improve the physical condition of the facility by resolving the electrical discrepancies identified by the OSHA inspection performed February 5 to 13, 2004 and documented in the "punch list" received at SLAC on April 7.

## 2. LESSONS LEARNED FROM OPERATIONS AT SLAC

### 2.1. Personnel Errors

**Critical Look**

Review of lessons learned from operations at SLAC confirmed certain recurring personnel errors. Examples included: failure to use proper personnel protective equipment (PPE), failure to properly carry out Lock Out/Tag Out (LOTO) policies including verification of safe-energy conditions, and failure to check/verify that wiring had been completed properly. In addition, site-wide and facility-specific safety inspections have documented incidents where unsafe conditions have been left after work is completed, including open pull boxes, exposed energized conductors, improper wiring methods (non-compliance to code, generally flexible wiring used instead of permanent wiring), and improper/missing grounds. The review included SLAC's Occurrence Reporting and Processing System (ORPS) data base, focusing on electrical incidents at SLAC from 1999 to present, whether or not they were categorized as reportable. A review of the OSHA inspection discrepancies (Section 3) also identifies personnel errors within the list of findings.

An analysis of 31 SLAC Electrical Hot Work permits from February 25, 2004 until May 25, 2004 was conducted. Of these, 8 were for diagnostic work which required that the systems be energized, and 23 were for maintenance/installation work. None of these 23 permits appeared to provide the necessary justification for the work to be conducted while systems were energized. For a few, the reasons given did not justify the hot work according to SLAC's hot work program; for the others,

it was not clear if conditions existed to justify the hot work. Additionally, 19 (61%) of all the work permits examined were missing some of the required information.

SLAC has strong tools in place to track ES&H-sponsored employee training and flag employees for required refresher training. Other SLAC-sponsored training is not tracked. A review of the training records shows that while most of the technician level staff are taking some form of electrical safety training, many of the research staff who work with custom electrical equipment and high voltage, low current detector components are not required to do so. Non-SLAC employees performing work at SLAC are currently not required to take any electrical safety training.

A Non-Employee Safety Training Program is being proposed by the Training Subcommittee of the Operating Safety Committee (OSC), a general safety committee with site-wide representation. This program will establish pre-work hazard analysis and safety training requirements for all non-SLAC employees. It will parallel the current Employee Safety Training Program by providing assessment tools, recording methods, and safety training classes to ensure that non-employees receive appropriate levels of training with regard to electrical safety, PPE selection and the proper implementation of LOTO procedures.

Another corrective action was initiated in December 2002, as a result of a contract electrician following incorrect procedures. The action required the participation of the ES&H Division Electrical Safety Engineer in all pre-job briefings held by the Purchasing Department for contracts involving electrical work of any kind. This may include interviewing subcontractors to determine qualifications and making recommendations to the Purchasing Department as needed. These briefings and interviews increase the awareness of the contractor to electrical safety issues on site.

The new Job Hazard Analysis and Mitigation (JHAM) Program being implemented at SLAC will also help to address electrical incidents caused by personnel error. Under this program, tasks are analyzed for hazards and the specific steps to mitigate those hazards are listed (including PPE and training). JHAMs for routine work are required to be updated annually, while JHAMs for non-routine jobs are written before the job is performed. Additionally, Area Hazard Analysis (AHA) documents are being prepared for each work area to list known hazards and their mitigations. Groups involved with higher risk activities are putting the system in place this fiscal year, with the rest of the lab to be completed by the end of Calendar Year 2004. The program includes periodic reviews of JHAMs and AHAs.

While the above corrective actions will help to reduce personnel errors, they are not sufficient in view of the significant and continuing number of personnel error issues identified above. As a result, the following actions are recommended. These actions address the key areas of ownership and knowledge, essential to significantly reduce personnel errors.

