U.S. Department of Energy

Office of Environment, Safety and Health

Type A Accident Investigation

Electrical Arc Injury on October 11, 2004, at the Stanford Linear Accelerator Center, Menlo Park, California

November 2004

This page intentionally left blank.

RELEASE AUTHORIZATION

On October 15, 2004, I appointed a Type A Accident Investigation Board (Board) to investigate the October 11, 2004, electrical arc blast that occurred at the Stanford Linear Accelerator Center. The Board's responsibilities have been completed with respect to this investigation. The analyses and the identification of the contributing causes, the root causes, and the Judgments of Need resulting from this investigation were performed in accordance with DOE Order 225.1A, *Accident Investigations*.

I accept the report of the Board and authorize the release of this report for general distribution.

John Spitaleri Shaw
Acting Assistant Secretary for Environment, Safety and Health
U.S. Department of Energy

Date: 11/15/04

This report is an independent product of the Type A Accident Investigation Board appointed by John Spitaleri Shaw, Assistant Secretary for Environment, Safety and Health, U.S. Department of Energy.

The Board was appointed to perform a Type A investigation of the accident and prepare an investigation report in accordance with DOE O 225.1A, *Accident Investigations*.

The discussion of the facts, as determined by the Board, and the views expressed in this report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents or subcontractors at any tier, or any other party.

This report neither determines nor implies liability.

This page intentionally left blank.

TABLE OF CONTENTS

TABLES

FIGURES

ACRONYMS

BSE	Bay Span Electrician
BSL	Bay Span Laborer
C	Celsius
CFR	Code of Federal Regulations
DEAR	Department of Energy Acquisition Regulation
DOE	Department of Energy
ES&H	Environment, Safety, and Health
F	Fahrenheit
FR	Flame Resistant
FS-1	SLAC Field Supervisor
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
JHAM	Job Hazard Analysis and Mitigation
JON	Judgment of Need
LINAC	Linear Accelerator
NEC	National Electric Code
NFPA	National Fire Protection Association
ORO	Oak Ridge Operations Office
OSHA	Occupational Safety and Health Administration
PAFD	Palo Alto Fire Department
PPE	Personal Protective Equipment
PWHA	Pre-Work Hazard Analysis
SC-3	Chief Operating Officer for the Office of Science, DOE
SE&M	Site Engineering and Maintenance Department
SLAC	Stanford Linear Accelerator Center
SPEAR	Stanford Positron-Electron Asymmetric Ring
SSO	DOE-Stanford Site Office
SSRL	Stanford Synchrotron Radiation Laboratory
UTR	University Technical Representative
V	Volt
WSS	Work Smart Standards

EXECUTIVE SUMMARY

The Accident

On October 11, 2004, at approximately 11:15 am, a subcontractor electrician working at the Stanford Linear Accelerator Center (SLAC) received serious burn injuries requiring hospitalization due to an electrical arc flash that occurred during the installation of a circuit breaker in an energized 480-Volt (V) electrical panel.

On October 15, 2004, the Acting Assistant Secretary for the U.S. Department of Energy (DOE) Office of Environment, Safety and Health appointed a Type A Accident Investigation Board (the Board) to investigate the accident in accordance with DOE Order 225.1A, *Accident Investigations*.

Analysis and Results

The accident resulted from deficiencies in SLAC's work control planning and implementation processes. The Site Engineering and Maintenance Department (SE&M) exhibits a culture where safety is often secondary to operations. The Board identified deficiencies in the line management organizations of the DOE Stanford Site Office (SSO), SLAC, and Bay Span, Inc. (Bay Span), the electrical subcontractor performing the work.

The events leading up to and during the installation of the circuit breaker and the resultant arc flash are characteristic of an unstructured and largely undocumented approach to work that does not ensure the safety and health of workers at SLAC. Managers, supervisors, and support staff do not take action to enforce compliance with the safety requirements for this very dangerous task. For the circuit breaker replacement, the Board identified the following key deficiencies:

- A "Pre-Work Hazard Analysis" (PWHA) form was not completed.
- There was no approved electrical hot work permit.
- The workers were not wearing the appropriate Flame Resistant (FR) clothing and all the required Personal Protective Equipment (PPE).
- The Bay Span Laborer (BSL) was not trained to be backup for an electrician.
- No one in the SLAC management chain had been informed of the decision by the SLAC Field Supervisor (FS-1) to install the circuit breaker in an energized panel.
- SLAC safety officials were not involved (only notified after such work occurred).

All SLAC management officials above FS-1 stated that it was unnecessary for the circuit breaker installation to be done with the panel energized, and they would not have approved working on an energized circuit breaker panel. The events that occurred on October 11, 2004, violated all of the Integrated Safety Management (ISM) Guiding Principles and Core Functions.

As recently as July 23, 2004, SLAC management prepared a report to the DOE Office of Science in which work on energized electrical equipment performed at SLAC was reviewed. On June 24, 2004, the SLAC Director formed an Electrical Safety Review Team to focus on areas of concern identified by DOE: (1) personnel errors, (2) work control problems, (3) configuration management weaknesses, (4) electrical intrusion events, and (5) vehicles. The review team's report analyzed 31 SLAC electrical hot work permits from February 25, 2004, through May 25, 2004, and found that 23 did not have the necessary justification for the work to be conducted while systems were energized. Nineteen of the hot work permits were missing some of the required information. This report also notes significant deficiencies in each area reviewed. As significant as the findings were, the review team, SLAC management, and SSO did not demonstrate a sense of urgency in implementing the recommendations that resulted from the review.

The significant breakdown in the enforcement of health and safety requirements is indicative of a work environment where occupational safety and health policies, programs, and procedures for worker protection are not fully implemented. The SE&M, in particular, has not balanced the priorities of accelerator operations and worker protection.

Conclusion

The Board concludes that this accident was preventable. The direct cause of the injury was an explosive release of energy resulting from an arc flash that occurred during the installation of a circuit breaker in a 480V energized panel. The circuit breaker installation on an energized panel was not justified. If proper permitting procedures had been followed, the work would not have been performed. The severity of the injuries could have been significantly reduced or eliminated had the worker been wearing the appropriate FR clothing and using the correct PPE. There were at least three people directly involved in the task with sufficient direct interaction and safety knowledge who could have exercised stop work authority because of the unsafe working conditions, yet no one took action.

The SLAC managers above FS-1 (the SE&M line managers responsible for the work in the area where the accident occurred) were not involved in work planning, task monitoring, or follow-up to ensure that the principles of ISM were applied. FS-1 stated that assignments associated with this work were verbal and that such informality was characteristic of the SE&M's work practices. SE&M management assigned FS-1 to function as a University Technical Representative (UTR), although he has not received the required training. UTRs manage the subcontractor.

FS-1 was not in the immediate area when the arc flash occurred; there was no site supervision by SLAC over this hazardous job. Personnel from the Environment, Safety, and Health (ES&H) Division were not present, as this organization monitors work on a random basis. Consequently, there was no SLAC safety professional involvement with this event. Interviews with other SLAC employees and managers indicated that this approach to work is prevalent in the SE&M. Bay Span, the subcontractor, provided no oversight. The injured Bay Span foreman was not wearing clothing or PPE appropriate for electrical work at the time of the accident.

The DOE SSO put safety and health performance criteria in the SLAC contract in response to previous safety problems. The thrust of the performance criteria is the full implementation of the ISM System. This investigation determined that violations of all seven ISM Guiding Principles and all five ISM Core Functions led to this accident. Table ES-1 identifies the Board's conclusions and the resulting Judgments of Need.

Table ES-1. Conclusions and Judgments of Need

Conclusions	Judgments of Need
There was no justification for installing the breaker in energized Panel 4P20R. Neither SLAC nor Bay Span fulfilled Title 29 Code of Federal Regulations (CFR), Part 1910.132 hazard assessment requirements for the breaker installation being attempted at the time of the accident. SE&M's and Bay Span's practices regarding working on or near energized electrical equipment violated the provisions of 29 CFR 1910.333(a)(1). Neither SE&M nor Bay Span management ensured that the Bay Span Electrician (BSE)-1, BSE-2, or BSL used electrical protective equipment appropriate for the specific parts of the body to be protected from arc flash hazards. This failure violated the provisions of 29 CFR 1910.335(a)(1)(i). BSE-1 meets 29 CFR 1910.332(b)(3) training requirements to be a "qualified person." Based on BSL's testimony, BSL is an "unqualified person." Given SE&M's and Bay Span's decision to install the circuit breaker with Panel 4P20R energized, they failed to identify other safety-related work practices (such as those included NFPA 70E) to protect the employees who were exposed to the electrical hazards involved. This failure violated the provisions of 29 CFR 1910.333(a)(2). The breaker installation that FS-1 directed BSE-1 to accomplish was work covered under 29 CFR 1910.331(a). In that context, BSE-1 was a qualified person and BSL was an unqualified person. The tool BSE-1 used at the time of the accident violated 29 CFR 1910.335(a)(2)(i) because the screwdriver being used at the time was not insulated. When an installation problem developed, BSE-1's options for diagnosing the problem were limited by the fact that the panel was energized.	**JON 1:** SLAC needs to enforce applicable Occupational Safety and Health Administration (OSHA) standards and all sections of National Fire Protection Association (NFPA) Standard 70E. **JON 2:** SLAC needs to ensure that SLAC's employees who work on or near exposed energized electrical conductors are trained on the implementation of electrical safety-related work practices. **JON 3:** SLAC needs to verify that subcontractor employees who work on or near exposed energized electrical conductors are trained on the implementation of electrical safety-related work practices. **JON 4:** SLAC and subcontractor supervisors and managers need to receive the same training as the workers.
Despite receipt of the lowered annual assessment rating and SSO's interaction with the SLAC ES&H Department and Director, SLAC has not responded with implementation of sound work planning and hazard control processes. SSO has not been effective in creating a "safety first" approach within SLAC.	**JON 5:** SSO needs to exercise the existing SLAC contract clauses, terms, and conditions that hold SLAC accountable for unacceptable safety performance, including stop work authority or the embargo of funds until SLAC demonstrates satisfactory electrical safety performance.
SLAC's policies, procedures, and contracting practices regarding subcontractor worker protection are not consistent with the OSHA safety electrical standards.	**JON 6:** SSO needs to ensure that legal interpretations by SLAC to establish each employer's worker protection responsibilities are consistent with OSHA's interpretations on multiemployer workplaces.

<table>
<tr><th>Conclusions</th><th>Judgments of Need</th></tr>
<tr><td>Since the Bay Span workers' tenure at SLAC is closely tied to satisfying the UTR, a situation exists where workers might willingly take risks in order to demonstrate productivity and thus continue to work at the high wages.

Bay Span employees BSE-1, BSE-2, and BSL contributed to this accident by failing to follow NFPA 70E, the terms of the Bay Span subcontract, and the guidance contained in the Bay Span employee handbook.

Because FS-1 met with BSE-1 to give him verbal instruction to perform the hot work, FS-1 was aware of the way BSE-1 was dressed. FS-1 failed to enforce the SLAC's contract requirements, and he failed to implement the SLAC/Bay Span safety processes (i.e., a PWHA and an approved hot work permit).</td><td>JON 7: SLAC needs to revise the contracting process to ensure that subcontractor workers can protect themselves from SLAC-related hazards in the same way that SLAC workers protect themselves. The terms and conditions of subcontracts should not encourage workers to take risks.</td></tr>
<tr><td>Documented safety processes are not effectively implemented.

Unsafe conditions and operations have become accepted as a part of the everyday way of doing business.

Problems with electrical safety, particularly electrical hot work, are known within the ES&H and SE&M organizations.

The SLAC line organizations have been resistant to safety oversight, which should have elevated electrical safety work practice deficiencies to SLAC management's attention for correction.

The work being done at the time of the accident violated every ISM Core Function and every ISM Guiding Principle. It also failed to provide worker protection in accordance with NFPA 70E.</td><td>JON 8: The SLAC Director needs to balance the priorities between operations and safety to:
Evaluate whether it is appropriate for the Technical Division to be responsible for scheduling Linear Accelerator (LINAC) operations and safely maintaining the LINAC infrastructure.
Achieve effective, proactive ES&H Division involvement.
Encourage SE&M employees to work safely and to exercise their stop work authority.</td></tr>
<tr><td>Within SE&M, the ISM Core Functions and Guiding Principles are not being followed and have effectively no impact because operations are placed above safety concerns.

Problems with electrical safety, particularly electrical hot work, are known within the ES&H and SE&M organizations.

The Electrical Safety Action Plan, Stanford Linear Accelerator Center identifies many of the same deficiencies identified in this investigation report.</td><td>JON 9: SLAC needs to develop and implement safety oversight programs designed to identify deficient electrical work practices and correct them in a timely manner that achieves continuous improvement.</td></tr>
<tr><td>The Electrical Safety Action Plan, Stanford Linear Accelerator Center identifies many of the same deficiencies identified in this investigation report.</td><td>JON 10: SSO needs to develop and implement safety oversight programs designed to identify deficient electrical work practices and correct them in a timely manner that achieves continuous improvement.</td></tr>
<tr><td>SLAC's emphasis on the scientific mission as a means to secure funding from the Office of Science and compete with other laboratories reached FS-1's level as direction to "just get the job done."</td><td>JON 11: The SLAC Director needs to ensure that employees at all levels fully understand that concern for mission accomplishment does not outweigh the need for safe operations.</td></tr>
</table>

Conclusions	Judgments of Need
SSO has not filled an existing vacant safety and health position. SSO could make more effective use of Oak Ridge Operations Office support.	**JON 12:** SSO needs to do a workload study to determine the resource level and skills mix necessary to fulfill their safety responsibilities.
SLAC's site readiness to prepare for a DOE accident investigation has improved.	No action required.
The emergency medical response was timely and well managed.	No action required.

This page intentionally left blank.

1.0 BACKGROUND

The organizations involved in this event were the DOE Stanford Site Office (SSO); Stanford University, which operates the Stanford Linear Accelerator Center (SLAC); and its subcontractor, Bay Span, Inc. (Bay Span). A brief description of each organization is provided in this section.

1.1 SLAC Facility Description

SLAC is a federally-funded basic research and development facility and operates under the programmatic direction of the U.S. Department of Energy (DOE) Headquarters' Office of Science. SLAC comprises numerous federally-owned facilities situated on land owned by Stanford University. The SLAC program centers on experimental and theoretical research in elementary particle physics using electron beams and a broad program of research in atomic and solid-state physics, chemistry, biology, and medicine using synchrotron radiation. The total SLAC staff numbers approximately 1,200, of which 150 are physicists with doctorate degrees. Each year, approximately 3,000 scientists from academic and industrial concerns in 20 countries are active in the high-energy physics and synchrotron radiation program. The Stanford University operates the site under contract with DOE.

SLAC is located just west of Highway 280 in Menlo Park, California. SLAC occupies 426 acres of Stanford-owned land in Menlo Park, California, which is leased to DOE at no cost. The SLAC property was first provided on a 50-year lease to the Atomic Energy Commission in 1962. The main research instrument, which is the 3.2 kilometer-long Linear Accelerator (LINAC) that generates high-intensity beams of electrons and positrons, began operations in 1966. The accident occurred in Sector 20 of the Klystron Gallery of the LINAC. (See Figure 1-1.)

1.2 DOE Stanford Site Office

The DOE SSO provides oversight of SLAC's activities and implements DOE's contract with SLAC. In addition, the DOE Oak Ridge Operations Office (ORO) is available to provide Environment, Safety, and Health (ES&H) oversight and technical support to SSO.

1.3 Stanford Linear Accelerator Center

Stanford University operates SLAC on behalf of DOE under a management and operating contract. Stanford University receives no fee for managing SLAC and does not charge DOE a rental fee for the 426-acre SLAC leasehold. For the purposes of this report, the term "SLAC" refers to Stanford University in this capacity. SLAC's mission can be summarized as follows:

- Perform and support world-class research in high-energy physics, particle astrophysics, and disciplines using synchrotron radiation.
- Provide accelerators, detectors, instrumentation, and support for national and international research programs in particle physics and scientific disciplines that use synchrotron radiation.
- Advance the art of accelerators and accelerator-related technologies and devices through the development of new sources of high-energy particles and synchrotron radiation, plus new techniques for their scientific utilization.
- Transfer practical knowledge and innovative technology to the private sector.
- Contribute to the education of the next generation of scientists and engineers and to the scientific awareness of the public.

