
Type B Accident Investigation Board Report Employee Burn Injury at the D Area Powerhouse

September 23, 2009



October 2009
U.S. Department of Energy
Savannah River Site



Disclaimer

This report is an independent product of an Accident Investigation Board appointed by Jeffrey Allison, Manager, Department of Energy Savannah River Operations Office.

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

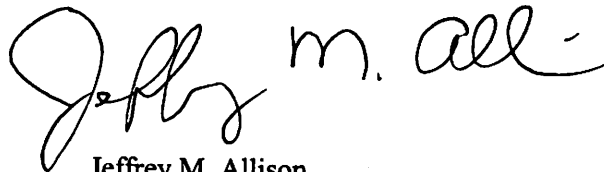
The discussion of facts, as determined by the Board, and the views expressed in this report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents, or subcontractors at any tier,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

This report neither determines nor implies liability.

Acceptance Statement and Release Authorization

On September 25, 2009, I established a Type B Accident Investigation Board to investigate the employee burn injury at the Savannah River Site D Area powerhouse on September 23, 2009. The Board's responsibilities have been completed with respect to this investigation. The analyses and the identification of contributing causes, the root cause, and judgments of need resulting from the investigation were performed in accordance with DOE Order 225.1A, *Accident Investigations*.

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



Jeffrey M. Allison
Manager
Savannah River Operations Office

TABLE OF CONTENTS

EXECUTIVE SUMMARY	i
ACRONYMS AND ABBREVIATIONS	v
1.0 INTRODUCTION	1
1.1 Background	1
1.2 Site/Facility Description	1
1.3 Scope and Methodology	3
2.0 THE ACCIDENT	4
2.1 Accident Overview	4
2.2 Event Chronology	5
2.3 Emergency Response and Medical Treatment	6
2.4 Investigative Readiness and Accident Scene Preservation	7
3.0 ACCIDENT FACTS AND ANALYSIS	8
3.1 SRS Integrated Safety Management Processes	8
3.2 Define the Scope of Work	9
3.3 Analyze Hazards	9
3.4 Develop and Implement Hazard Controls	11
3.5 Perform Work within Controls	15
3.6 Provide for Feedback and Improvement	19
3.7 Summary of Analytical Methods and Results	24
4.0 CONCLUSIONS AND JUDGMENTS OF NEED	26
5.0 BOARD SIGNATURES	28
6.0 BOARD MEMBERS, ADVISORS, AND STAFF	29

Appendices

Appendix A: Board Appointment Letter

Appendix B: Barrier Analysis

Appendix C: Change Analysis

Appendix D: Events and Causal Factors Chart

Appendix E: Opportunities for Improvement

Exhibits, Figures and Tables

Table ES-1: Conclusions and Judgments of Need

Figure 1-1: 484-D Powerhouse

Figure 2-1: 484-D Powerhouse Switchgear Layout

Figure 2-2: AT2AL Breaker

Figure 3-1: AT2AL Arc Flash Label

Table 3-1: Selected Opportunities for Improvement Identified in the June 2009 DOE-SR SRS Electrical Safety Review

Table 3-2: DOE-SR Assistant Manager for Closure Project, FY2009 Annual Assessment Plan, Facility Representative Assessments

Table 4-1: Conclusions and Judgments of Need

EXECUTIVE SUMMARY

This report documents the results of the Type B Accident Investigation Board investigation of the September 23, 2009, employee burn injury at the Department of Energy (DOE) Savannah River Site (SRS) D Area powerhouse.

Accident Summary

While troubleshooting in a 480 volt breaker cubicle, an electrical and instrumentation (E&I) mechanic received second and third degree burns to his arms and first and second degree burns to his face when a metal tool (9-inch torpedo level) contacted the energized "A" phase of the breaker causing a direct short to ground and arc flash event. The tool had been placed in the energized cabinet by a second E&I mechanic as part of troubleshooting activities to determine the extent of "adjustments" needed to align the breaker within the cabinet.

Procedurally, the breaker cubicle was of a sufficient arc flash hazard category that work in the vicinity of the cubicle was not allowed with the cubicle door open and the conductors energized. In addition, neither E&I mechanic was wearing arc flash suits or flame retardant coveralls with face shields that are normally required for working within the vicinity of energized switchgear. Immediate supervision was aware of ongoing troubleshooting and repair with the equipment energized.