**Recommended Actions**

- Electrical Hot Work permit program:
    - Conduct a site-wide assessment of the Electrical Hot Work permit program and process. This assessment should review compliance with SLAC's ES&H guidelines

and include examples of extraordinary circumstances that would require hot work as well as ways to avoid conducting work hot.
    - Provide information to managers covering hot work requirements and the consequences of not following the proper approval methods.
- Training:
    - Review and select the most effective way for all SLAC and non-SLAC employees to receive some form of electrical safety training, either by making Course 239 (Electrical Safety for Non-Electrical Workers) mandatory; by modifying Course 219 (Employee Orientation to ES&H), both lecture and CBT, to emphasize electrical safety; or by other similar approaches.
    - Include all SLAC-sponsored electrical safety training in a database.
    - Implement a non-employee safety training program.
    - Require Course 251, Electrical Safety for R&D Equipment, for all persons (including employees and users) who install, maintain, and operate R&D equipment (i.e., electrical engineers, electrical technicians, electrical safety coordinators, and researchers).
    - Add refresher training requirement for:
        - Course 274 (Electrical Safety, Low and High Voltage) every 3 years
        - Course 251 (Electrical Safety for R&D Equipment) every 3 years
    - Advertise the safety library which includes videos and books that can be checked out for individual or group use.

## 2.2. Work Control Problems

**Critical Look**

A recent OSHA compliance review of the SLAC Lock Out/Tag Out (LOTO) program for the control of hazardous energy found several compliance issues. The two areas of primary concern were that some personnel did not have exclusive control of the key to their personal LOTO locks (red locks) as required under the SLAC program, and that the various SLAC work groups had independently developed different "Operational Lock Out" programs, including the use of LOTO personnel safety locks (red locks) to lock out operations, leading to confusion between groups. OSHA's LOTO requirements mandate that the lock for personnel safety ("my life is on the line") can only be used to lock out energy sources when someone is actively working on the equipment. A different kind of lock out is needed for the control of energy sources for operational reasons, between shifts, etc. Additionally, OSHA-mandated annual recertification for LOTO was not being conducted for all LOTO trained personnel. If someone is trained for LOTO, OSHA mandates that they be recertified for use of LOTO on an annual basis.

SLAC's Electrical Lockout Procedure (ELP) scheme for documenting the steps to properly lock out devices with multiple or unusual energy sources is not consistent site-wide. Additionally, many of the ELPs are still in a draft state after startup of the equipment with which they are to be used.

SLAC develops custom electronics to support its research mission. It is not practical to have this equipment certified by a Nationally Recognized Testing Laboratory (NTRL) as to its safe operation. However, ORPS events include incidents where poor design of the equipment has contributed to the event (for example, a metal cover sagging into 110VAC on an internal

component). SLAC has no work control requirements to inspect custom electrical equipment prior to use.

There have been problems associated with construction projects involving methods (improper techniques), compliance with code requirements, use of unsafe equipment (broken/missing parts, frayed cords), and non-adherence to SLAC ES&H policies. Some of these have been contributing factors to events in ORPS, while others were cited during the recent OSHA review. One action initiated to address these concerns is early involvement of the ES&H Division in construction project planning. Site Engineering and Maintenance (SEM) has implemented a new construction project approval process that requires signoff by designated ES&H personnel and the acquisition of necessary work permits.

Work planning is a process that evaluates and improves the program by which work is identified, planned, approved, controlled, and executed. Current site work control programs facilitate identification, approval, planning, execution, and analysis of the work performed. The programs also allow tracking of safety issues. These programs include the SEM "Service Request" and SLAC and SSRL Operations "Accelerator Remedy Trouble Entry and Maintenance Information System" (ARTEMIS). These are both integrated databases that provide a method to organize maintenance and operations' functions. The ARTEMIS Job Form, as an example, allows identification of requirements for Lock and Tag, Radiation Safety Work Control Form, and area access. Both the ARTEMIS job form and SEM Service Request allow identification of an item as a safety issue.

While the above actions will help to reduce work control problems, they are not sufficient to address all of the concerns identified. As a result the following actions are recommended:

**Recommended Actions**

- Control of Hazardous Energy:
  - Implement the existing LOTO program in all groups; specifically, each designated employee must have exclusive control of the key for his/her LOTO locks (red locks).
  - Establish a cross-divisional working group to develop a SLAC Control of Hazardous Energy program, incorporating the existing LOTO program and adding an operational lock-out component. This program can be modeled on appropriate industry consensus standards such as ANSI/ASSE Z244.1-2003 or other professional organizations' programs.
  - Develop a consistent site-wide ELP program including user-friendly procedures that follow DOE procedural guidelines per the previously-referenced ANSI standard.
- Electrical Equipment Certification:
  - Establish a SLAC Electrical Equipment Inspection Program (EEIP) to document that SLAC-designed equipment, or commercial equipment modified by SLAC or lacking a certification from a recognized NRTL, meets minimum standards for electrical safety.
  - The EEIP should include a designer's manual to detail how to design equipment to pass the inspection and follow the model of existing programs such as the one at LLNL.