The Technical Division is one of six divisions at SLAC. The Site Engineering & Maintenance Department (SE&M) is part of the Technical Division. The other divisions are the Stanford Synchrotron Radiation Laboratory (SSRL), the Research Division, the Business Services Division, ES&H Division, and the Linear Coherent Light Source Division.

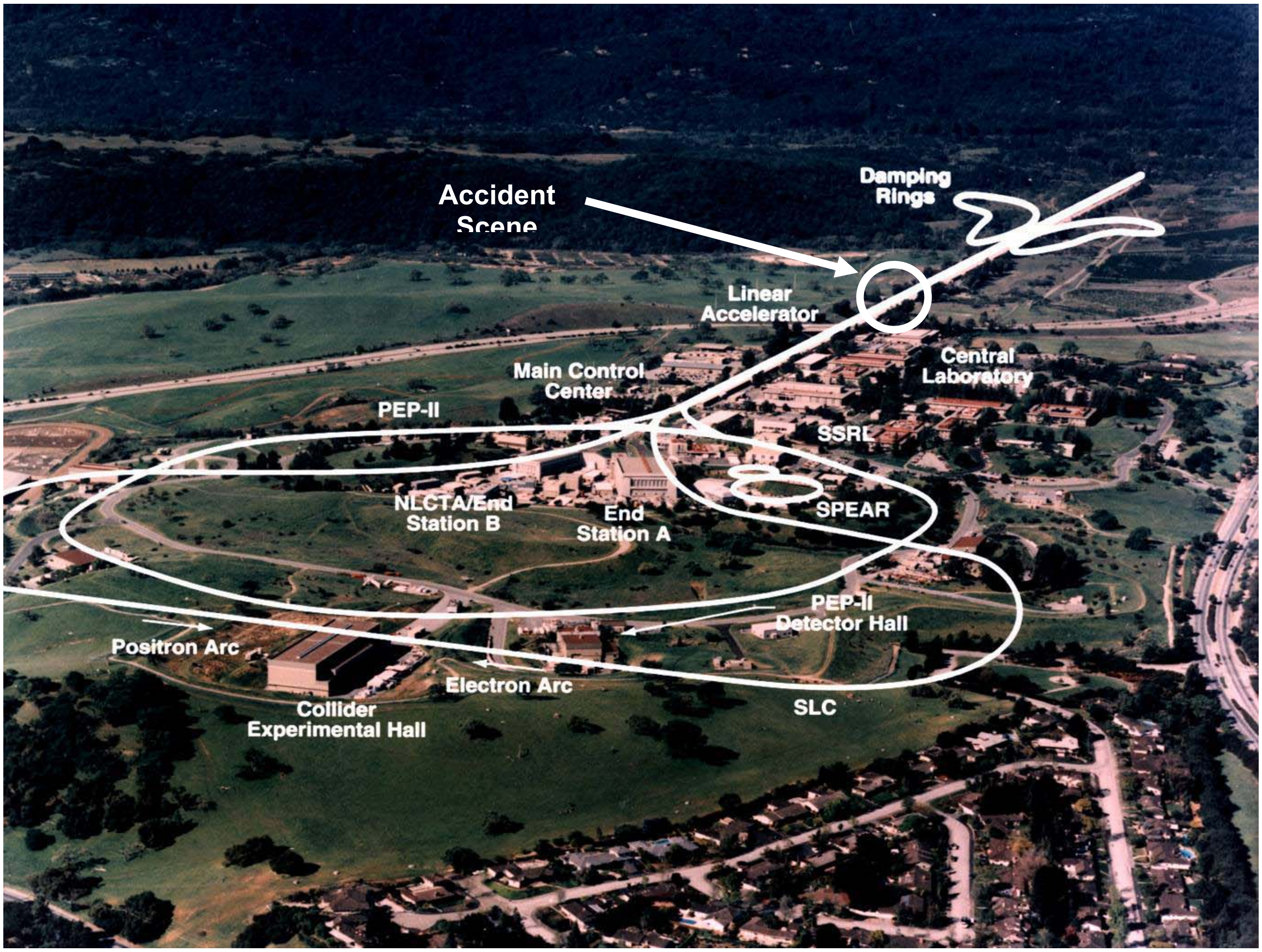


Figure 1-1. Stanford Linear Accelerator Center with Accident Scene Marked

1.4 Bay Span, Inc.

Bay Span is a woman-owned, small business that provides construction and maintenance labor services to SLAC and private industry companies in Northern California. The electrician who was injured in the October 11, 2004, accident is a Bay Span employee. Bay Span is a nonunion company; however, the work performed for SLAC is covered under the Davis-Bacon Act.

1.5 Scope and Methodology

The Accident Investigation Board (Board) was appointed on October 15, 2004. The scope of the Board's investigation was to identify all relevant facts; analyze the facts to determine the direct, contributing, and root causes of the accident; develop conclusions; and determine Judgments of Need (JONs). (See Figure 1-2 for an explanation of accident investigation terminology).The investigation was performed in accordance with DOE Order 225.1A, *Accident Investigations,* using the following methodology:

- The accident scene was inspected, physical evidence was collected, and photographs were taken of the scene.
- Facts relevant to the accident were gathered through interviews, reviews of documentation, and examination of the physical evidence.
- The facts were analyzed to identify the causal factors using event and causal factors analysis, barrier analysis, root cause analysis, and change analysis.
- Conclusions and JONs were developed to guide the development of corrective actions that, if implemented, should prevent recurrence of similar accidents.

Accident Investigation Terminology

A **causal factor** is an event or condition in the accident sequence that contributes to the unwanted result. There are three types of causal factors: **direct cause(s)**, which is the immediate event(s) or condition(s) that caused the accident; **root cause(s)**, which is the causal factor that, if corrected, would prevent recurrence of the accident; and the **contributing causal factors**, which are the causal factors that collectively with the other causes increase the likelihood of an accident but which did not cause the accident.

Event and causal factors analysis includes charting, which depicts the logical sequence of events and conditions (causal factors that allowed the accident to occur), and the use of deductive reasoning to determine the events or conditions that contributed to the accident.

Barrier analysis reviews the hazards, the targets (people or objects) of the hazards, and the controls or barriers that management systems put in place to separate the hazards from the targets. Barriers may be physical or administrative.

Change analysis is a systematic approach that examines planned or unplanned changes in a system that caused the undesirable results related to the accident.

Figure 1-2. Accident Investigation Terminology

This page intentionally left blank.

2.0 ACCIDENT DESCRIPTION AND CHRONOLOGY OF EVENTS

2.1 Accident Description

On the morning of October 11, 2004, a SLAC Field Supervisor (FS-1) directed a Bay Span Electrician (BSE-1) to install a circuit breaker in energized electrical circuit breaker Panel 4P20R. Panel 4P20R is a 480 Volt (V) electrical supply panel in Sector 20 of the LINAC Klystron Gallery. FS-1 provided direction to BSE-1 as a University Technical Representative (UTR). FS-1 provided BSE-1 with a circuit breaker. FS-1 had chosen Panel 4P20R because it had an available slot for an additional circuit breaker.

At approximately 11:15 am, BSE-1 was installing the circuit breaker and an arc flash occurred, igniting BSE-1's clothing. A Bay Span Laborer (BSL) serving as the backup to BSE-1 was standing two to three feet behind and to the right of BSE-1 and was knocked down by the arc flash pressure burst. Another Bay Span Electrician (BSE-2) was working approximately 14 feet away performing an unrelated task. BSE-2 heard a power surge and turned toward the area when the arc flash occurred. BSE-2 saw BSE-1 on the floor with his clothing on fire and rushed over to him. BSE-2 immediately removed his shirt and started to smother BSE-1's burning clothing. As soon as BSL got up, BSE-2 told him to call 9-911. BSL left the area and attempted to call 9-911.

Upon learning that notification had already been made, he immediately returned to the accident scene. BSL removed his own shirt and assisted BSE-2 in smothering BSE-1's burning clothing. BSE-2 and BSL continued to administer assistance until the on-site Palo Alto Fire Department (PAFD) emergency medical services personnel arrived at the scene at 11:20 am. The PAFD paramedics ensured that BSE-1 was stable and transported him to the Valley Medical Center Burn Unit in San Jose, California. The PAFD decided to use the ambulance as the quickest means of transportation after determining that the nearest medical evacuation helicopter was approximately 27 minutes away.

Table 2-1. Event Chronology Table

Date	Time	Event
10/29/1999		The Phase II Integrated Safety Management System (ISMS) verification report identifies weaknesses in hazard assessment and control development. (Core Functions 2 and 3)
FY2001		SLAC and SSO jointly performed four Integrated Safety Management (ISM) Quarterly Reviews.
FY2002		SLAC and SSO jointly performed two ISM Quarterly Reviews.
1/28/2003		A DOE Type B Accident Investigation was performed of the January 2003 fall injury at the SSRL.
4/2003		SLAC renewed the Bay Span subcontract.
2/11/2004		The *Environmental Health & Safety Independent Site Assessments for the Stanford Linear Accelerator Center* prepared by an independent consulting firm identifies deficiencies in electrical safety work practices.
4/2004		SLAC received the results of an Occupational Safety and Health Administration (OSHA) audit and began prioritizing the numerous electrical violations.
7/23/2004		SLAC completed its *Electrical Safety Action Plan, Stanford Linear Accelerator Center* in response to a request from the Chief Operating Officer for the Office of Science (SC-3) and identified unjustified work on energized electrical equipment.
8/2004		Electrical work associated with this accident started in early August. Discovery of a noncompliant circuit breaker terminal connection prevented the work from being completed. To correct the condition, one of the circuits needed to be removed and relocated to a circuit breaker in Panel 4P20R.
9/2004		An ORO team reviewed SLAC's progress in implementing JONs 1 and 2 from the Type B Accident Investigation at the SSRL.

Date	Time	Event
10/11/2004	7:00 – 11:15 am	FS-1 verbally directed BSE-1 to install a circuit breaker in energized Panel 4P20R. FS-1 also verbally directed BSE-2 and BSL to pull wire in Sector 20.
		BSE-1 began to install the circuit breaker alone. He was wearing a short-sleeved cotton/polyester shirt, leather gloves over V-rated gloves, safety glasses, and a hard hat. FS-1 had not obtained an approved electrical hot work permit. BSE-1 had not developed a documented Pre-Work Hazard Analysis (PWHA).
		BSE-2 observed BSE-1 working alone. BSE-1 had removed the deadfront panel cover. BSE-1 asked BSE-2 to act as his backup, and BSE-2 agreed.
		BSE-2 advised BSE-1 to get a rubber insulating floor mat. BSE-1 obtained a mat, laid it on the floor in front of the panel, and knelt on it.
10/11/2004	7:00 – 11:15 am	BSL returned from his break. BSE-2 asked BSL to take over as BSE-1's backup. BSL took up a position two or three feet behind and to the right of BSE-1. BSE-2 gave BSL a shop floor broom with a long wooden handle.
		BSL asked BSE-2 what was to be done with the broom. BSE-2 explained the purpose of the broom was to push BSE-1 away from the panel in case of electric shock. BSE-2 then returned to his assigned task nearby.
		BSL observed BSE-1 struggling to install the third screw.
		BSE-2 heard a power surge. An electrical arc flash occurred. BSE-1's clothing ignited, and he was blown away from the panel. BSL was knocked down.
		BSE-2 removed his shirt and began smothering BSE-1's burning clothing. BSE-2 told BSL to go call 9-911. BSL discovered a 9-911 call had already been made and returned to the scene. BSL removed his shirt to help BSE-2 smother BSE-1's burning clothing. FS-1 arrived at the scene.
		The PAFD received the 9-911 call.
	11:20 am	The on-site PAFD Engine 7 arrived at the accident scene.
	11:21:56 am	PAFD Engine 6 arrived at the accident scene.
	11:22 am	The SLAC Medical Officer and Security personnel arrived at the scene.
	11:27 am	Having ensured that BSE-1 was stable, the PAFD transported BSE-1 to the Valley Medical Center Burn Unit by ambulance.
	12:03:45 pm	BSE-1 arrived at the Valley Medical Center Burn Unit.

2.2 Emergency Response

The PAFD has a fire station on the SLAC site. Within the SLAC four-minute criteria established for emergency response, PAFD emergency response vehicles began arriving at the accident scene. PAFD emergency medical service providers had the capability of providing both basic and advanced life support.

The SLAC on-site Medical Officer and Security personnel arrived at the scene at 11:22 am. The SLAC Medical Officer observed PAFD's treatment of BSE-1 and described BSE-1 as lucid and ambulatory. SLAC Security took control of the accident scene.

The PAFD inquired about the availability of a helicopter ambulance and learned that the nearest helicopter support was still approximately 27 minutes away. The PAFD determined that the quickest means of transportation was their ambulance.

The Board concludes that the emergency medical response was timely and well managed.

2.3 Description of Injuries

BSE-1 received third degree burns on the face, chest, and legs and second degree burns on the arms, involving approximately 50% of his body. Because of the seriousness of BSE-1's condition, the Board was not able to interview him. BSL later received treatment by SLAC Medical for soreness in his back.

2.4 Photographic Record of the Accident Scene

The following photographs show the conditions at the accident scene.