Facility Description

The D Area Powerhouse (484-D) is located near the Savannah River on the southern boundary of the Site. The facility has been operating since the early 1950s and serves SRS by exporting both steam and electrical power. The powerhouse consists of four 330-kilopound/hour pulverized coal boilers, seven 12 to 15 megawatt turbine generators, and support systems and equipment. Steam is used primarily for processing in SRS production areas and is transported at 385 pounds per square inch through a large distribution pipeline to the end users who are five to seven miles away. Feed-water for the D Area powerhouse is drawn from the Savannah River via a dedicated pump station. In addition to steam, the powerhouse produces approximately 20 megawatts of electricity to offset the utility power purchased by SRS.

Summary Facts and Analysis

Qualified Electrical Workers (E&I Mechanics) introduced a non-insulated tool (9-inch metal torpedo level) into an energized electrical component. It fell, contacting the "A" phase of the energized 480 volt breaker. The two Qualified Electrical Workers worked in the energized electrical cubicle without donning basic electrical personal protective equipment (PPE) or arc flash suits. While the root cause of the event was determined to be that experienced Qualified Electrical Workers failed to comply with required and expected safe electrical work practices, significant contributing causes enabled the event to occur.

The most significant contributing cause was that the work control processes failed to prevent work activities from occurring in the vicinity of energized equipment. SRS Procedure 18Q-2, *Safe Practices On or Near Electrical Conductors or Live Parts*, implements DOE requirements (National Fire Protection Association (NFPA) 70E, *Standard for Electrical Safety in the Workplace*). These requirements restrict work on energized electrical equipment with an arc flash hazard rating greater than 40 calories/cm². The breaker that was worked in this case was rated at 87.6 calories/cm². The supervisor, who was also a Qualified Electrical Worker, stated he assumed the breaker was less than 40 calories/cm² consistent with the other breakers in the switchgear. The supervisor failed to verify the work was within the scope of the generic monthly troubleshooting work package and its corresponding hazard analysis. Despite these errors, if the Qualified Electrical Workers had worn the required PPE for the assumed work conditions, the injury would have been prevented or significantly mitigated.

The second important contributing cause was the lack of an effective pre-job briefing. The supervisor and mechanics performed a perfunctory exercise to sign the required paperwork and did not discuss the specific tasks to be performed, the limitations on troubleshooting, the potential hazards, or required controls. The hazards analysis for most electrical work is based on simple pre-screenings that reference Procedure 18Q-2. In this case, the Qualified Electrical Workers were the single line of defense and they failed to ensure the actual electrical hazards and needed controls were identified and implemented.

Other contributing causes that influenced the overall work environment included facility/equipment conditions that necessitated frequent reactive maintenance, and past operating practices that fostered an environment conducive to shortcuts and work-arounds. While recent initiatives have had a positive effect on these conditions, 484-D Conduct of Operations and Maintenance programs have not fully matured.

Table ES-1 lists the Board’s Conclusions and Judgments of Need that were identified during the course of this investigation. Appendix E lists additional opportunities for improvement the Board identified during the course of the investigation.

Table ES-1: Conclusions and Judgments of Need

Conclusions	Judgments of Need
Actions taken to respond to the arc flash, fire and the injured mechanic were adequate (Section 2.3).	N/A
The accident scene was adequately controlled (Section 2.4).	N/A
The commitment to comply with Integrated Safety Management System and regulatory requirements was adequately captured in contract documents and Site-level procedures (Section 3.1).	N/A
<p>The work in progress at the time of the event was poorly defined and was outside the scope of Procedure 18Q-2, <i>Safe Practices On or Near Electrical Conductors or Live Parts</i>, and the troubleshooting work package (Section 3.2).</p> <p>The hazards associated with the work scope performed were not adequately analyzed (Section 3.3).</p> <p>Experienced Qualified Electrical Workers disregarded proper implementation of hazard controls and failed to comply with required work planning and control practices by beginning corrective maintenance with no specific authorization or work package and later continuing corrective maintenance with a work package that did not cover the scope of the activities being conducted (Section 3.4).</p>	<p>SRNS needs to ensure that technical work documents contain specific activities that are defined in sufficient detail to allow for proper identification of hazards and implementation of hazard controls.</p> <p>SRNS needs to ensure that 484-D work is reviewed, authorized, supervised and performed by personnel that clearly understand the work scope, limitations, hazards, and controls prior to work execution.</p>
The arc flash calculations provided a conservative safety envelope (Section 3.3).	N/A