## 2.3. Configuration Management Weaknesses

**Critical Look**

DOE's April 2004 "Operating Experience and Lessons Learned Report" identified that weakness in configuration management contributed to about one-fifth of the occurrences involving electrical work at the DOE labs. In the occurrences, job planners' failures to verify as-built conditions at the work site and identify unexpected sources of energy are contributing factors to the events. The lack of accurate drawings to safely isolate electrical systems is also a contributing factor. While the contribution of documentation errors to the identified issues has not been fully identified, it is clear that not all documentation is up to date and as-built.

In the past, major modifications to accelerator systems were made with inconsistent attention and follow-through, with respect to configuration control. We found that SLAC communicates configuration management policies by the use of at least seven different documents. The document control process varies from project to project and there is no single point of contact to learn how the "system" works.

Various databases track electrical and electronic cable and equipment locations. Work order systems that identify cables to be installed or removed, documentation standards for drawings and procedures, and change order processes for updating older equipment are inconsistent, with different processes implemented in different areas of the lab.

**Recommended Actions**

- Configuration Management Plan:
  - Enhance drawing maintenance programs and for new work, enforce existing programs. Before working on existing systems, confirm drawings are accurate; if not, make appropriate corrections.
  - Establish a working group to:
    - Review lessons learned from DOE for identification of configuration management causes. Identify needed improvements to address configuration management deficiencies which resulted in electrical safety hazards.
    - Review the configuration management documents for accuracy, completeness, and avoidance of conflicts, relative to safety and site-wide consistency.
- Training:
  - Provide instructions to those responsible for maintaining drawings.
  - Educate the SLAC population on the requirements of the SLAC Documentation Control Program and the importance of their efforts in this area to electrical safety and the mission of the lab.
  - Place as much importance on as-built drawings as on the other aspects of a project.

## 2.4. Electrical Intrusion Events

**Critical Look**

A majority of the electrical intrusion incidents documented in the site's occurrence reports involved inexperienced or unqualified workers attempting to perform work on or near electrical systems. Personnel errors were the dominant root causes cited in the occurrence reports; e.g., inattention to detail and procedures not used or used incorrectly. Other contributing factors were inadequate assessment or identification of hazards; improper or inadequate use of detection equipment; lack of sub-surface penetration permits; and inadequate job planning.

ES&H Division's Excavation Clearance Form presents strict documentation and approval requirements before any below-ground entries which may result in electrical intrusion events. This allows the SLAC Construction Inspector, among others, to ensure that reviews of as-builts and other pertinent information have taken place before the work begins. Also, there is no form for above-ground penetrations, here defined as work which entails drilling or cutting into walls, conduits, or other structures.

**Recommended Actions**

- Training:
  - Managers:
    - Need to ensure that persons with the appropriate training, skills and experience are assigned to perform such tasks as drilling into structures or cutting conduit.
    - Need to call on the ES&H Division Electrical Safety Engineer to meet with groups required to perform these work activities and discuss improved procedures and tools (e.g., use of scanning and drill-stop equipment; appropriate PPE).
  - See Section 2.1, Personnel Errors - Recommended Actions, Training
  - Review the DOE documentation including, "A Review of Electrical Intrusion Events at the Department of Energy: 2000-2001" June 2002, and the "April 2004 Operating Experience and Lessons Learned Report". Assure that applicable lessons learned are incorporated into the appropriate training.
- Programs:
  - Ensure that the JHAM Program (See Section 2.1, Personnel Errors – Critical Look) is implemented this year by groups who might have an employee or sub-contractor conduct a penetration (potential intrusion) and that related hazards are specifically called out in their initial training.
  - The Electrical Safety Committee will consider the introduction of an above-ground penetration program as site policy, similar to the existing sub-surface penetration excavation program.
  - Strengthen the site Lessons Learned Program (see 2.6 below) to give higher visibility to such incidents and thereby heighten worker awareness in this area.

## 2.5. Vehicles

**Critical Look**

The overhead electric power supply lines are maintained and operated by only one group within SLAC, thus achieving positive control. Work in or around the transmission and distribution lines is under positive control via locks, gates, fencing, and signage. It requires two people to unlock the area of highest probable vehicular intrusion, and the de-energizing of the electrical equipment. The overhead conductors are constructed, marked and attached to distinctive insulators or cross arms, so as to facilitate identification by employees. Work requiring passage under the conductors, or in proximity to the conductors, in those areas where the overhead conductors are accessible to normal vehicular traffic, requires an escort, which fulfills the OSHA required "spotter" role.