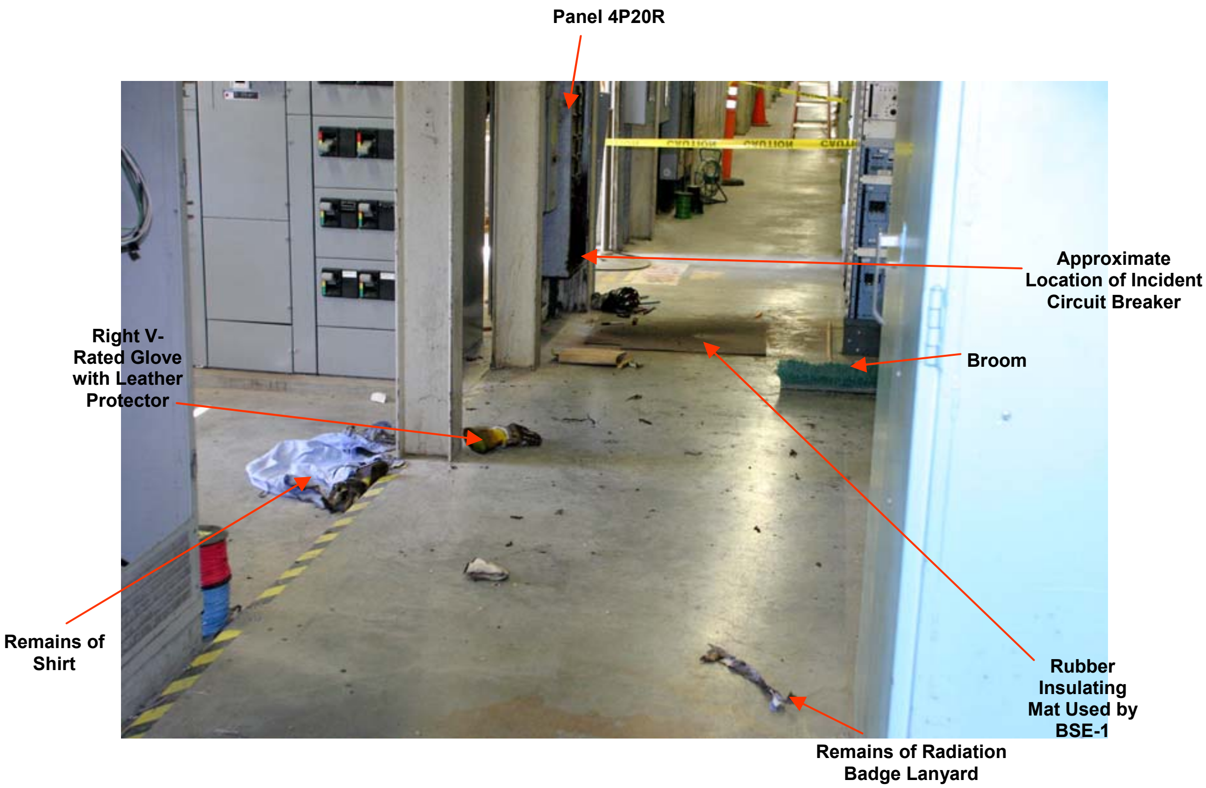
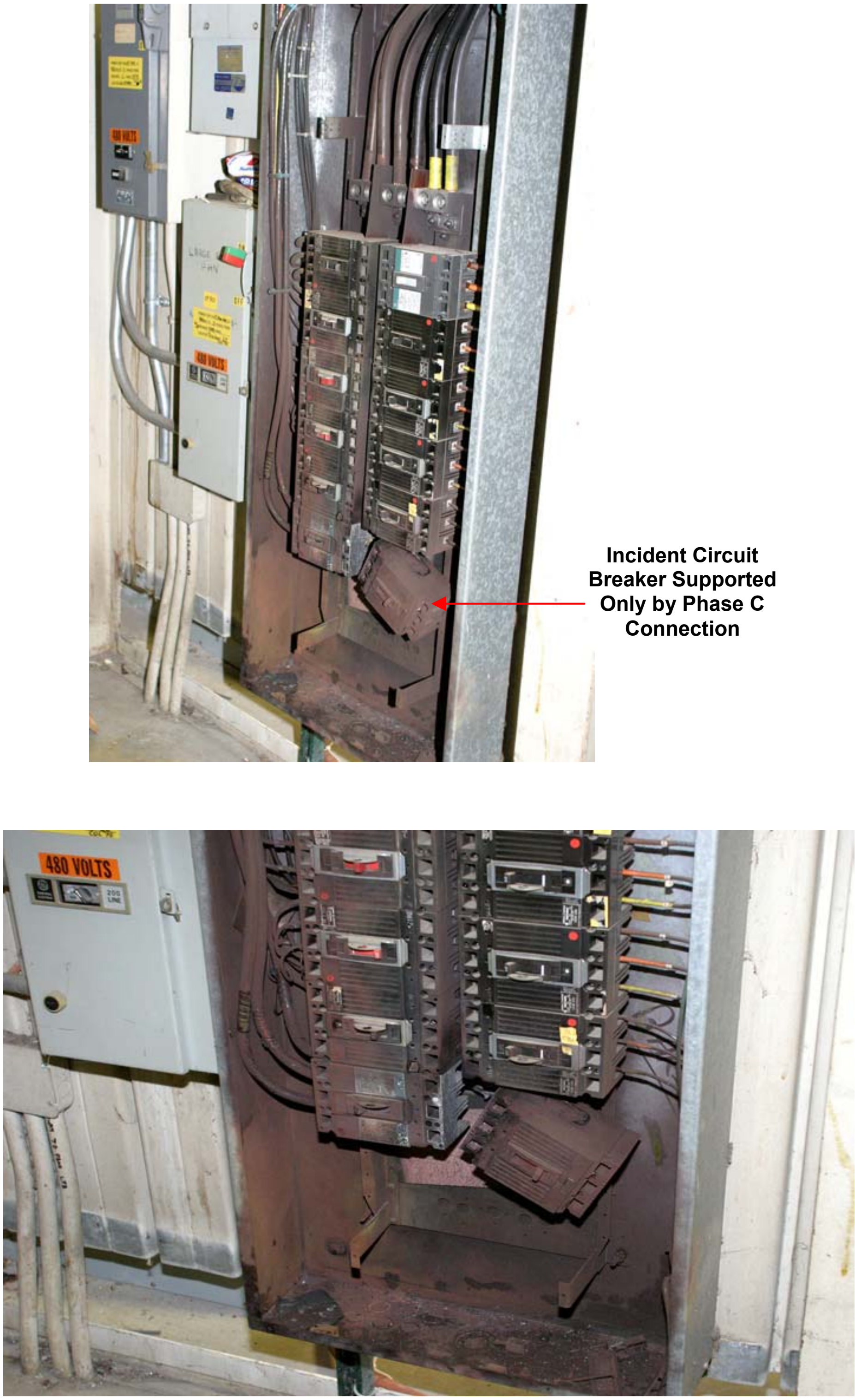


Figure 2-1. Scene immediately after the accident



Figures 2-2a and b. Panel 4P20R after the arc flash

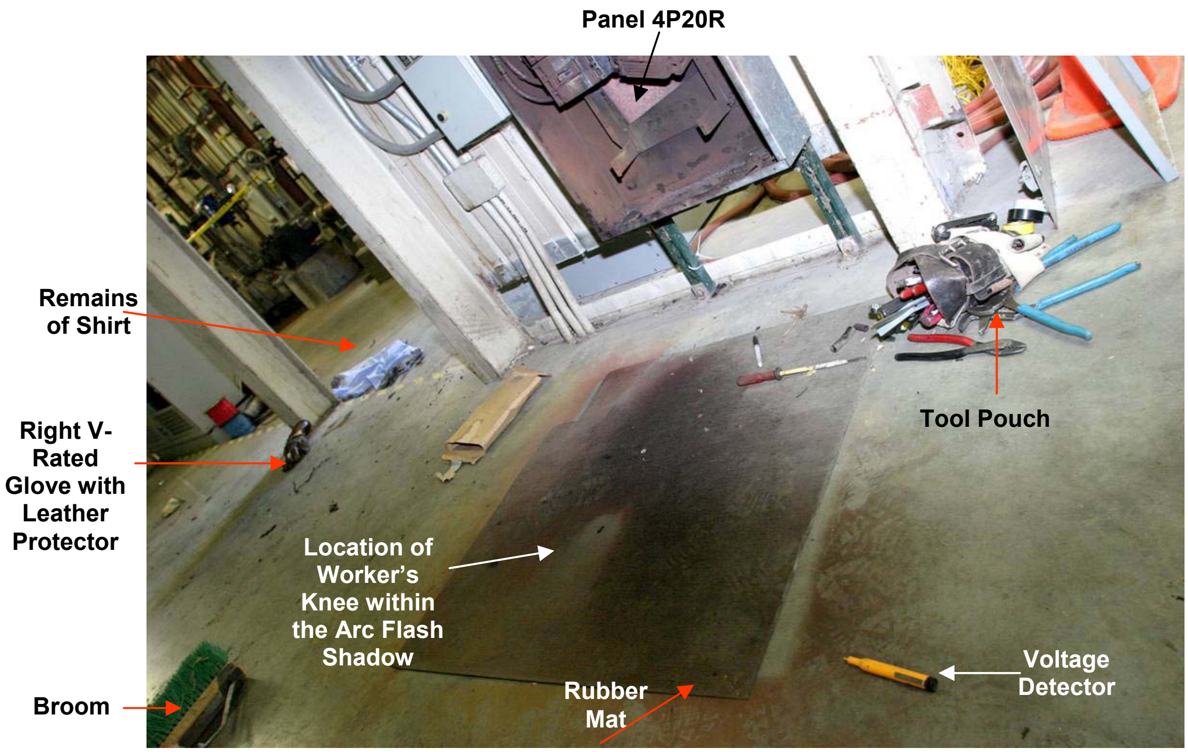


Figure 2-3. The insulating mat with the outline of BSE-1's knee in the arc flash shadow

Figure 2-4. Warning label on Panel 4P20R

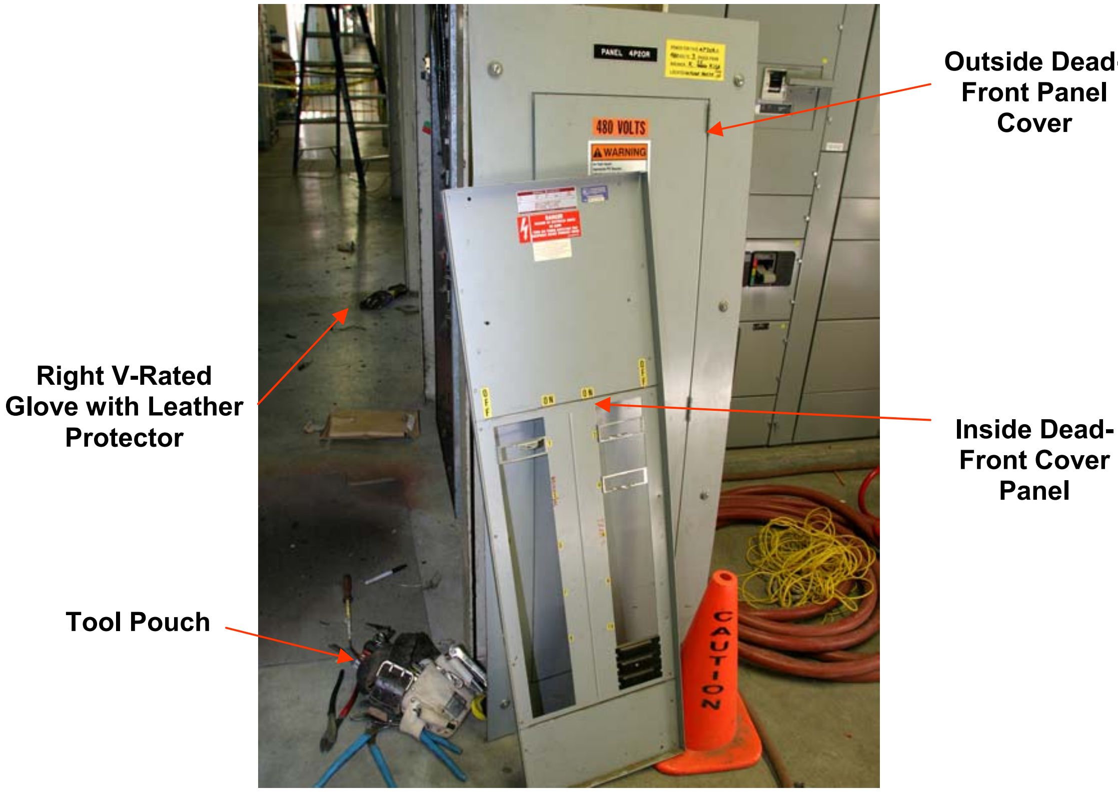


Figure 2-5. Both panel covers for the energized 480V panel

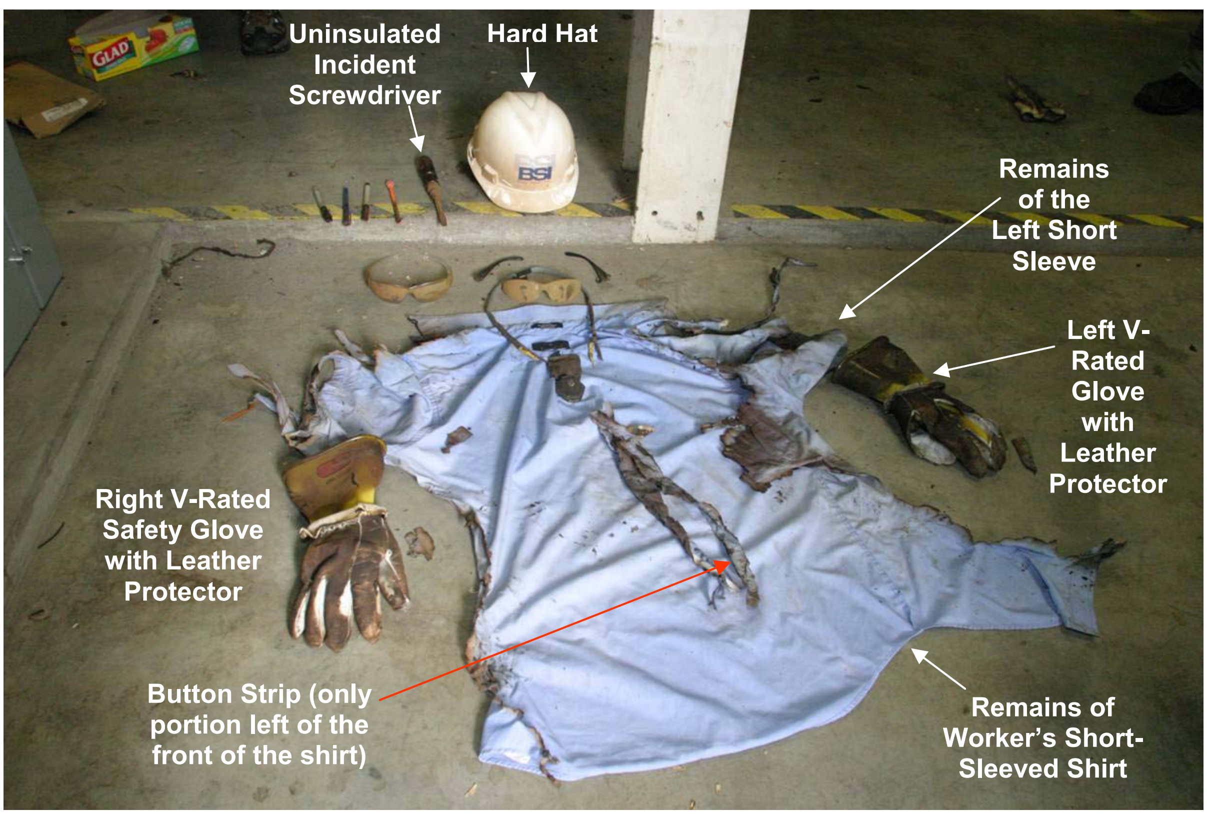


Figure 2-6. BSE-1's burned shirt and his flash-damaged PPE and tools

Figure 2-7. Closeup of BSE-1's burned cotton/polyester shirt

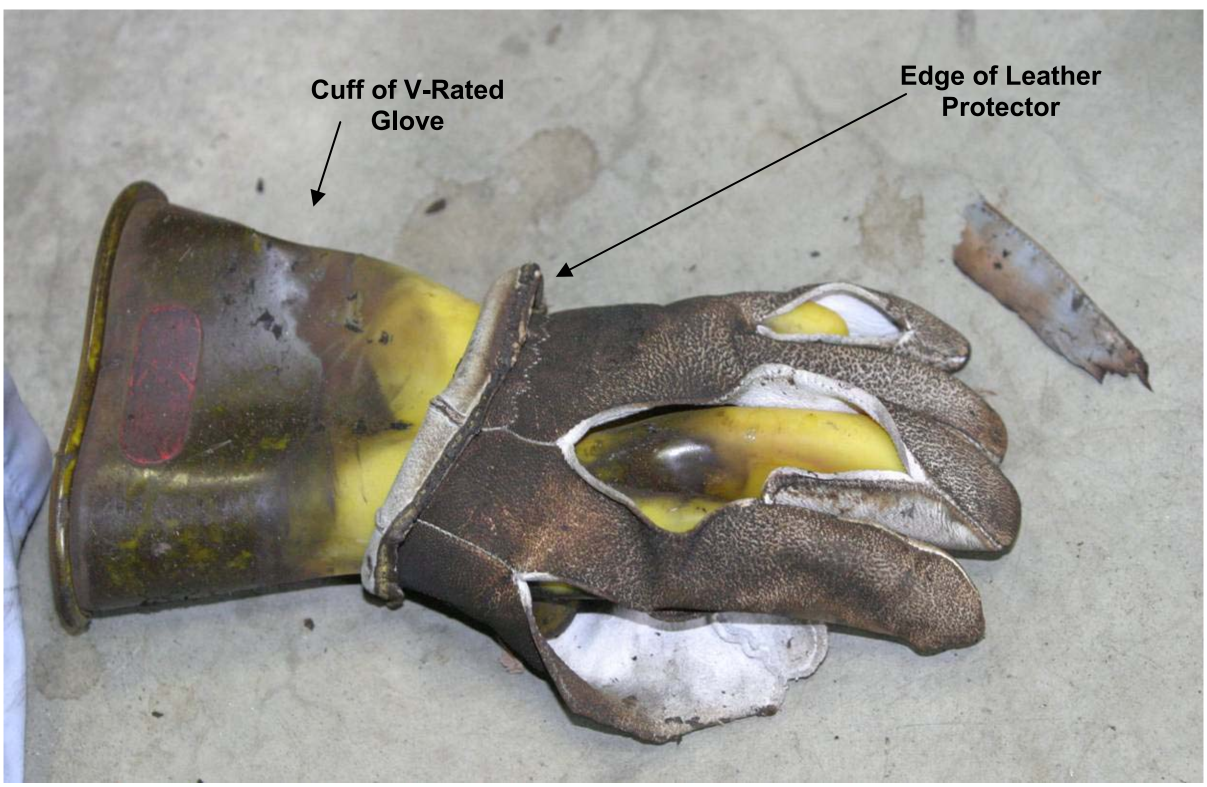


Figure 2-8. Closeup of one of BSE-1's burned gloves

Figure 2-9. Closeup of the screwdriver the Board believes BSE-1 was using when the arc flash occurred