Conclusions	Judgments of Need
The 484-D monthly troubleshooting package did not comply with Procedure 1Y-8.03, <i>Troubleshooting</i> , requirements for troubleshooting (Section 3.4).	SRNS needs to ensure that troubleshooting work is controlled by a job-specific work order in compliance with Procedure 1Y-8.03.
Procedure 18Q-2 contained the necessary controls to safely perform this work and personnel were trained and qualified to the 18Q-2 requirements (3.4).	N/A
An effective process had not been implemented to control equipment (material and tools) introduced into energized electrical components (Section 3.5).	SRNS needs to develop a process to ensure adequate control of tools and equipment used on or near energized electrical components.
A perfunctory pre-job briefing was conducted for troubleshooting activities. The pre-job briefing failed to communicate the mechanics' specific tasks, the arc flash and shock hazards, appropriate tools, or the required personal protective equipment for the activity (Section 3.5).	SRNS needs to ensure that 484-D powerhouse personnel perform effective pre-job briefings in accordance with Manual 2S, <i>Conduct of Operations</i> , Alternate Implementing Method (2S AIM), including, but not limited to, discussing specific work scope and limitations, associated hazards, and controls necessary to perform work safely.
Experienced Qualified Electrical Workers failed to comply with general safe work practices and electrical procedures (section 3.5).	SRNS needs to reinforce individual responsibility to comply with safe work practices and electrical procedures.
Management failed to exercise leadership/oversight to ensure work was performed safely (Section 3.5).	SRNS needs to ensure that management and supervision set and enforce the expectation that activities are conducted in accordance with Site policies and procedures. This includes, but is not limited to, setting a good example with their actions, maintaining awareness of work activities under their cognizance, and maintaining an effective presence at the work site.
Conduct of Operations and Maintenance had not been effectively implemented in 484-D and the safety culture had not fully matured (Section 3.5).	SRNS needs to take prompt action to implement a step change in Conduct of Operations and Maintenance practices at the 484-D powerhouse. This includes, but is not limited to, near-term compensatory measures prior to completion of final corrective actions.

Conclusions	Judgments of Need
484-D powerhouse initiatives involving facility improvement, management presence in the field, and aggressive re-enforcement of expectations, although immature, were having a positive impact in some areas (Section 3.6).	N/A
The corrective actions taken as a result of numerous issues related to implementation of Procedure 18Q-2 requirements have not been effective in ensuring that personnel understand and properly apply electrical safety requirements (Section 3.6).	SRNS needs to reduce the excessive reliance on Qualified Electrical Workers knowledge as the single line of defense in identifying needed controls for electrical work.

ACRONYMS AND ABBREVIATIONS

AHA	Assisted Hazards Analysis
AMCP	DOE-SR Assistant Manager for Closure Project
Board	Accident Investigation Board
CR	Control Room
DOE	U.S. Department of Energy
E2	E2 Consulting Engineers, Inc
E&I	Electrical & Instrumentation
ESPC	Energy Savings Performance Contract
FLM	First Line Manager
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
NFPA	National Fire Protection Association
OFI	Opportunity for Improvement
PPE	Personal Protective Equipment
QEW	Qualified Electrical Worker
SCE&G	South Carolina Electric & Gas Company
SERB	Senior Electrical Review Board
SIMTAS	Site Integrated Management Total Assessment System
S/RID	Standards / Requirements Identification Document
SR	Savannah River Operations Office
SRNS	Savannah River Nuclear Solutions, LLC
SRS	Savannah River Site
SRSFD	Savannah River Site Fire Department
STAR	Site Tracking, Analysis and Reporting
WSMS	Washington Safety Management Solutions
WSRC	Westinghouse Savannah River Company / Washington Savannah River Company

1.0 INTRODUCTION

1.1 Background

At 1246 hours on September 23, 2009, an electrical and instrumentation (E&I) mechanic received second and third degree burns to his arms and first and second degree burns to his face when a metal tool (9-inch torpedo level) contacted the energized "A" phase of a 480 volt breaker causing a direct short to ground and an arc flash event.