Rules as outlined by the National Electrical Safety Code, IEEE publication C2-2002, are carefully implemented so as to insure the safeguarding of persons from hazards arising from the operation and maintenance of overhead electric supply lines.

Though electrical events of this kind have not occurred at SLAC in the recent past, vigilance is necessary to ensure that this safety trend continues. Credit for good performance in this area can be given to at least three causes: related work is restricted to small areas of SLAC which are clearly posted; a full-time Construction Inspector (under ES&H Division) is constantly monitoring such potential situations in the field and via pre-job hazard analyses and briefings; and SLAC's Electrical Safety Committee reviews any requests for easement in the stated SLAC policies which govern this topic, rarely granting exceptions.

SEM's Crane Inspection Group distributes lessons learned, both from other DOE Laboratories, as well as from general industry. These lessons learned are shared via videos of real-life accidents in progress and provide a graphic way in which to distribute and reinforce safety rules.

**Recommended Actions**

- Safety videos involving potential vehicle-related electrical safety hazards should be made available through the safety library (See Sec. 2.1, Personnel Error - Recommended Actions, Training).

## 2.6. Lessons Learned Program

**Critical Look**

SLAC has a number of systems in place which enable managers and safety professionals to learn from incidents at SLAC, other labs, or industry, thereby reducing the likelihood of recurrence in future operations at SLAC. They include:

- SLAC's ES&H Lessons Learned Coordinator, ES&H Assistant Director, and SEM Crane Inspector review numerous sources of information and selectively distribute write-ups of incidents which could mirror our site operations.
- SLAC's ES&H Lessons Learned Coordinator monitors and alerts his contacts in appropriate parts of the SLAC organization about any applicable product recalls, working with appropriate Subject Matter Experts to include information on disposition of recalled material and acquisition of acceptable replacements.

- The staff person for ES&H Coordinating Council (comprised of the site's associate directors) captures any lessons learned issues sent by the ES&H Lessons Learned Coordinator as an agenda item for that group's next meeting. The Council discusses the issue(s) and determines whether any further action or education should take place.
- The OSC includes on its monthly meeting agenda a standing item of "near misses" which encourages members to share such incidents and resulting lessons learned; minutes are distributed to the safety professionals and management at SLAC, including the Directorate, and are also available on-line.
- SLAC's ORPS Program Manager distributes to approximately 125 site managers and safety professionals
    - pending corrective actions from investigated incidents on a monthly basis
    - an e-mail link to a web-posted investigative report when it has been completed
    - summaries of reportable occurrences from SLAC and other labs with similar operations twice a year.

The results of this assessment and the associated OSHA inspection indicate that the lessons learned program at SLAC is not fully effective. The following recommendations, in conjunction with other recommendations throughout this report, are intended to improve the effectiveness of the program in electrical safety.

**Recommended Actions**

- Promote the Lessons Learned Program.
- Provide ES&H Division personnel support to the SLAC Lessons Learned Coordinator to assist with determining the applicability, preparing, distributing, and applying lessons learned.
- On a quarterly basis, SLAC Lessons Learned Coordinator will meet with Division ES&H Coordinators, Citizen Committee Chairs, and Operating Safety Committee Chair to increase cross-divisional review and discussion of both SLAC and DOE lessons learned and provide a forum for sharing any actions taken.

## 3. ADDRESSING OSHA CONCERNS: IMPROVING THE PHYSICAL CONDITION OF THE FACILITY

### 3.1. Major Electrical Concerns

Of the 1142 total "discrepancies" identified in the OSHA safety inspection "punch list," 376 (32.9%) were from 29CFR Part 1910, Subpart S. Furthermore, these 376 discrepancies identified over 1350 "instances" (the term for individual observations) relating to electrical safety and the physical condition of the facility as it relates to electrical safety. This is the largest percentage for a single discipline (electrical). The remaining electrical discrepancies are from 29CFR Part 1910, Subpart J and P and 29CFR Part 1926 and identified approximately 30 additional electrical safety instances. The majority of all electrical instances fall into the following general categories, as defined in the May 24, 2004 DOE memorandum. The instances have been categorized in Table 1 for purposes of general discussion and development of an overall response plan, but regardless of category, each instance will be appropriately addressed.