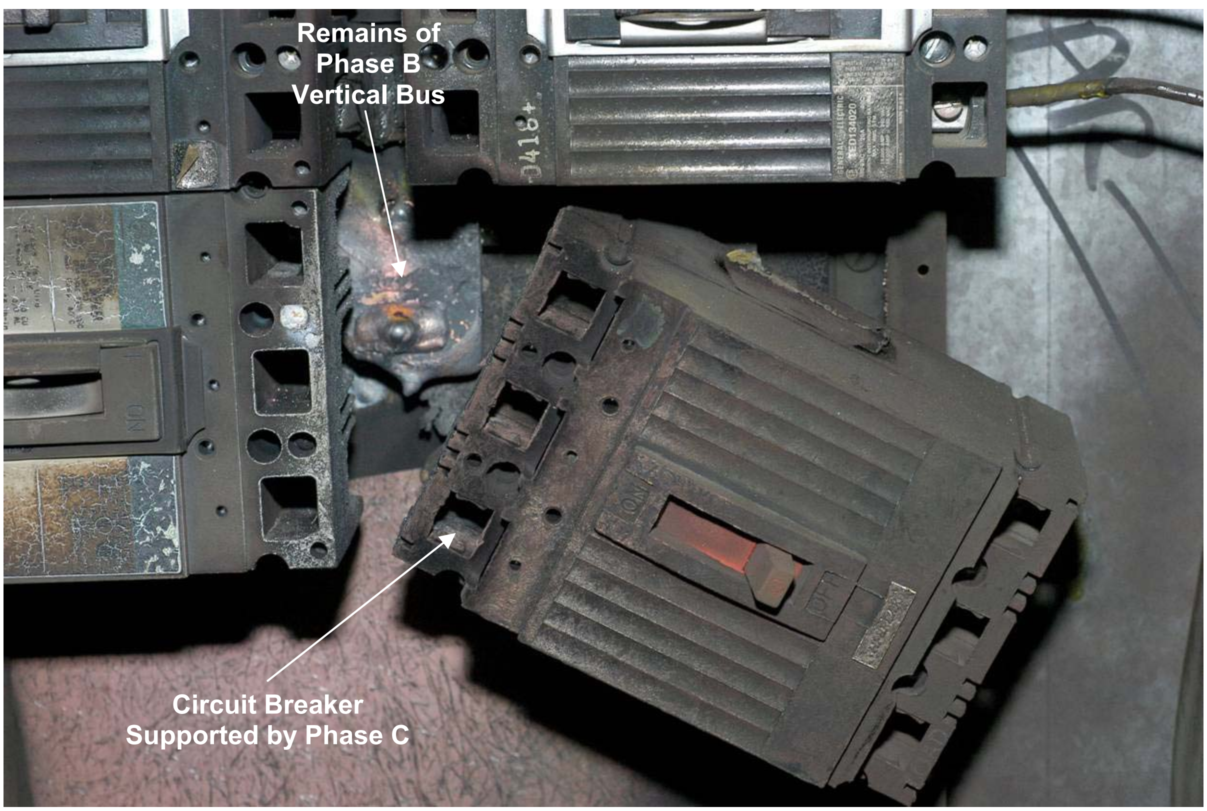


Figure 2-10. Closeup 1 of the damaged circuit breaker panel

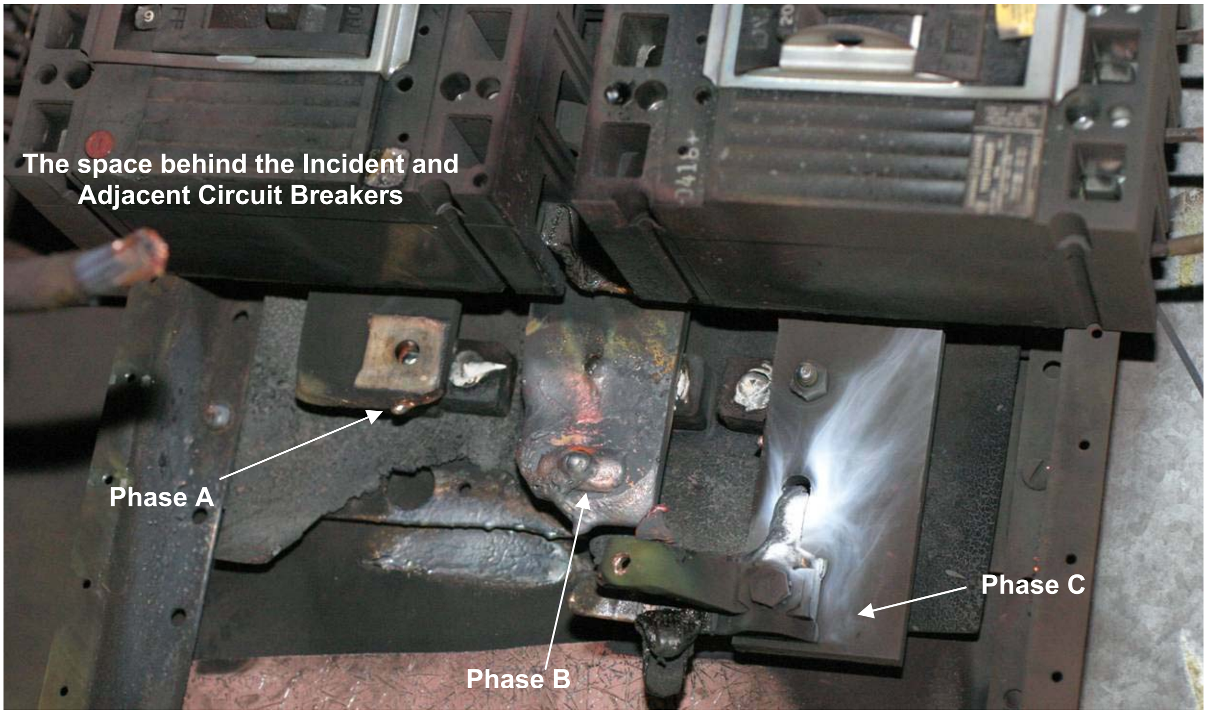


Figure 2-11. Closeup 2 of the damaged circuit breaker panel after removal of incident and adjacent circuit breakers

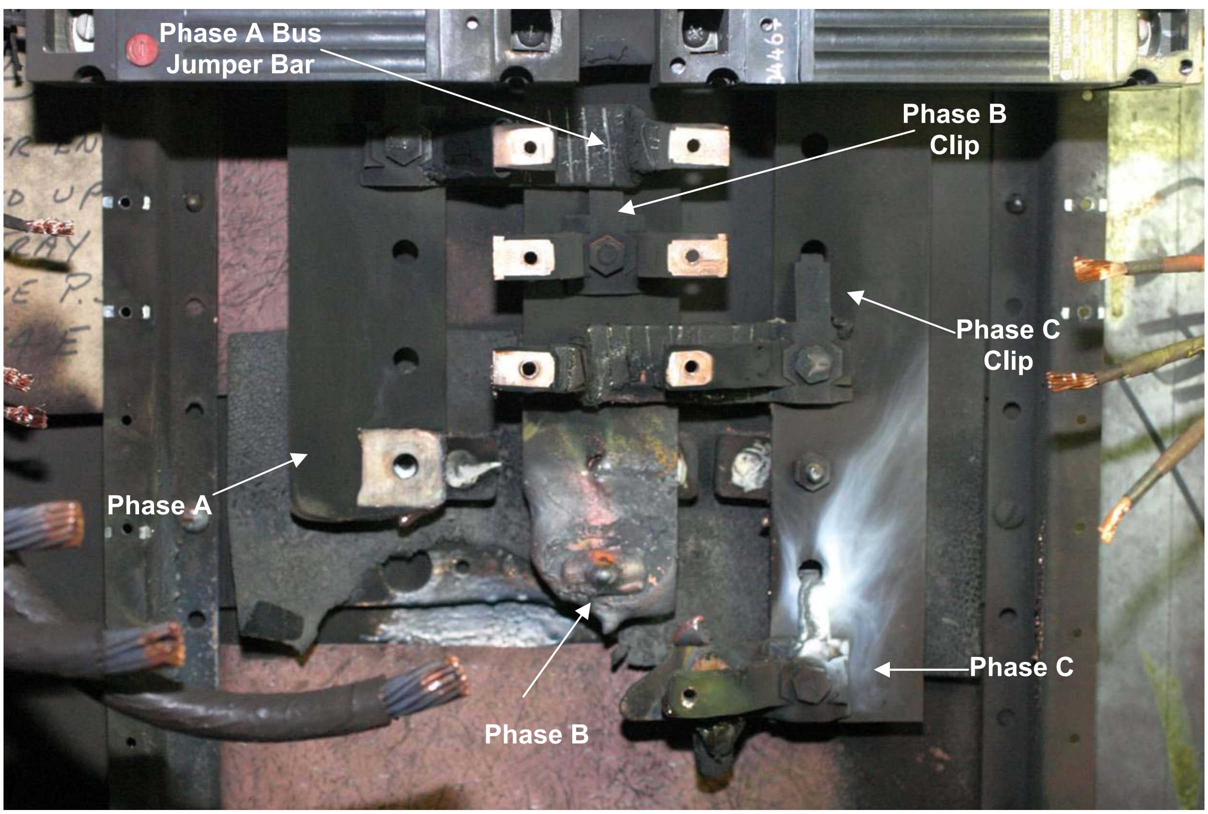


Figure 2-12. Circuit breaker panel after removal of the incident circuit breaker, adjacent circuit breakers, and the two circuit breakers above

2.5 SLAC Site Readiness Evaluation

The 2003 Type B Accident Investigation found that SLAC did not control the accident scene in order to preserve evidence. After this accident, SLAC did a much better job of preserving and photographing the accident scene. However, the Board learned that the SE&M Labor Coordinator authorized Bay Span to remove some of their storage facilities before the Board could verify the presence of FR clothing. BSE-1's keys were found in his pants but were not turned over to the Board as evidence.

The Board concludes that SLAC's site readiness to prepare for a DOE accident investigation has improved.

3.0 ACCIDENT ANALYSIS

3.1 Accident Reconstruction

3.1.1 Circuit Breaker Panel Design

Circuit breaker Panel 4P20R has three vertical 480V buses: phase A on the left, phase B in the center, and phase C on the right. Bus jumper bars are used to connect the circuit breakers to the buses (See Figure 3-1).

3.1.2 Reconstruction of BSE-1's Actions

A subcontractor journeyman electrician, BSE-1, was installing a circuit breaker into position 12 of 480V circuit breaker Panel 4P20R. The proper installation sequence would have been to install the mechanical connections first to stabilize the breaker before making the electrical connections. At the time of the accident, phases B and C had been connected, and BSE-1 was attempting to connect phase A. None of the mechanical connections had been made. BSE-1 was attempting to complete the phase A connection, but he had trouble getting the screw to hold the circuit breaker. The screw connects the circuit breaker to the bus jumper bar via a threaded hole.

During the Board's reconstruction of the accident, another journeyman electrician was directed to simulate BSE-1's actions (in de-energized Panel 4R20P) by installing a circuit breaker of the same type in the position directly above the incident circuit breaker. This position was selected because the bus was not damaged at this location by the arc flash. The Board believes that BSE-1 connected the phases in this sequence: phase C (bottom) first, phase B (middle) second, and phase A (top) last. Two bolts should have been used to make the mechanical connection, but these were not installed on the incident circuit breaker, so they were not used for this simulation. The electrician had no difficulty installing the circuit breaker for this simulation.

There are several possible reasons to explain why BSE-1 had trouble getting the screw to hold: damaged threads at the tip of the screw; damaged threads in the threaded hole on the bus link; the bus jumper bar may have been slightly misaligned; or the circuit breaker may have been slightly

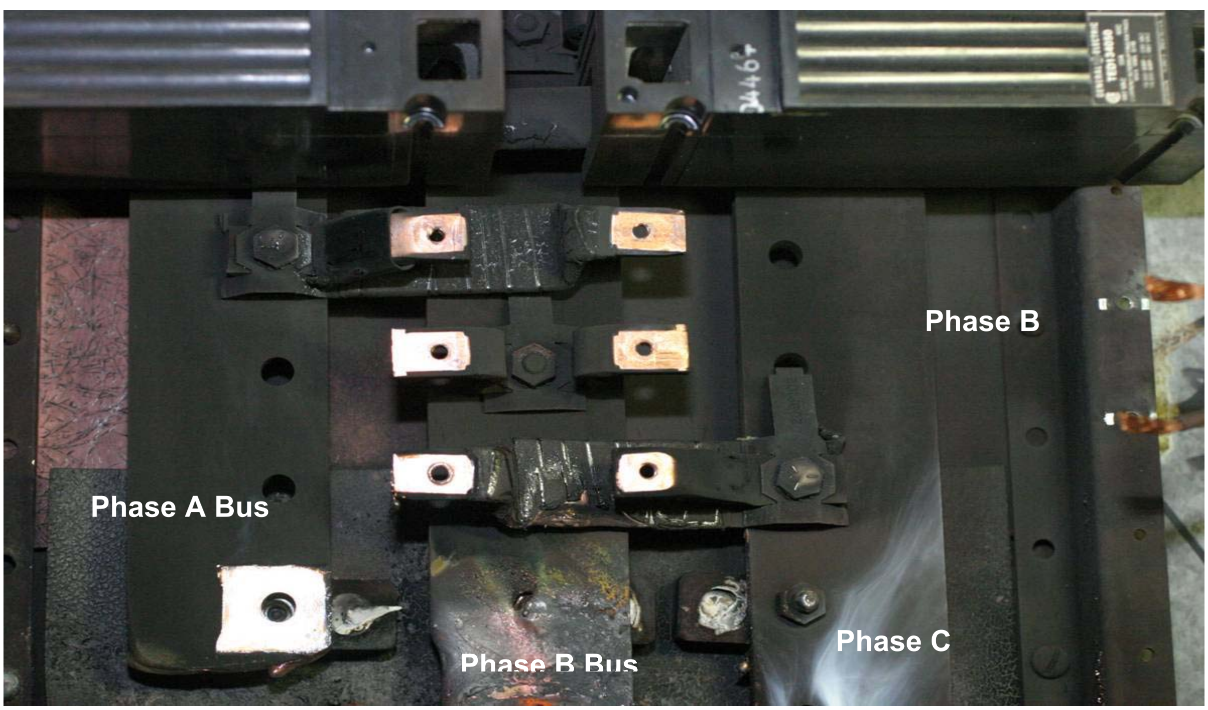


Figure 3-1. Circuit breaker panel after removal of the incident circuit breaker and the three surrounding circuit breakers

misaligned. The Board believes that BSE-1 was pushing with the screwdriver harder than would normally be required in order to engage the threads on the bus link when the arc flash occurred.

The Board concludes that when an installation problem developed, BSE-1's options for diagnosing the problem were limited because the panel was energized.

3.1.3 Failure Analysis

When the phase A screw failed to engage the bus jumper bar and BSE-1 applied additional force to engage it, the phase A bus jumper bar (which is supported at the bus for phase A in a cantilever fashion) deflected toward the phase B stabilizing clip. This additional force caused the stabilizing clip to contact the phase A bus jumper bar and compressed the rubber insulation.

Compressing the insulation with the clip increased the electric field stress in the insulation in two ways. First, it decreased the distance over which the electric field was distributed. Second, it further increased the field intensity in the region of the sharp edges of the clip. The Board believes that the increase in electric field stress could cause a failure of the insulation and result in an arc flash. (See Figure 3-2.)