On September 25, 2009, the Department of Energy (DOE) Savannah River Operations Office (SR) Manager appointed a Type B Accident Investigation Board (Board) to investigate the event in accordance with DOE Order 225.1A, *Accident Investigations*. The appointment memorandum is included in Appendix A to this report.

1.2 Site/Facility Description

The Savannah River Site (SRS) is a 310-square mile government-owned, contractor-managed facility near Aiken, South Carolina. Since August 1, 2008, DOE has contracted with Savannah River Nuclear Solutions, LLC (SRNS) for overall management and operation of Site activities.

Powerhouse Description

The D Area powerhouse (484-D) is located near the Savannah River on the Site's southern boundary. The facility has been operating since the early 1950s and serves SRS by exporting both steam and electrical power. The powerhouse consists of four 330-kilopound/ hour pulverized coal boilers, seven 12-15 megawatt turbine generators, and support systems and equipment. Steam is used primarily for processing in F, H, and S Areas. The steam is transported at 385 pounds per square inch through a large distribution pipeline to the end users who are five to seven miles away. Feed-water for the D Area powerhouse is drawn from the Savannah River via a dedicated pump station. In addition to steam, the powerhouse produces approximately 20 megawatts of electricity to offset the utility power purchased by SRS.

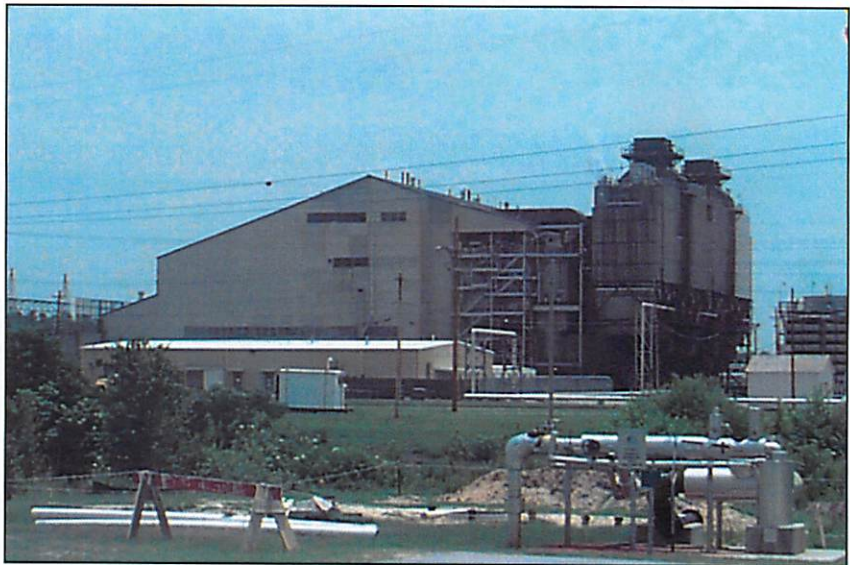


Figure 1-1: 484-D Powerhouse

Facility History

The 484-D powerhouse was constructed in the early days of SRS primarily to provide the steam required for processing activities in the Site's production areas. From the early 1950s until September 30, 1995, the powerhouse was operated by the SRS Management and Operating (M&O) contractor. On October 1, 1995, responsibility for operations and maintenance of the powerhouse was transferred to Prime South, a subsidiary of South Carolina Electric & Gas

Company (SCE&G), via a 10-year direct contract with DOE-SR. As part of this privatization initiative, the SRS 115 kilovolt electrical transmission and distribution system was turned over to SCE&G under a 40-year lease and a contract for maintenance and upgrades.

From October 1, 1995, to January 31, 2006, Prime South operated the plant in accordance with their commercial programs, policies, and procedures. The operating protocol also included a run-to-failure strategy because the powerhouse was expected to be replaced or to no longer be needed at the end of the original 10-year contract with Prime South. A primary driver for privatization of the 484-D powerhouse was avoidance of a \$30-\$50 million government capital reinvestment in the plant. The M&O contractor and DOE-SR had previously determined that this reinvestment to refurbish the plant was needed to ensure the plant could meet the projected long-term steam needs of the SRS processing facilities. Over the Prime South contract period, no action was taken to either replace or upgrade 484-D and the 10 year run-to-failure approach resulted in further degradation of the plant and significant deferred maintenance. During this period, DOE Conduct of Operations and Maintenance program improvements being implemented across SRS were not implemented in the powerhouse because they were not required by the Prime South contract with DOE-SR.