**Table 1: OSHA Punch List Summary of Electrical Citations**

| Issue | Number of Instances | 29CFR Part (Main Reference) |
|---|---|---|
| Improper use of extension cords and equipment | 211 | 1910.303(a) and (b) |
| Electrical equipment not labeled or labeled illegibly | 285 | 1910.303(e) and (f) |
| Access to electrical panels, breakers, and disconnects | 390 | 1910.303(g) |
| Equipment not properly grounded | 96 | 1910.304(f) |
| Flexible wiring in lieu of required fixed wiring and wiring practices | 380 | 1910.305 |
| Ground fault circuit interrupters not installed or inoperable | 9 | Various |
| Sub-contractor safety issues | 20 | 1926 |

### 3.2. Programs in Progress to Improve the Physical Conditions

A "punch list" cost estimate was provided in SLAC's April 22, 2004 submittal to DOE which detailed estimated funding required to initiate the electrical corrections.

The two most significant cost areas included in the above "punch list" are cable trays and the exposed 480V in Sectors 20 and 21. Both are previously identified problems at the site.

- Replacement of panels with exposed 480V is an Activity Data Sheet (ADS) project funded for FY04 and scheduled to be completed by September 2004.
- Many of the cable tray installations at SLAC do not meet NEC standards and are thus in violation of OSHA requirements. This includes high-voltage cable trays overfilled with electrical cables, trays that do not have grounding straps, and adjacent electrical cables not separated by at least one cable's width. ADS projects have been established to fully define the scope of this issue and provide the basis for correction or formal waivers where appropriate.

The ES&H Electrical Safety Program and Chapter 8 of the ES&H Manual provide electrical safety guidance to comply with OSHA regulations, the NEC and other established safety standards. They provide specific guidance that addresses all of the general categories identified by DOE's May 24$^{th}$ memorandum and listed in Table 1.

However, the existing site condition, as identified by the OSHA safety inspection "punch list" and cost estimate demonstrates that additional action is required to improve performance in electrical safety. The activities summarized above need to be completed to address the current physical condition. In addition, further programmatic changes are required to prevent similar installations.

### 3.3. Additional Actions to Improve the Physical Condition and Prevent Similar Occurrences

There are several activities in initial development at SLAC that will significantly improve performance in the area of electrical safety. They include an EEIP, a stronger lessons learned program (as discussed in Section 2.6 above), and uniform guidance for identified OSHA findings. One significant aspect of these activities is the recent addition of a new employee in SEM to coordinate, prioritize, and oversee the effort to correct all the site OSHA findings, including electrical. The coordinator will use the outline of activities contained herein to prepare more detailed guidelines and plans specifying appropriate and uniform corrective actions site-wide.

The large number of OSHA discrepancies point to people not knowing or understanding the day-to-day electrical hazards, or assuming that they do not apply. The following actions are recommended to increase the awareness and knowledge of electrical issues and to establish ownership by all:

- See Section 2.1, Personnel Errors - Recommended Actions, Training
- The annual 2005 site self-assessment, designed and implemented by the Safety and Environmental Discussion Assistance Committee, will require that all groups evaluate their areas for compliance with the major electrical concerns, supported by the ES&H Division. This will confirm that generic issues were not missed in some areas and provide a review of safety requirements by all affected groups. This assessment will be conducted by June 2005.
- Greater use of work planning programs such as the current SEM "Service Request" and the SLAC and SSRL Operations ARTEMIS will be encouraged. The work planning helps develop criteria for determining how jobs can be performed more safely and effectively.

### 3.4. Corrective Action Schedule

The OSHA Audit was performed February 5 to 13, 2004. The OSHA "punch list" was received at SLAC on April 7 and the cost estimate was submitted to DOE on April 22, 2004. Table 2 provides a summary-level schedule for resolving the majority of the OSHA electrical findings.

**Table 2: Summary-Level Schedule**

| Description | Duration | Start | Finish |
|---|---|---|---|
| **Physical Condition** | | | |
| Cable Tray Issue Definition | 1 year | FY04 | FY05 |
| Panels with Exposed 480V | 1 year | FY04 | FY04 |
| Address majority of OSHA Electrical Issues | 1 year | FY04 | FY05 |
| 2005 site self-assessment | | | June 2005 |
| **Training** | | | |
| Electrical Safety Training Program Revisions defined | 1 year | FY04 | FY05 |
| Refresher Training | 3 years | FY04 | FY06 |