During the Board reconstruction, the aforementioned journeyman electrician was asked to push directly on the bus jumper bar with a screwdriver as a simulation of the event to see if he was able to make the bus jumper bar contact the clip. He was able to do so with what appeared to be a moderate amount of force.

A post-accident inspection of the rubber mat that the BSE-1 was using as an insulated work platform revealed the arc flash geometry. The arc image is roughly cone shaped, with an angular dispersion of approximately 80 degrees. There is a small clear area that shows no sign of arc damage. Because BSE-1 was kneeling at the time of the arc flash, the clear area is probably an image of BSE-1's left thigh and knee. BSL was standing behind and to the right of BSE-1. BSL received little incident energy but sufficient arc blast pressure to knock him off his feet.

The arc flash was initiated behind the incident circuit breaker. The circuit breaker acted as a partial blast shield and directed a significant portion of the arc flash and arc blast downward and outward. This could explain why BSL received little arc flash but enough arc blast energy to knock him off his feet. The leather protector over BSE-1's V-rated gloves burned and ripped open at several locations. This is because the gloves were closer to the arc blast than the rest of his body. Figure 3-3 lists the protective clothing and PPE that BSE-1 should have been wearing at the time of the accident.

3.2 Arc Flash Hazard

Installing a 480V, 30-amp, 3-pole, molded case circuit breaker in an energized 480V panel exposes workers to the risk of shock or an arc flash. An arc flash is the result of an electrical short circuit and has the potential to cause serious and even fatal injuries to the electrician or those nearby.

When an arc flash occurs the temperatures can reach 35,000° Fahrenheit (F). Exposure to these extreme temperatures burns the skin and causes ignition of clothing, which adds to the burn injury. The majority of hospital admissions due to electrical accidents are from arc flash burns, not from shocks. Each year more than 2,000 people are admitted to burn centers with severe arc flash burns. Arc flashes can and do kill at distances of 10 feet.

An arc blast results from the tremendous temperatures of the arc and causes the explosive expansion of both the surrounding air and the metal in the arc path. For example, copper expands by a factor of 67,000 times when it turns from a solid to a vapor. The danger associated with this expansion is one of high pressures, sound, and shrapnel. The high pressures can easily exceed hundreds or even thousands of pounds per square foot, knocking workers off ladders, rupturing ear drums, and collapsing lungs. The peak sound pressure level can exceed 160 decibels. Finally, material and molten metal are expelled away from the arc at speeds exceeding 700 miles an hour, fast enough for shrapnel to completely penetrate the human body.

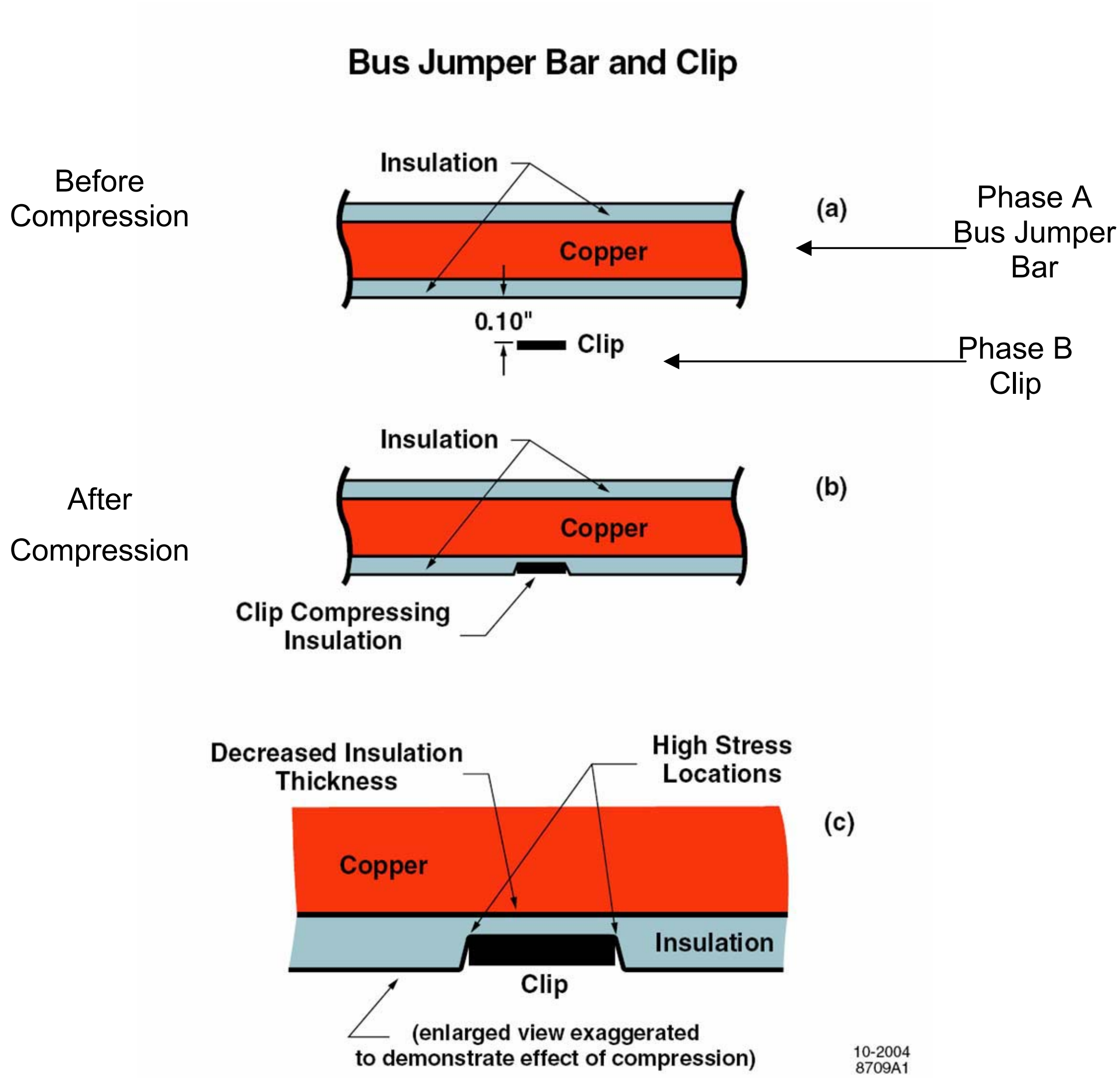


Figure 3-2. The effect of contact between the bus jumper bar and the clip (not to scale)

Clothing will ignite at a range of 400° to 800° Celsius (C). The victim is subject to direct contact of the flame temperature of the cloth, or about 800°C. An incurable burn results from a temperature of 80 to 96°C at the base of the epidermis for 0.1 second or longer. ("The Other Electrical Hazard: Electric Arc Blast Burns" by Ralph H. Lee, *IEEE Transactions on Industrial Applications*, Volume IA-18, No. 3, May/June 1982, Pages 250-251.)

List of PPE and Protective Clothing that BSE-1 Should Have Been Wearing

NFPA 70E Task Hazard Risk Category: 2*

Protective Clothing and Personal Protective Equipment Required:

- V-rated gloves with leather protectors
- V-rated tools
- Nonmelting or untreated natural fiber T-shirt and underwear
- FR pants (8 calorie/cm2) – Or, FR coverall over cotton long-sleeved shirt and pants
- FR shirt (8 calorie/cm2) – Or, FR coverall over cotton long-sleeved shirt and pans
- Safety glasses
- Double-layer switching hood (with FR face shield)
- Hearing protection
- Leather work shoes

See the photographs in Figures 3-4 and 3-5.

Figure 3-3. List of protective clothing and PPE that BSE-1 should have been wearing

Figure 3-4. Worker wearing the correct protective clothing and PPE

Figure 3-5. Worker wearing the eye and hearing protection to be worn under the double-layer switching hood

This page intentionally left blank.

4.0 MANAGEMENT SYSTEMS EVALUATION

4.1 Contracting Practices, Roles, and Responsibilities

4.1.1 DOE Stanford Site Office Roles and Responsibilities

The DOE SSO functional roles and responsibilities are stated in the Office of Science draft "Management System Description" and SSO's draft "Contract Management Plan." SSO's roles include the following:

- Identifying requirements
- Implementing policy
- Advising SC-3 of inconsistencies or areas of conflict
- Providing input on the requirements the site will require from Support Offices
- Providing program guidance and funding to the contractor
- Providing infrastructure and on-site project/program oversight, as required
- Providing on-site ES&H and security oversight
- Providing on-site emergency preparedness management
- Providing on-site state, local, and public interactions and addressing concerns from these entities

SSO is also expected to be closely involved in the contractor's ISMS approval and configuration control process and in the contractor's self-assessment validation process. In executing their oversight role, SSO is required to perform critical, honest self-assessments; perform line management reviews of the contractor (such as inspections, surveillances, surveys, and walkthroughs); examine the contractor's management systems; and check the validity of the contractor self-assessments and independent oversight reviews and the closure of associated corrective actions.

The SSO Manager performs the DOE line management function. SSO provides guidance to the contractor in program execution, including ES&H. SSO is responsible for establishing performance measures in the contract. SSO is also responsible for verifying, validating, and approving SLAC's self-assessments.

In response to previous safety problems at SLAC, SSO has included significant safety performance measures in the contract to emphasize the importance of the ISM Core Functions and Guiding Principles. According to SSO personnel, despite numerous safety issues identified during the previous full appraisal period, SLAC rated their performance as "Outstanding" in their annual self-assessment; however, SSO lowered the rating to "Excellent." In order to effect change, the contract also allows SSO to exercise stop work authority or embargo SLAC's funds.

In the ES&H area, the SSO Manager is currently assisted by a single staff person whose time is split between working on a critical, long-term environmental issue and working safety issues. Another ES&H staff position has been requested but has not been filled. The SSO Manager can also obtain safety and health assistance from the DOE Chicago Office or ORO. The SSO Manager expressed a concern to the Board about the level of on-site staffing in the safety area; he has requested authorization to hire an additional person to fill an on-site safety position. ORO performed two on-site reviews during calendar year 2004.

The Board concludes that SSO has not filled an existing vacant safety and health position.

The Board concludes that SSO could make more effective use of ORO support.

The Board concludes that the DOE SSO has not been effective in creating a "safety first" approach within SLAC. Despite receipt of the lowered annual assessment rating and SSO's involvement with the SLAC ES&H Department and Director, SLAC has not responded with implementation of sound work planning and hazard control processes.

4.1.2 SLAC's Roles and Responsibilities

The SLAC contract is a management and operating, performance-based, no-fee contract. Appendices to the contract identify the appropriate OSHA and National Electric Code (NEC) requirements. The contract contains a clause which states that the safety and health requirements listed in the Work Smart Standards (WSS) set are to flow down to any subtier contractor. The Board has determined that the WSS set in the DOE-SLAC contract correctly identifies the safety standards from OSHA, the NEC, and NFPA 70E that are applicable to this accident. However, the Board concludes that the WSS set is not being fully implemented within SLAC.

The contract requires SLAC to fully implement ISM. Within SLAC, the Laboratory Director has assigned implementation of ISM to the ES&H Assistant Director. Line management is responsible for safe operations in the areas under their control, and dedicated safety employees are assigned to the line organizations. The accident occurred in an area under the SE&M's control. The SE&M reports to the Technical Services Assistant Director, so the SE&M is a support organization reporting to a line position. The Technical Services Assistant Director is responsible for LINAC operations.

The Board concludes that the ineffectiveness of ISM in certain divisions within SLAC has been a long-term and continuing problem. It appears that SLAC has consistently placed operations ahead of safety.

SLAC has documented processes for electrical hot work. These processes range from hazard analysis and electrical hot work permitting to the qualification of those overseeing or performing the work, regardless of whether the work is performed in-house or by a subcontractor. A 2004 review of safety processes performed by ORO found that the safety processes (Job Hazard Analysis and Mitigation [JHAM] and Area Hazard Analysis) are documented. The Board concludes that the documented safety processes are not effectively implemented by the SE&M.

On July 23, 2004, SLAC issued an electrical safety report (*Electrical Safety Action Plan*, *Stanford Linear Accelerator Center*) in response to SC-3's request for a review of electrical safety. This report states that 23 out of 31 times during a 90-day period in 2004, work was performed on energized circuits when it was unnecessary to do so. This report was issued seven months after an OSHA inspection that identified numerous electrical violations. The OSHA report was preceded by a SLAC subcontract review of electrical issues in December 2003 that also cites a high number of findings. The Board found that SLAC has not taken effective actions to mitigate or abate these recognized hazards.

The Board interviewed several people who stated a concern that the SE&M organization is routinely performing electrical hot work without a PWHA, JHAM, or hot work permit. The SE&M safety person has only been informed of electrical hot work after the fact.

The Board concludes that unsafe conditions and operations have become an accepted part of the everyday way of doing business. The Board concludes that problems with electrical safety, particularly electrical hot work, are known within the ES&H and SE&M organizations.

The Board concludes that rigorous safety oversight, which should have elevated these issues for correction, is frowned upon and given very low priority.

The Board concludes that within some divisions and departments at SLAC, the ISM Core Functions and Guiding Principles are not being followed and have effectively no impact because operations are placed above safety concerns.

SLAC receives funding directly from program offices within the Office of Science. Members of SLAC management told the Board that SLAC receives funding for science, the Laboratory is in competition with other laboratories, and SLAC has to show scientific achievement results in order to remain competitive. With regard to this accident, FS-1 knew how the processes were supposed to be implemented. FS-1's understanding was that operations took precedence over safety and administrative issues. FS-1 stated that he was supposed to get the job done and make his department look good.

The Board concludes that SLAC's emphasis on the scientific mission as a means to secure funding from the Office of Science and compete with other laboratories reached FS-1's level as direction to "just get the job done."

4.1.3 Bay Span Subcontract

Bay Span is a woman-owned, small business subcontractor to SLAC. Bay Span is contractually obligated to provide skilled, qualified labor for electrical work, pipefitting, carpentry, and general labor. The Board has determined that the Bay Span subcontract flows down the OSHA, NEC, and NFPA 70E requirements as required by the DOE-SLAC contract. Appropriately applied, these regulatory measures and/or the subcontract should have provided adequate administrative controls and physical barriers sufficient to protect the employees.

To order labor services from Bay Span, a designated SLAC employee requests workers with defined skill sets from the Bay Span labor pool (i.e., carpenters, electricians, or laborers). Bay Span screens the employees' qualifications and provides the requested workers.

Once on-site, Bay Span employees are required to work under the technical direction of SLAC UTRs. The SLAC UTR process specifies that to serve as a UTR, an individual must take two courses (contract administration and construction safety). On the day of the accident, FS-1 functioned as a UTR, although he was not qualified as a UTR per SLAC's criteria because he has not taken the required construction safety course.

Work acceptance and the determination of a subcontract worker's qualifications are the UTR's decisions. In other words, whether or not a Bay Span worker is allowed to stay on a SLAC task is principally at the UTR's discretion.

Bay Span is a nonunion company; however, when working at SLAC, the Davis-Bacon Act applies and wages are paid at Davis-Bacon Act rates. The base hourly rate for an electrical foreman is approximately $50 an hour under the Davis-Bacon Act versus $25-30 an hour for nonunion work. Since the Bay Span workers' tenure at SLAC is closely tied to satisfying the UTR, the Board concludes that a situation exists where workers might willingly take risks in order to demonstrate productivity and thus continue to work at the high wages.

The Bay Span subcontract requires that Bay Span workers complete a PWHA and obtain the UTR's agreement that it is properly completed prior to initiating work. The Board found no evidence that the requirements in the Bay Span subcontract are being followed. The Bay Span employee handbook also states that individual employees have the right to refuse work when an imminent danger hazard is identified. The Bay Span subcontract generally cites the NFPA requirement to wear PPE. Bay Span is contractually obligated to provide PPE. BSE-1, BSE-2, and BSL were not wearing the appropriate protective clothing or PPE at the time of the accident. In fact, BSE-1 was wearing a short-sleeved cotton/ polyester blend shirt when the accident occurred. Bay Span management stated that FR protective clothing was provided when required, but the Board observed none at the accident scene.