In November 2005, DOE-SR informed the M&O contractor that the Prime South contract would not be extended. On February 1, 2006, the M&O contractor assumed responsibility for powerhouse operations and maintenance. As part of this arrangement, approximately 65 incumbent Prime South personnel were hired by Washington Safety Management Solutions (WSMS), an affiliate of the M&O contractor's managing partner, Washington Group International. WSMS provided operations and maintenance services to the M&O contractor through an affiliate agreement and the M&O contractor assumed responsibility for the overall management, engineering, and other support functions previously provided by Prime South. During the WSRC/WSMS contract period, simultaneous programs were initiated to begin Energy Savings Performance Contract (ESPC) replacement of the 484-D powerhouse; invest selectively to work off deferred maintenance and increase plant reliability; and re-establish DOE-compliant operating and maintenance practices. The ESPC project was slow in initial development, but construction was underway at the time of the Board's investigation. During this short period, WSRC and WSMS made limited progress in improving material condition and Conduct of Operations and Maintenance at the 484-D powerhouse.

On July 21, 2008, 10 days before SRNS became the new SRS M&O contractor, the incumbent M&O contractor implemented a staff augmentation subcontract with E2 Consulting Engineers, Inc. (E2) to provide powerhouse operations and maintenance personnel. The subcontract replaced the affiliate agreement with WSMS and E2 hired most of the incumbent WSMS staff. This arrangement was in place at the time of the Board's investigation, with E2 providing the majority of the powerhouse operations and maintenance staff. SRNS directly staffs the plant manager, maintenance manager, and three maintenance First Line Manager positions and performs overall management, engineering, and other support functions. Since August 2008, SRNS has increased emphasis on material condition and Conduct of Operations and Maintenance improvement programs, but both remain continuing challenges that contributed to the work environment and culture that set the stage for this accident.

Because unplanned outages create significant impacts for SRS processing facilities, the powerhouse is operated under the management directive to maintain two boilers operating and one in standby. Falling below this status and the resulting urgency to re-establish two operating boilers is not uncommon. The constant struggle to maintain the desired operating status, coupled with inertia from more than 10 years of employing work practices that are less demanding than

current DOE Conduct of Operations and Maintenance standards, has resulted in a work environment that is conducive to shortcuts and work-arounds.

1.3 Scope and Methodology

The Board began its investigation on September 29, 2009, and submitted the final report to the DOE-SR Manager on October 22, 2009. The scope of the investigation included identifying all relevant facts; analyzing the facts to determine the direct, contributing, and root cause of the incident; developing conclusions; and determining judgments of need that, when implemented, should prevent the recurrence of the accident. The Board's scope also included addressing the role of DOE and contractor organization Integrated Safety Management Systems as well as an analysis of the application of lessons learned from similar accidents. The investigation was performed in accordance with Savannah River Implementation Procedure 225.1, *Accident Investigations*, based on the requirements of DOE O 225.1A, *Accident Investigations*, and DOE Workbook, *Conducting Accident Investigations*, Revision 2.

The Board conducted its investigation using the following methodology:

- Facts relevant to the accident were gathered through interviews, document reviews, and examination of physical evidence.
- Event and causal factor charting, barrier analysis, and change analysis techniques were used to analyze the facts and identify the causes of the accident.
- Based on the above analyses, Judgments of Need were developed to identify corrective actions to prevent recurrence of the accident.

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, which is the immediate event or condition that caused the accident; root cause, which is the causal factor that, if corrected, would prevent recurrence of the accident; and contributing causes, which are the causal factors that collectively, with the other causes, increase the likelihood of the accident but that did not cause the accident.

Events and causal factors analysis includes charting to depict the logical sequence of events and conditions 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 physical and/or administrative barriers put in place to separate the hazards from the targets.

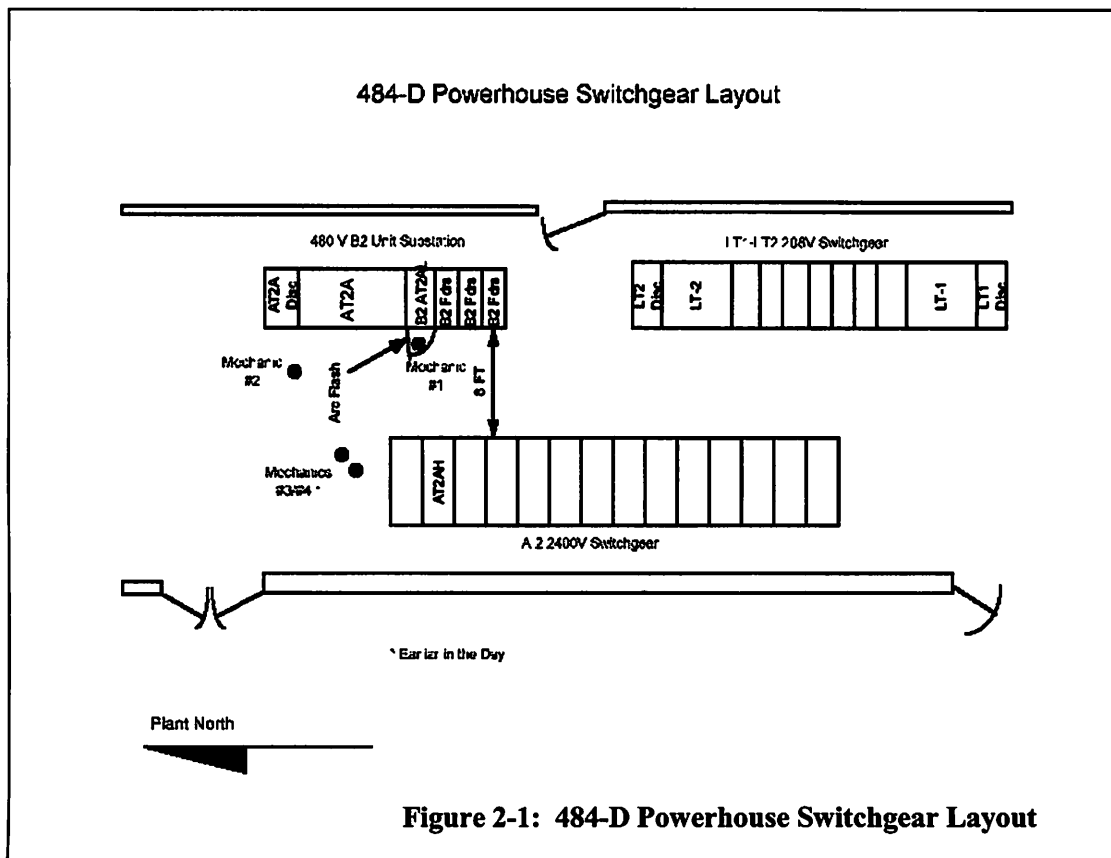
Change analysis is a systematic approach that examines the planned or unplanned changes in a system that caused the undesirable results related to the accident.

Judgments of Need are managerial controls and safety measures necessary to prevent or minimize the probability or severity of accident recurrence.

2.0 THE ACCIDENT

2.1 Accident Overview

At 1246 hours on September 23, 2009, an electrical and instrumentation (E&I) mechanic (E&I Mechanic #1) received second and third degree burns to his arms and first and second degree burns to his face when a metal tool (9-inch torpedo level) contacted the energized "A" phase of a 480 volt breaker, causing a direct short to ground and an arc flash event. At the time of the accident, two E&I mechanics were troubleshooting/repairing the breaker and cubicle because the breaker would not close. During earlier attempts to close the breaker, the mechanics concluded the problem was related to an un-level track resulting in breaker misalignment in the cubicle. The level was placed in the energized cabinet by E&I Mechanic #2 to determine the extent of "adjustments" needed to position the breaker within the cabinet. The level fell from the top of the arc chute down the left side of the breaker (when facing the breaker) and is suspected to have lodged between the "A" phase breaker moving contact and the breaker support brace, causing the arc flash. The arc flash severely damaged the left side of the breaker, generated excessive heat, and resulted in splattering of material within the cubicle and surrounding area, including evidence of slag embedded in the electrical equipment approximately ten feet away. E&I Mechanic #1 was positioned at the front of the breaker cabinet without an arc flash suit or flame-retardant coveralls. He recognized the level was falling and positioned his arms horizontally to protect his head and face. He experienced second and third degree burns to his arms and first and second degree burns to the right side of his face. E&I Mechanic #2 had stepped away from the cabinet and was outside the effect of the arc flash. Based on the condition of the circuit breaker and cubicle, the Board determined the fault current was interrupted before the short was able to develop a plasma arc cloud which would have made the event a fully engulfed arc flash, creating more extreme consequences including more serious injuries to the workers.