The Board was unable to talk to BSE-1 because of his injuries and could not determine the reason the Bay Span employees were working on October 11, 2004, without appropriate PPE, protective clothing, a PWHA, and an approved hot work permit. In addition, BSL was performing a function (backup) for which he was not qualified.

The Board concludes that Bay Span employees BSE-1 and BSE-2 contributed to this accident by failing to follow NFPA 70E, the terms of the Bay Span sub-contract, and the guidance contained in the Bay Span employee handbook.

Because FS-1 met with BSE-1 to give him verbal instruction to perform the hot work, the Board concludes that FS-1 was aware of the way BSE-1 was dressed. FS-1 failed to enforce the WSS set and SLAC's work planning requirements, and he failed to implement SLAC's safety processes (i.e., a PWHA and an approved hot work permit).

4.2 OSHA Compliance

The OSHA standards cited in Section 4.2 are from Title 29 Code of Federal Regulations (CFR) 1910. The OSHA Interpretation letters cited are available on the OSHA webpage.

4.2.1 OSHA Interpretations

The Board considered the following OSHA interpretations to be pertinent to SLAC's and Bay Span's worker protection policies and procedures in view of the safety and health terms and conditions detailed in the SLAC-Bay Span subcontract.

The following discussion was excerpted from the OSHA Interpretations webpage. (Note: Brackets indicate respective responsibilities for clarification and are not part of the OSHA interpretation.)

“In addition, you [Bay Span] want to know what your responsibilities are to ensure that the host employer’s [SLAC] energy control procedures effectively protect your employees. When employees are working on machines or equipment in which the uncontrolled hazardous energy could cause injury to employees, both the host employer [SLAC] and the contractor employer [Bay Span] have independent obligations to provide the protection under the standard for their respective employees.

OSHA recognizes that the host employer [SLAC] often will have greater familiarity with the energy control procedures used at the host facility; however, contract employers [Bay Span] may have their own procedures for protecting their employees from hazardous energy. Thus, at 29 CFR 1910.147(f)(2)(i), the standard requires the host employer [SLAC] and contract employer [Bay Span] to inform each other about their respective lockout or tagout procedures. Such coordination is necessary to ensure that both sets of employees will be protected from hazardous energy.

A contractor employer [Bay Span] would not be obligated under OSHA to independently audit the host employer's [SLAC’s] energy control procedures. However, the contractor employer [Bay Span] must take reasonable steps consistent with its authority to protect its employees if the contractor knows, or has reason to know, that the host employer's [SLAC’s] energy control procedures are deficient or otherwise insufficient to provide the requisite protection to its [Bay Span’s] employees.”

The Board concludes that SLAC’s policies, procedures, and contracting practices regarding subcontractor worker protection are not consistent with the OSHA electrical standards.

The Board also considered the following excerpt from an OSHA Interpretation letter to be pertinent to this accident:

“Question (2): I note that OSHA has not incorporated the personal protective equipment portions of NFPA 70E by reference in §1910.132 (personal protective equipment, general requirements) or §1910.335 (safeguards for personal protection). Does an employer have an obligation under the General Duty Clause to ensure that its own employees comply with personal protective equipment requirements in NFPA 70E?”

“Answer: These provisions are written in general terms, requiring, for example, that personal protective equipment be provided “where necessary by reason of hazards . . .” (§1910.132(a)), and requiring the employer to select equipment "that will protect the affected employee from the hazards . . .” (§1910.132(d)(1)). Also, §1910.132(c) requires the equipment to “be of safe design and construction for the work performed.”

“Similarly, §1910.335 contains requirements such as the provision and use of "electrical protective equipment that is appropriate for the specific parts of the body to be protected and the work to be performed (§1910.335(a)(i))."

“Industry consensus standards, such as NFPA 70E, can be used by employers as guides to making the assessments and equipment selections required by the standard. Similarly, in OSHA enforcement actions, they can be used as evidence of whether the employer acted reasonably.”

4.2.2 Employee Qualifications

Qualified Person. *“One familiar with the construction and operation of the equipment and the hazards involved.”*

Note 1: Whether an employee is considered to be a “qualified person” will depend on various circumstances in the workplace. It is possible and, in fact, likely for an individual to be considered “qualified” with regard to certain equipment in the workplace but “unqualified” as to other equipment. (See 29 CFR 1910.332(b)(3) for training requirements that specifically apply to qualified persons.)

Note 2: An employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated the ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person is considered to be a qualified person for the performance of those duties.”

Based on a review of BSE-1's resume and on BSE-2's testimony, the Board concludes that BSE-1 meets the 29 CFR 1910.332(b)(3) training requirements to be a "qualified person." Based on BSL's testimony, the Board concludes that BSL is an "unqualified person."

4.2.3 Hazard Assessment

29 CFR 1910.132(d)(1) – "The employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of PPE. If such hazards are present, or likely to be present, the employer shall:

- **1910.132(d)(1)(i)** – Select, and have each affected employee use, the types of PPE that will protect the affected employee from the hazards identified in the hazard assessment;
- **1910.132(d)(1)(ii)** – Communicate selection decisions to each affected employee; and,
- **1910.132(d)(1)(iii)** – Select PPE that properly fits each affected employee.

Note: Non-mandatory Appendix B contains an example of the procedures that would comply with the requirement for a hazard assessment."

1910.132(d)(2) – "The employer shall verify that the required workplace hazard assessment has been performed through a written certification that identifies the workplace evaluated, the person certifying that the evaluation has been performed, the date(s) of the hazard assessment, and which identifies the document as a certification of hazard assessment."

In order to comply with 29 CFR 1910.132(d)(2), as well as ISMS Core Function 2, SLAC had begun implementing the JHAM process. The JHAM process was developed as part of the corrective actions developed in response to the January 2003 Type B Accident Investigation of a fall from a ladder at the SSRL. Under the provisions of the JHAM process, JHAMs are prepared for SLAC employees but not for contractor employees such as BSE-1 and BSE-2. According to SLAC safety and health representatives, Bay Span was responsible for performing a PWHA for their employees. Bay Span management representatives expressed the opinion that, without the participation of the SLAC employees directing the Bay Span employees, Bay Span would have difficulty preparing task-specific PWHAs.

The Board was not provided evidence that any documented hazard assessment had been accomplished for the circuit breaker installation. Since BSE-1 was not wearing FR clothing and PPE appropriate for working on or near energized electrical equipment, the Board determined that BSE-1, a Bay Span foreman, had not prepared a PWHA as required by the Bay Span subcontract.

The Board concludes that neither SLAC nor Bay Span fulfilled the 29 CFR 1910.132 hazard assessment requirements for the circuit breaker installation being attempted at the time of the accident.

4.2.4 Electrical Safety Work Practices

1910.331(a) – "Covered work by both qualified and unqualified persons: The provisions of 1910.331 through 1910.335 cover electrical safety work practices for both qualified persons (those who have training in avoiding the electrical hazards of working on or near exposed energized parts) and unqualified persons (those with little or no such training) working on, near, or with the following installations:"

1910.331(a)(1) – "Premises wiring: Installations of electric conductors and equipment within or on buildings or other structures and on other premises such as yards, carnival, parking, and other lots, and industrial substations."

1910.331(a)(2) – "Wiring for connection to supply: Installations of conductors that connect to the supply of electricity."

The Board concludes that the circuit breaker installation that FS-1 directed BSE-1 to accomplish was work covered under 29 CFR 1910.331(a). In that context, BSE-1 was a qualified person and BSL was an unqualified person.

1910.333(a) – "General. Safety-related work practices shall be employed to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts when work is performed near or on equipment or circuits which are or may be energized. The specific safety-related work practices shall be consistent with the nature and extent of the associated electrical hazards."

The Board concludes that neither SLAC nor Bay Span employed safety-related work practices to prevent injuries resulting from either direct or indirect electrical contacts with circuits that were energized during BSE-1's circuit breaker installation.

1910.333(a)(1) – "De-energized Parts. Live parts to which an employee may be exposed shall be de-energized before the employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Live parts that operate at less than 50V to ground need not be de-energized if there will be no increased exposure to electrical burns or to explosion due to electric arcs."

Note 1: Examples of increased or additional hazards include interruption of life support equipment, deactivation of emergency alarm systems, shutdown of hazardous location ventilation equipment, or removal of illumination for an area.

Note 2: Examples of work that may be performed on or near energized circuit parts because of infeasibility due to equipment design or operational limitations include testing of electric circuits that can only be performed with the circuit energized and work on circuits that form an integral part of a continuous industrial process in a chemical plant that would otherwise need to be completely shut down in order to permit work on one circuit or piece of equipment.

Note 3: Work on or near de-energized parts is covered by paragraph (b) of this section."

Neither SLAC nor Bay Span management provided the Board with any justification for not de-energizing Panel 4P20R before BSE-1 attempted to install the circuit breaker. The SLAC Area Manager stated that there was no reason the panel could not have been locked and tagged out. SE&M management stated that they would not have authorized an electrical hot work permit had one been requested for the circuit breaker installation. FS-1 stated that he knew of no reason why the circuit breaker installation had to be attempted with Panel 4P20R energized.

The Board concludes that SE&M's and Bay Span's cavalier attitude regarding working on or near energized electrical equipment are inconsistent with the provisions of 29 CFR 1910.333(a)(1).

1910.333(a)(2) – "Energized Parts. If the exposed live parts are not de-energized (i.e., for reasons of increased or additional hazards or infeasibility), other safety-related work practices shall be used to protect employees who may be exposed to the electrical hazards involved. Such work practices shall protect employees against contact with energized circuit parts directly with any part of their body or indirectly through some other conductive object. The work practices that are used shall be suitable for the conditions under which the work is to be performed and for the voltage level of the exposed electric conductors or circuit parts. Specific work practice requirements are detailed in paragraph (c) of this section."

Given SE&M's and Bay Span's decision to attempt to install the circuit breaker with Panel 4P20R energized, they failed to identify other safety-related work practices (such as NFPA 70E) to protect employees who were exposed to the electrical hazards involved. The Board concludes that this failure violated the provisions of 29 CFR 1910.333(a)(2).

1910.335(a)(1)(i) – "Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed.

Note: PPE requirements are contained in Subpart I of this part."

1910.335(a)(1)(v) – "Employees shall wear PPE for the eyes or face wherever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from electrical explosion."

1910.335(a)(2)(i) – "When working near exposed energized conductors or circuit parts, each employee shall use insulated tools or handling equipment if the tools or handling equipment might make contact with such conductors or parts. If the insulating capability of insulated tools or handling equipment is subject to damage, the insulating material shall be protected."

The Board concludes that neither SE&M nor Bay Span ensured that BSE-1, BSE-2, or BSL used electrical protective equipment appropriate for the specific parts of the body to be protected from arc *flash hazards. This failure violated the provisions of 29 CFR 1910.335(a)(1)(i).*

The Board concludes that the tool BSE-1 was using at the time of the accident violated 29 CFR 1910.335(a)(2)(i) because the screwdriver being used at the time was not insulated.

4.3 National Fire Protection Association (NFPA) 70E

NFPA70E is a *Standard for Electrical Safety Requirements for Employee Workplaces* and is included in the DOE-SLAC contract. This standard was not followed in a critical number of important areas.

Article 110.7, "Electrical Safety Program," requires that the employer shall implement an overall electrical safety program that directs activity appropriate for the voltage, energy level, and circuit conditions. The SLAC Electrical Safety Program is a collection of policies, manuals, and procedures whose contents lack important requirements that are specified in NFPA 70E and that are essential for worker safety, e.g., guidance for entering shock approach boundaries as contained in NFPA 70E, Annex C, or guidance on the selection of FR clothing in relation to task performed or calculated incident energy as contained in NFPA 70E, Article 130.7.C(10) through Article 130.7.C(16). In addition, the *SLAC ES&H Manual*, Chapter 8, Table 8-2, incorrectly lists the arc flash boundary as a function of voltage, and for 600V or less, it lists the arc flash boundary as three feet.

NFPA 70E, Article 130.3(A), states, "For systems that are 600 volts or less, the Flash Protection Boundary shall be 4.0 ft, based on the product of clearing times of 6 cycles (0.1 second) and the available bolted fault current of 50 kA or any combination not exceeding 300 kA cycles (5000 ampere seconds). For clearing times and bolted fault currents other than 300 kA cycles, or under engineering supervision, the Flash Protection Boundary shall alternatively be permitted to be calculated. At voltage levels above 600 volts, the Flash Protection boundary is the distance at which the incident energy equals 5 J/cm2 (1.2 cal/ cm2). For situations where fault clearing time is 0.1 second (or faster), the Flash Protection Boundary is the distance at which the incident energy level equals 6.24 J/ cm2 (1.5 cal/ cm2)."

Article 110.3, "Responsibility," requires that "the employer shall provide the safety-related work practices and shall train the employee who shall implement them." Many important safety-related work practices that apply to the incident task were not implemented. For example, "live parts to which an employee might be exposed shall be put into an electrically safe work condition before an employee works on or near them." This was not done as is discussed in Article 130.1 below. Also, if work is done hot, the worker must wear appropriate protective clothing (FR rated), PPE, and safety glasses and use V-rated tools and V-rated gloves appropriate to the task. In addition, for the incident task under discussion, a double-layer switching hood (with an FR face-shield) and hearing protection is required. At the time of the accident, BSE-1 wore a hard hat, safety glasses, and V-rated gloves but lacked the balance of the aforementioned protective clothing and equipment. In addition, BSE-1 was wearing a short-sleeved, cotton/polyester shirt.

NFPA 70E, Article 130.7C(14)(a), "Melting," states, "Clothing made from flammable synthetic materials that melt at temperatures below 315 degrees C (600 degrees F) such as acetate, nylon, polyester, polypropylene, and spandex, either alone or in blends, shall not be used." Fine Print Note (FPN) No. 1 states, "Non-FR cotton, polyester-cotton blends, nylon, nylon-cotton blends, silk, rayon, and wool fabrics are flammable. These fabrics could ignite and continue to burn on the body, resulting in serious burn injuries." This important prohibition is not included in the *SLAC ES&H Manual*, Chapter 8. At the time of the accident, the injured worker was wearing a short-sleeved shirt that was made of 60% cotton and 40% polyester. Also, NFPA 70E, Table 130.7(C)(10), specifies that long-sleeved shirts must be worn.

Article 110.4, "Multi-employer Relationship," requires that "the on-site employer and the outside employer(s) shall inform each other of existing hazards, personal protective equipment/clothing requirements, safe work practice procedures, and emergency/evacuation procedures applicable to the work to be performed. This coordination shall include a meeting and documentation." It was reported that a meeting between the SLAC Field Supervisor, FS-1, and the Bay Span Acting Foreman, BSE-1, took place on the morning of the accident, but it was not documented, and hot work was directed and initiated even though an approved hot work permit did not exist.

Article 110.6 (D)(1), "Qualified Person," specifies the training requirements for a "*Qualified Person*," which include, in addition to other safety elements, training "in the decision making process to determine the degree and extent of the hazard and the personal protective equipment and job planning necessary to perform the task safely." This element is a key part of the definition of a qualified person, and it sets the standard for an electrical worker to work safely. The definition of qualified person included in the *SLAC ES&H Manual*, Chapter 8, Section 4, omits this element.

Article 110.8(B)(1), "Electrical Hazard Analysis," requires that "appropriate safety-related work practices be determined before any person approaches exposed live parts within the Limited Approach Boundary by using both shock hazard analysis and flash hazard analysis." There was no documentation to indicate that SLAC or Bay Span identified safety-related work practices or performed a shock or flash hazard analysis.

Article 110.8(B)(2), "Energized Electrical Work Permit," requires that energized electrical work "shall be performed by written permit only." FS-1 and BSE-1 initiated the work activity without an approved hot work permit. This is also a SLAC requirement, and it is specified in the *SLAC ES&H Manual*, Chapter 8, Section 10.3.2.