2.2 Event Chronology

Related Activities Prior to September 23, 2009

- 8/5/2009: Breaker removed for preventive maintenance, spare installed but not closed
- 8/31/2009: Breaker preventive maintenance completed
- 9/10/2009: Breaker returned from shop and re-installed but not closed

September 23, 2009

- Morning: Report of 484-D Transformer #1 overheating/ burning smell. Operations management decides to return electrical distribution system to its normal operating alignment
- 1020 hours: 484-D Control Room attempt to close breaker fails; Shift Operations Manager calls E&I personnel for assistance
- Morning: Three E&I personnel (one First Line Manager (FLM) and two mechanics) go to inspect breaker and request Control Room to attempt to close breaker (attempt fails)
- Morning: E&I personnel rack breaker out and in, request Control Room to attempt to close breaker again (attempt fails)
- 1100 hours: Operations directs E&I personnel to rack original breaker out, rack spare in
- 1100, 1122 and 1139 hours: Control Room attempts to close breaker fail
- 1142 hours: E&I attempt to manually close breaker locally fails
- Midday: E&I personnel break for lunch
- 1230 hours: E&I FLM holds Pre-Job Briefing for breaker troubleshooting activities

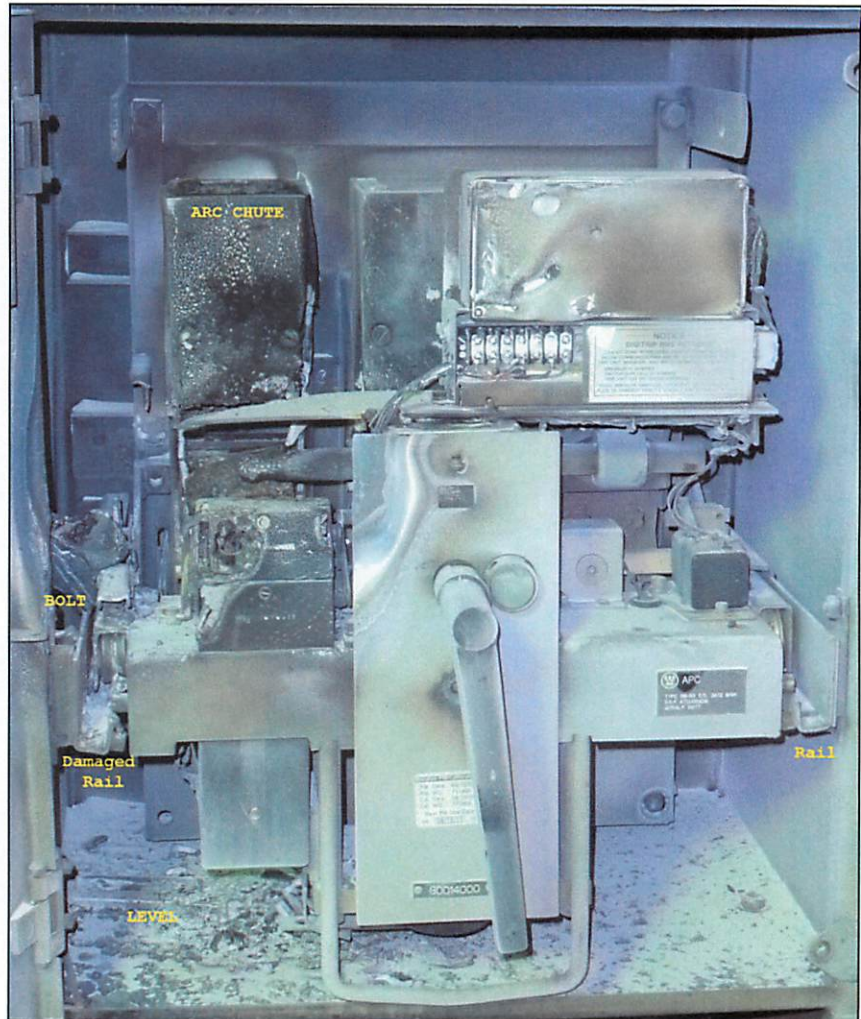


Figure 2-2: AT2AL Breaker

- Unknown: E&I Mechanics #1 and #2 begin troubleshooting breaker
- 1245 hours: E&I Mechanic #2 places metal torpedo level on breaker and walks away
- 1246 hours: Metal torpedo level falls in breaker while E&I Mechanic #1 is attempting to stabilize it
- 1246 hours: Arc Flash occurs, E&I Mechanic #1 is injured
- 1246 hours: D2 boiler tripped
- 1247 hours: Fire reported in switchgear room / SRS Fire Department (SRSFD) called
- 1249 hours: SRSFD dispatched to 484-D
- Unknown: E&I Mechanic #1 (injured) walking toward nearby shop to obtain medical assistance, met by responding personnel; E&I Mechanic #2 proceeding to Control Room to report event and seek help
- 1250 hours: Control Room orders evacuation of non-essential personnel to rally point
- 1254 hours: Panel verified de-energized (post-event - 125 volt Direct Current breaker control power was not de-energized)
- 1254 hours: Responder and E&I Mechanic #1 approach Barricade 7 in government vehicle
- Unknown: 484-D Area Operations Manager puts out fire using ABC extinguisher prior to Fire Department responding to scene
- 1257 hours: Ambulance/Medical and Emergency Personnel arrive at Barricade 7 (location of E&I Mechanic #1)
- 1300 hours: SRSFD Battalion Chief assumes command of 484-D incident scene
- 1301: Medical personnel and E&I Mechanic #1 en route to Doctors Hospital Burn Unit in Augusta, Georgia
- 1302 hours: SRSFD enters facility to verify fire is out
- 1335 hours: Ambulance/E&I Mechanic #1 (injured) arrive at hospital