Article 130.1 specifies that "live parts to which an employee might be exposed shall be put into an electrically safe work condition before an employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations." The afore-mentioned criteria for working hot are included in SLAC's *Lock and Tag Program for the Control of Hazardous Energy*, SLAC-1-730-0A10Z-001. The work that led to the accident did not meet the criteria for hot work specified by NFPA 70E or SLAC-1-730-0A10Z-001, and it could have been performed de-energized.

Article 130.1(A)(2), "Elements of Work Permit," specifies safety "elements of a work permit. The energized electrical work permit shall include, but not be limited to, the following items:

1. A description of the circuit and equipment to be worked on and their location
2. Justification for why the work must be performed in an energized condition (130.1)
3. A description of the safe work practices to be employed [110.8(B)]
4. Results of the shock hazard analysis [110.8(B)(1)(a)]
5. Determination of shock protection boundaries [130.2(B) and Table 130.2(C)]
6. Results of the flash hazard analysis [130.3]
7. The Flash Protection Boundary [130.3(A)]
8. The necessary personal protective equipment to safely perform the assigned task [130.3(B), 130.7 (C)(9), and Table 130.7(C)(9)(a)]
9. Means employed to restrict the access of unqualified persons from the work area [110.8(A)(2)]
10. Evidence of completion of a job briefing, including a discussion of any job-specific hazards [110.7(G)]
11. Energized work approval (authorizing or responsible management, safety officer, or owner, etc.) signature(s)

The Board reviewed the procedure for the SLAC hot work permit and found that it included only items (2) and (11) of the safety elements specified in NFPA 70E. Also, the worker who acted as a Safety Watch Person, BSL-1, was unqualified and in violation of the requirements specified in the *SLAC ES&H Manual*, Chapter 8, Section 2.5 (second bullet).

Table 130.2(C), "Approach Boundaries to Live Parts for Shock Protection," specifies the shock protection boundaries for live parts, and Annex C, "Limits of Approach," specifies the procedure for entering each approach boundary. The *SLAC*

ES&H Manual, Chapter 8, specifies the approach boundaries but does not include a procedure for entering each approach boundary.

Table 130.7(C)(9)(a), "Hazard/Risk Category Classifications," specifies the hazard/ risk category for various electrical tasks and can be used in lieu of the flash hazard analysis of 130.3(A). The *SLAC ES&H Manual*, Chapter 8, does not include this table, nor does it reference it.

Article 130.7(10), "Protective Clothing and Personal Protective Equipment Matrix," provides guidance in the selection of protective clothing and a description of the characteristics and proper use of FR clothing. Table 130.7(C)(10), "Protective Clothing and Personal Protective Equipment (PPE) Matrix," provides a means of selecting protective clothing and PPE based on the hazard/risk category. Table 130.7(C)(11), "Protective Clothing Characteristics," provides a description of the clothing systems for each hazard/risk category. Together, the NFPA 70E articles and tables provide a complete guide for the selection, use and, care of protective clothing. The *SLAC ES&H Manual*, Chapter 8, provides insufficient guidance in the selection, use, and care of protective clothing.

Article 120.1(5), "Process of Achieving an Electrically Safe Work Condition," specifies the use of an adequately rated voltage detector to test each phase conductor or circuit part to verify they are de-energized. "Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the voltage detector is operating satisfactorily." SLAC's *Lock and Tag Program for the Control of Hazardous Energy*, SLAC-1-730-0A10Z-001, Section 8.1, requires that the test equipment be checked before and after each measurement only for circuits over 600V. If the voltage detector failed just before the "0" voltage check, the worker would conclude, based on measurement of the circuit in question, that it is de-energized when it may not be. This would expose the worker to injury due to shock and or arc blast without the protection that is normally used when working hot.

SLAC's *Lock and Tag Program for the Control of Hazardous Energy*, SLAC-1-730-0A10Z-001, Section 14, "References," does not reference NFPA 70E.

The Board concludes that the SLAC ES&H Manual*, Chapter 8, does not meet the requirements of NFPA 70E*.

4.4 SLAC's Integrated Safety Management System

The SLAC ES&H Division developed the *SLAC Safety Management System*, which describes how ISM is achieved and ensures SLAC's safety and work practices. The document states that the *SLAC Safety Management System* is responsive to DOE Policy 450.4, *Integrated Safety Management System Policy*. This policy describes the Seven Guiding Principles and Five Core Functions of safety management. This policy is incorporated into the SLAC contract via DOE Acquisition Regulation (DEAR) clause 970.5223-1, *Integration of Environment, Safety, and Health into Planning and Execution.*

The *SLAC Safety Management System* states on page 5, "This document describes how SLAC integrates safety and environmental protection into management and work practices at all levels so that its mission is accomplished while protecting the worker, the public, and the environment (SLAC 1991)." However, in the "Overview" section, it also makes the following statements with respect to hazard controls: *"The control of hazards may be within the manager's experience, and can be specified and implemented at the manager's discretion"* and *"Normally, authorization to proceed is simply an instruction from the manager or supervisor."*

The Board finds these last statements to be so vague that they contribute to a work environment where SE&M managers routinely perform undocumented hazardous work, making it difficult to audit any hazardous task following the *SLAC Safety Management System*. In fact, the Board finds that the "Overview" section words undermine the value of the *SLAC Safety Management System*. The following is the Board's assessment of how the SLAC ISMS functioned with respect to the October 11, 2004, accident.

Core Function 1, Define the Scope of Work: The SE&M did not translate the mission needs into work. This task was not a mission-critical need, and nothing required the work to be performed while the panel was energized. The SE&M did not prioritize the task properly. There is no auditable work package for the task on October 11. The Board found no evidence that the scope of work was fully defined.

Core Function 2, Analyze the Hazards: The SE&M has no documentation to show that any hazard analysis was performed as required by SLAC's procedures and NFPA 70E. NFPA 70E also provides tables for assessing the potential for hot work at these energy levels and then provides detailed guidance that prescribes the required PPE and protective clothing. No one properly categorized the PPE and protective clothing for the task; therefore, proper PPE and protective clothing for hazardous work were not selected.

Core Function 3, Develop/Implement Controls: The SE&M did not fully implement NFPA 70E as required by the SLAC-DOE contract, including the failure to fully implement the required controls (proper level of PPE and FR clothing). The person serving as backup was a laborer and unqualified for this function; thus, there was no protection under the defense-in-depth safety concept required by the *SLAC ES&H Manual*, Chapter 8. There was no SE&M or SLAC safety representative presence at the jobsite. The administrative controls related to this event were not in place (i.e., there was no approved hot work permit). The SE&M's JHAM for this work was not followed.

Core Function 4, Perform Work Safely: An unqualified person (BSL) served as the backup for the energized electrical work. BSL has no training in electrical safety and, in fact, did not even know what to do with the broom that was handed to him by BSE-2. Testimony from subcontractor employees indicated that application of PPE and protective clothing is generally based on the experience and preference of the person in charge or, in other words, "skill of the craft." Before any backup was brought into the job, the deadfront panel cover had already been removed, which is a violation of the *SLAC ES&H Manual*, Chapter 8, requirements. None of the Bay Span workers were properly attired to perform NFPA 70E work.

Core Function 5, Feedback and Improvement: On July 23, 2004, SLAC informed the DOE Office of Science that based on a recent analysis of hot work permit authorizations for a 90-day period, 23 of 31 recent hot work permits did not contain the necessary justification for work to be conducted while the systems were energized. This report is a very important feedback element, yet it has had no impact on the SE&M's operations. Some SE&M managers are not even aware of the report.

Section 8.4 of the report issued by URS for its November 2003 safety review states that the electrical safety procedures for working near exposed live electrical parts do not contain sufficiently detailed specifications to ensure that only qualified persons having the necessary knowledge and experience are allowed to perform the work. The report goes on to state that the Klystron Gallery contains many pieces of equipment with exposed live parts. The report further states that PPE should be provided. The November 2003 URS report should have resulted in management actions requiring workers to use appropriate PPE and protective clothing and ensuring that BSL, who is a laborer, did not perform the backup function during the work which led to the October 11, 2004, accident. Moreover, DOE *Safety Bulletins* have described electric arc flash accidents and the necessary safety measures.

The Board reviewed the findings from a 2004 OSHA review at SLAC and a total of 24 SLAC occurrence reports from 2002 to October 2004. Of these 24 occurrences, 3 were related to electrical activities. In general, the contributing factors for all of these events and findings are:

- Lack of formality in following procedures
- Inadequate procedures
- Poor work planning, poor pre-job hazard analysis, and incomplete JHAM

Guiding Principle 1, Line Management Responsibility for Safety: SLAC line management did not review or authorize hot work, but hot work took place on October 11, 2004. Interviews led the Board to believe that line management places operations and operational readiness before safety.

Guiding Principle 2, Clear Roles and Responsibilities: Using a laborer as backup for an electrical worker indicates inadequate understanding of roles. The SLAC person assigned UTR responsibilities was not a qualified UTR. No backup was identified before the task was started. SLAC's governing procedures at the time of the October 11, 2004, accident identify the few people who can approve hot work; however, a key person, the chair of the Electric Safety Committee, is not a signature on any of the hot work permits the Board reviewed. An ad hoc system exists, and there are no clear roles and responsibilities for hot work performed by the SE&M.

Guiding Principle 3, Competence Commensurate with Responsibilities: Neither FS-1 nor BSL was qualified for the tasks assigned to them. None of the workers was knowledgeable of the NFPA 70E guidance for determining the level of PPE or protective clothing required for working on exposed 480V circuits.

Guiding Principle 4, Balanced Priorities: Based on the Board's interviews, there was no reason to work on this circuit breaker installation on October 11. There was no SLAC mission need or any other need for this modification to be performed while the panel was energized.

Guiding Principle 5, Identification of Safety Standards and Requirements: NFPA 70E is a requirement of the DOE-SLAC contract, but it is not fully incorporated in the *SLAC ES&H Manual*, Chapter 8. Chapter 8 flows down the DOE-SLAC contract requirements into SLAC's work processes. NFPA 70E and all DOE and SLAC requirements are not in the SLAC-Bay Span subcontract per se. Therefore, the safety requirements do not really flow down to the work.

Guiding Principle 6, Hazard Controls Tailored to Work Being Performed: The worker performing the task was wearing a blended cotton and polyester shirt (instead of 100% cotton and FR clothing) and inadequate PPE. NFPA 70E tables require much more than BSE-1 was wearing. In addition, the backup should be as qualified as the person doing the job, but BSL, the backup, was not qualified to perform any electrical function. He was only there as a laborer.

Guiding Principle 7, Operations Authorization: The work did not have the required approved hot work permit. NFPA 70E specifies that the organization doing hot work should have hot work permit procedures, and it sets minimum standards for such procedures. SLAC has hot work permit procedures, but they are not being followed. In addition, SLAC's hot work procedures contain deficiencies with regard to the criteria in NFPA 70E. FS-1 did not follow the SLAC hot work permit process. Everyone in the management chain above FS-1 stated there was no requirement to perform this task on an energized panel.

The Board concludes that there was no justification for installing the circuit breaker in energized Panel 4P20R.

The Board concludes that the work being done at the time of the accident violated every ISM Core Function and every ISM Guiding Principle. It also failed to provide worker protection in accordance with NFPA 70E.

This circumstances leading to the accident failed to meet the expectations stated in the *SLAC Safety Management System*, page 5 as follows: "This document describes the SLAC SMS and how SLAC integrates safety and environmental protection into management and work practices at all levels so that its mission is accomplished while protecting the worker, the public, and the environment (SLAC 1991)."

4.5 SLAC Electrical Safety Action Plan

The Board reviewed the *SLAC Electrical Safety Action Plan, Stanford Linear Accelerator Center*, which was prepared by SLAC Electrical Safety Review Team and issued on July 23, 2004, in response to the memorandum entitled "Department of Energy Electrical Safety Month" from SC-1, dated May 24, 2004. The Board endorses this action plan in its entirety.

The *SLAC Electrical Safety Action Plan, Stanford Linear Accelerator Center* is included as Appendix C.

This page intentionally left blank.

5.0 CAUSAL FACTORS

5.1 Direct Cause

The direct cause of the accident was BSE-1's attempt to install a circuit breaker in energized Panel 4P20R. Violations of OSHA, DOE, SLAC, and Bay Span electrical safe work practices increased both the probability that an arc flash could occur and the severity of the resulting consequences.

5.2 Root Cause

Neither SLAC nor Bay Span fulfilled their responsibilities under OSHA and DOE's ISM policies and procedures to provide the electricians and the laborer with a workplace free of recognized electrical hazards, such as arc flash.

5.3 Contributing Causes

1. BSE-1 worked on an energized circuit breaker panel without sufficient justification for exposure to the arc flash hazard. BSE-1 did not exercise the stop work authority granted him by the DOE, SLAC, and Bay Span policies and procedures.
2. BSE-2 did not exercise his stop work authority when he observed BSE-1 working on an energized circuit breaker without FR clothing and appropriate PPE.
3. FS-1 directed BSE-1 to install a circuit breaker in an energized panel without ensuring that BSE-1 understood the hazard and appropriate controls. FS-1 did not provide sufficient justification for exposure to the arc flash hazard. FS-1 did not direct BSE-1 to lock and tag out Panel 4P20R. FS-1 did not advise BSE-1 that BSE-1's clothing was not appropriate for electricians or that additional FR clothing and PPE were required for electrical hot work.
4. Bay Span's oversight failed to identify their electricians' deviation from the safety and health terms and conditions in their contract with SLAC.
5. SLAC's policy on worker protection did not ensure that Bay Span's employees received the same protection against electrical hazards that SLAC employees were provided. SLAC's policy violated OSHA standards and interpretations on worker protection in multiemployer workplaces.
6. SLAC's electrical safety oversight failed to detect and correct SE&M's and Bay Span's deviation from established electrical safe work practices.
7. The DOE SSO's electrical safety oversight failed to detect and correct SLAC's violation of OSHA standards and interpretations on worker protection in multiemployer work-places.
8. SSO and SLAC failed to ensure that lessons learned from numerous potential sources (e.g., the ISMS Phase II Verification Report, the URS independent study, the 2003 Type B Accident Investigation report, et al.) led to continuous improvement of electrical safe work practices.
9. SSO did not direct SLAC to take immediate, effective corrective actions in response to the *Electrical Safety Action Plan, Stanford Linear Accelerator Center* submitted in July 2004.

This page intentionally left blank.

6.0 CONCLUSIONS AND JUDGMENTS OF NEED

JONs are the managerial controls and safety measures determined by the Board to be necessary to prevent or minimize the probability or severity of a recurrence. These JONs are linked directly to the causal factors, which are derived from facts and analyses and form the basis for corrective action plans and which are the responsibility of line management. The following table, Table 6-1, contains the Board's conclusions and the JONs.

Table 6-1. Conclusions and Judgments of Need

Conclusions	Judgments of Need
There was no justification for installing the breaker in energized Panel 4P20R. Neither SLAC nor Bay Span fulfilled 29 CFR 1910.132 hazard assessment requirements for the breaker installation being attempted at the time of the accident. SE&M's and Bay Span's practices regarding working on or near energized electrical equipment violated the provisions of 29 CFR 1910.333(a)(1). Neither SE&M nor Bay Span management ensured that BSE-1, BSE-2, or BSL used electrical protective equipment appropriate for the specific parts of the body to be protected from arc flash hazards. This failure violated the provisions of 29 CFR 1910.335(a)(1)(i). BSE-1 meets 29 CFR 1910.332(b)(3) training requirements to be a "qualified person." Based on BSL's testimony, BSL is an "unqualified person." Given SE&M's and Bay Span's decision to install the breaker with Panel 4P20R energized, they failed to identify other safety-related work practices (such as those included NFPA 70E) to protect the employees who were exposed to the electrical hazards involved. This failure violated the provisions of 29 CFR 1910.333(a)(2).	**JON 1:** SLAC needs to enforce applicable OSHA standards and all sections of NFPA 70E. **JON 2:** SLAC needs to ensure that SLAC's employees who work on or near exposed energized electrical conductors are trained on the implementation of electrical safety-related work practices. **JON 3:** SLAC needs to verify that subcontractor employees who work on or near exposed energized electrical conductors are trained on the implementation of electrical safety-related work practices.
The breaker installation that FS-1 directed BSE-1 to accomplish was work covered under 29 CFR 1910.331(a). In that context, BSE-1 was a qualified person and BSL was an unqualified person. The tool BSE-1 used at the time of the accident violated 29 CFR 1910.335(a)(2)(i) because the screwdriver being used at the time was not insulated. When an installation problem developed, BSE-1's options for diagnosing the problem were limited by the fact that the panel was energized.	**JON 4:** SLAC and subcontractor supervisors and managers need to receive the same training as the workers.

Conclusions	Judgments of Need
Despite receipt of the lowered annual assessment rating and SSO's interaction with the SLAC ES&H Department and Director, SLAC has not responded with implementation of sound work planning and hazard control processes. SSO has not been effective in creating a "safety first" approach within SLAC.	**JON 5:** SSO needs to exercise the existing SLAC contract clauses, terms, and conditions that hold SLAC accountable for unacceptable safety performance, including stop work authority or the embargo of funds until SLAC demonstrates satisfactory electrical safety performance.
SLAC's policies, procedures, and contracting practices regarding subcontractor worker protection are not consistent with the OSHA safety electrical standards.	**JON 6:** SSO needs to ensure that legal interpretations by SLAC to establish each employer's worker protection responsibilities are consistent with OSHA's interpretations on multiemployer workplaces.
Since the Bay Span workers' tenure at SLAC is closely tied to satisfying the UTR, a situation exists where workers might willingly take risks in order to demonstrate productivity and thus continue to work at the high wages. Bay Span employees BSE-1, BSE-2, and BSL contributed to this accident by failing to follow NFPA 70E, the terms of the Bay Span subcontract, and the guidance contained in the Bay Span employee handbook. Because FS-1 met with BSE-1 to give him verbal instruction to perform the hot work, FS-1 was aware of the way BSE-1 was dressed. FS-1 failed to enforce the SLAC's contract requirements, and he failed to implement the SLAC/Bay Span safety processes (i.e., a PWHA and an approved hot work permit).	**JON 7**: SLAC needs to revise the contracting process to ensure that subcontractor workers can protect themselves from SLAC-related hazards in the same way that SLAC workers protect themselves. The terms and conditions of subcontracts should not encourage workers to take risks.
Documented safety processes are not effectively implemented. Unsafe conditions and operations have become an accepted part of the everyday way of doing business. Problems with electrical safety, particularly electrical hot work, are known within the ES&H and SE&M organizations. The SLAC line organizations have been resistant to safety oversight, which should have elevated electrical safety work practice deficiencies to SLAC management's attention for correction. The work being done at the time of the accident violated *every* ISM Core Function and *every* ISM Guiding Principle. It also failed to provide worker protection in accordance with NFPA 70E.	**JON 8:** The SLAC Director needs to balance the priorities between operations and safety to: ▪ Evaluate whether it is appropriate for the Technical Division to be responsible for scheduling LINAC operations and safely maintaining the LINAC infrastructure. ▪ Achieve effective, proactive ES&H Division involvement. ▪ Encourage SE&M employees to work safely and to exercise their stop work authority.

Conclusions	Judgments of Need
Within SE&M, the ISM Core Functions and Guiding Principles are not being followed and have effectively no impact because operations are placed above safety concerns. Problems with electrical safety, particularly electrical hot work, are known within the ES&H and SE&M organizations. The *Electrical Safety Action Plan, Stanford Linear Accelerator Center* identifies many of the same deficiencies identified in this investigation report.	**JON 9:** SLAC needs to develop and implement safety oversight programs designed to identify deficient electrical work practices and correct them in a timely manner that achieves continuous improvement.
The *Electrical Safety Action Plan, Stanford Linear Accelerator Center* identifies many of the same deficiencies identified in this investigation report.	**JON 10:** SSO needs to develop and implement safety oversight programs designed to identify deficient electrical work practices and correct them in a timely manner that achieves continuous improvement.
SLAC's emphasis on the scientific mission as a means to secure funding from the Office of Science and compete with other laboratories reached FS-1's level as direction to "just get the job done."	**JON 11:** The SLAC Director needs to ensure that employees at all levels fully understand that concern for mission accomplishment does not outweigh the need for safe operations.
SSO has not filled an existing vacant safety and health position. SSO could make more effective use of ORO support.	**JON 12:** SSO needs to do a workload study to determine the resource level and skills mix necessary to fulfill their safety responsibilities.
SLAC's site readiness to prepare for a DOE accident investigation has improved.	No action required.
The emergency medical response was timely and well managed.	No action required.

This page intentionally left blank.

7.0 BOARD SIGNATURES

Richard M. Stark
DOE Accident Investigation Board Chairperson
U.S. Department of Energy
Office of Facility Operations Support

Pranab K. Guha
DOE Accident Investigation Board Member
U.S. Department of Energy
Office of Quality Assurance Programs

Marcus L. Hayes
DOE Accident Investigation Trained Board Member
National Nuclear Security Administration
Albuquerque Service Center

Bobby Price
DOE Accident Investigation Board Member
U.S. Department of Energy
Oak Ridge Operations Office

This page intentionally left blank.

8.0 LIST OF BOARD MEMBERS, ADVISORS, AND STAFF

Board Members

Chairperson	Richard M. Stark, Director, Office of Facility Operations Support, DOE Office of Environment, Safety and Health
Member	Pranab K. Guha, Electrical Engineer, Office of Quality Assurance Programs, DOE Office of Environment, Safety and Health
Analyst	Marcus L. Hayes, Occupational Safety and Health Manager, National Nuclear Security Administration Service Center
Member	Bobby Price, Information Resources Management Division Director, DOE Oak Ridge Operations Office

Advisors

Advisor	David O'Neil, PE, Electrical Engineer
Advisor	Patrick M. Burke, Assistant Chief Counsel, Chicago Office, West Coast Area Office
Advisor	Dr. Maria Gherman, SLAC Medical Officer

Technical and Administrative Support

Coordinator/Technical Editor	Karen Brown, Quality Assurance Specialist III, Parallax, Inc.
Administrative Support	Mike Grissom, Assistant Associate Director of ES&H, SLAC
	Sharon Oden, Administrative Associate in Knowledge Management, SLAC
Court Reporter	Carol Dunne, Grossman & Cotter

This page intentionally left blank.

APPENDIX A – APPOINTMENT OF TYPE A ACCIDENT INVESTIGATION BOARD

Department of Energy
Washington, DC 20585

October 15, 2004

MEMORANDUM TO: John Muhlestein
Director
Stanford Site Office

FROM: John Spitaleri Shaw
Acting Assistant Secretary
Office of Environment, Safety & Health

SUBJECT: Investigation of the October 11, 2004, Worker Injury at Stanford Linear Accelerator Center

A Type A Accident Investigation Board is hereby established to investigate the October 11, 2004, worker electrical burn injury at the Stanford Linear Accelerator Center.

The Office of Environment, Safety, and Health will lead the Accident Investigation. I have appointed Richard Stark, Director, Office of Facility Operations Support as the Accident Investigation Board Chairperson. The Board will be composed of members, advisors and other personnel as deemed necessary by the Board Chairperson.

The scope of the Board's investigation will include, but is not limited to, analyzing causal factors, identifying root causes resulting in the accident, and determining Judgment of Need to prevent recurrence. The investigation will be conducted in accordance with DOE Order 225.1A, Accident Investigation. The Board will also focus on management roles responsibilities and application of lessons learned from similar accidents on site or within the Department.

The Board will provide my office with periodic reports on the status of the investigation. These periodic reports should not include any findings or arrive at any premature conclusions until an analysis of all the causal factors have been completed. Discussions of the investigation and copies of the draft report will be controlled until I accept and authorize release of the final report.

The report should be provided to my office 30 calendar days from the date of this memorandum.

cc:
R. Orbach, SC-1
M. Johnson, SC-1
R. Stark, EH-24
R. Hardwick, EH-2

Department of Energy
Washington, DC 20585

October 15, 2004

MEMORANDUM FOR: John Spitaleri Shaw
Acting Assistant Secretary
Office of Environment, Safety and Health

FROM: Richard M. Stark
Director
Office of Facility Operations Support

SUBJECT: Type A Accident Investigation at the Stanford Linear Accelerator Center

As the appointed Chair of the Type A Accident Investigation Board for the investigation of the injury at Stanford Linear Accelerator Center, I have assumed responsibility for the investigation effective immediately. I have commenced the investigation in accordance with the requirements of DOE Order 225.1, *Accident Investigations*. In addition to myself as Chair, the other Board members are:

- Pranab Guha, EH Headquarters
- Marcus Hayes, NNSA Albuquerque
- Bobby Price, EM, Oak Ridge Operations Office.

David O'Neil will serve as an electrical advisor to the Board. The Board will be assisted by other advisors, consultants, and support personnel as I deem necessary.

In accordance with DOE Order 225.1, the Board will identify the relevant facts, analyze the facts to determine the cause of the accident; develop conclusions; and determine Judgments of Need to prevent similar accidents in the future. I anticipate having the investigation and subsequent report complete in 30 days. I will provide you with periodic reports on the status of the investigation.

cc:
Accident Investigation Team
R. Hardwick, EH-2
R. Orbach, SC-1
M. Johnson, SC-3
J. Muhlestein, Stanford Site Office

This page is intentionally blank.

APPENDIX B – BARRIER ANALYSIS

This page intentionally left blank.

Barrier Analysis

Barrier analysis is based on the premise that hazards are associated with all tasks. For an accident to occur, there must be a hazard that comes into contact with a target because the barriers or controls were not in place, not used, or failed. A hazard is the potential for unwanted energy flow to result in an accident or other adverse consequence. A target is a person or object that a hazard may damage, injure, or fatally harm. A barrier is any means used to control, prevent, or impede the hazard from reaching the target, thereby reducing the severity of the resultant accident or the adverse consequence. The results of the barrier analysis are used to support the development of the causal factors. The results of the barrier analysis are contained in the following table.

Table B-1. Barrier Analysis Table

Barriers	How Did It Perform	How Did Barrier Performance Contribute to Accident
An effective lockout/tagout procedure (*SLAC ES&H Manual*, Chapter 8)	Panel 4P20R was not de-energized because FS-1 and BSE-1 decided to install the circuit breaker in an energized panel.	FS-1's decision and BSE-1's willingness to install the circuit breaker while Panel 4P20R was energized meant that uncontrolled electrical energy was available to cause an arc flash.
SLAC UTRs fulfill their responsibility to ensure that Bay Span workers comply with SLAC's electrical safe work practices.	The UTR (FS-1) did not ensure that the circuit breaker installation was in compliance with DOE, OSHA, NFPA 70E, or SLAC's electrical safe work practices.	FS-1 had not received all the training required for a UTR before assuming the role. FS-1 did not have the competency necessary to fulfill the responsibilities of a UTR.
An electrical hot work permit documents the justification for working on energized electrical equipment, analyzes the attendant hazards, and establishes the necessary controls.	The UTR did not obtain an approved electrical hot work permit prior to BSE-1 beginning the circuit breaker installation.	SE&M management was not afforded the opportunity to prevent FS-1 from directing BSE-1 to install the circuit breaker in an energized panel.
SLAC management ensures that the SE&M organization's and Bay Span's electrical work is accomplished in accordance with the *Policy on Hot Work* (SLAC-I-730-OA1OZ-001)	Neither SLAC, SE&M, nor Bay Span management fulfilled their responsibility to ensure that FS-1 and BSE-1 complied with the SLAC policy on electrical hot work.	Panel 4P20R was energized when BSE-1 attempted to install the circuit breaker.
Workers working on or near energized electrical equipment are protected by wearing the appropriate FR clothing and PPE in accordance with NFPA 70E	The *SLAC ES&H Manual*, Chapter 8, does not fully incorporate NFPA 70E. BSE-1, BSE-2, BSL, and FS-1did not follow either Chapter 8 or NFPA 70E.	When the arc flash occurred, BSE-1 and BSL were not wearing proper FR clothing and PPE.
Electrical workers are trained to recognize hazards and protect themselves in accordance with applicable electrical safe work practices	BSE-1, BSE-2, BSL, and FS-1 did not have the required NFPA 70E training. BSL is not a qualified electrical person, but he was asked to back up an electrician.	There was a loss of defense in depth. BSE-1 and BSE-2 failed to recognize the magnitude of the hazards and obtain appropriate protection. Moreover, BSL was not qualified to recognize the hazards.

Barriers	How Did It Perform	How Did Barrier Performance Contribute to Accident
Work is planned in a manner that defines the scope of work to support hazards analysis in order to identify appropriate controls (Core Functions 1 and 4; Guiding Principle 7)	No documentation exists to define the scope of the circuit breaker installation task. No hazard analysis was performed for the circuit breaker installation.	SE&M management and Bay Span management did not ensure that the workers understood the scope of the work, the hazards involved, or the appropriate protection strategy.
SLAC, SE&M, and Bay Span management ensure electrical safe work practices (e.g., 29 CFR 1910.333 and the *SLAC ES&H Manual*) are implemented in a manner that protects the workers	Oversight capable of detecting and correcting unsafe work practices was not implemented at any level of management.	BSE-1 and BSL were exposed to arc flash hazards without adequate engineered and administrative controls or appropriate protective clothing and equipment.
Hazard analysis provides the basis for selecting appropriate engineering and administrative controls and PPE (Core Function 2)	A task-specific hazard analysis was not performed for BSE-1's circuit breaker installation in Panel P420R.	Neither Bay Span nor the SE&M had analyzed the hazards, so they had no method for selecting effective controls and protective clothing and PPE.
Skill of the Craft	Reportedly, journeyman electricians (BSE-1 and BSE-2) did not employ recognized safe work practices when installing the circuit breaker.	
Appropriately identified and fully implemented safety standards	SLAC's and Bay Span's programmatic documents identify controls that would have minimized the likelihood of this accident. SE&M elected not to implement them. (Guiding Principle 5)	Failure to implement task-specific standards and procedures exposed BSE-1 and BSL to uncontrolled arc flash hazards.
SSO, SLAC, and Bay Span safety oversight detects and corrects deviations from electrical safe work practices	Several sources had identified significant deficiencies in SLAC's electrical safe work practices, but SSO and SLAC management had not taken timely or effective corrective actions. No evidence of Bay Span oversight existed. (Core Function 5)	Identified deficiencies in the SLAC and SE&M electrical safe work practices were not corrected.

Table B-1. Barrier Analysis Table (continued)

Barriers	How Did It Perform	How Did Barrier Performance Contribute to Accident
SE&M and Bay Span employees are empowered to exercise stop work authority	BSE-1, BSE-2, BSL, and FS-1 would all have been justified in exercising their stop work authority, but none of them elected to do so.	BSE-1's unsafe attempt to install the circuit breaker in energized Panel 4P20R proceeded until the arc flash occurred.
SSO and SLAC management develop and implement a lessons learned program that drives continuous improvement in electrical safe work practices	SSO and SLAC management failed to ensure that SE&M and Bay Span used information available from DOE, SLAC, and general industry to improve to electrical safe work practices. (Core Function 5)	The circuit breaker installation was attempted on an energized panel without justification. SE&M did not consistently implement an electrical hot work permitting process.
Implementation of SLAC's "Two Person Rule" ensures that the backup person has the knowledge to recognize unsafe practices and the authority to stop them.	An unqualified person, BSL, was assigned as backup to BSE-1.	BSL did not have the training and experience to recognize the hazards attendant to BSE-1's circuit breaker installation and exercise his stop work authority.

This page intentionally left blank.

APPENDIX C – SLAC ELECTRICAL SAFETY ACTION PLAN, JULY 2004

This page intentionally left blank.

Electrical Safety Action Plan

Stanford Linear Accelerator Center (SLAC)
July 23, 2004

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.

LESSONS LEARNED FROM OPERATIONS AT SLAC

Personnel Errors

<u>Critical Look</u>

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.

Work Control Problems

<u>Critical Look</u>

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 <u>personnel safety</u> locks (red locks) to lock out <u>operations</u>, 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.

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.

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.

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).

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.

Addressing OSHA Concerns: Improving the Physical Condition of the Facility 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	29 CFR 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, circuit 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
Subcontractor safety issues	20	1926

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 24th 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.

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.

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

This page intentionally left blank.