- 1338 hours: Facility personnel with personal protective equipment and meter verify 480 volt power is off
- 1423 hours: All clear is given
- 1440 hours: SRSFD returns command back to 484-D

2.3 Emergency Response and Medical Treatment

The emergency response and medical treatment during this event were reviewed and found to be adequate with one area identified as an opportunity for improvement.

The Control Room's first indicator that an abnormal situation existed was loss of the D2 boiler as a result of the power losses that occurred after the arc flash. The Control Room made a general area announcement related to the boiler trip. Personnel responding to the Control Room announcement noted smoke coming from the switchgear room and communicated via radio that there was a potential fire situation. Responding personnel opened the area to ventilate the smoke, verified that the Alternating Current power was isolated, and used a single portable ABC fire extinguisher to put out what was described as a small flame inside the breaker cabinet. The SRS Fire Department arrived on the scene (response time was approximately 15 minutes), inspected the switchgear for hot spots to ensure the fire was totally extinguished, and cleared the scene approximately 1.5 hours after arrival. The Board did not identify any issues of significance

related to the fire response other than noting that 125 volt Direct Current power had not been de-energized in the switchgear.

Medical treatment of the injured mechanic at the scene was minimal. E&I Mechanic #2 verbally questioned E&I Mechanic #1 at the scene to determine E&I Mechanic #1's condition. Based on E&I Mechanic #1's responses, E&I Mechanic #2 directed E&I Mechanic #1 to a nearby shop building to seek medical assistance. E&I Mechanic #2 then proceeded to the Control Room to report the incident. As E&I mechanic #1 (the injured mechanic) walked toward the shop, he met a responder approaching the powerhouse. The responder retrieved a government vehicle and transported E&I Mechanic #1 to Barricade 7 to meet the ambulance. The ambulance was arriving as they approached the barricade. E&I Mechanic #1 was transferred to the ambulance and taken to the Doctor's Hospital Burn Unit in Augusta, Georgia, for treatment. Based on SRS Emergency Operations Center logs, the time from the event to ambulance transfer was approximately 15 minutes. While transport of an injured worker by non-medical personnel is not normally recommended, no adverse impacts resulted in this case and the action actually reduced the overall medical response time. A noteworthy item was the Emergency Duty Officer's actions to provide advance notification to the security helicopter that a medical transportation (medivac) may be requested. This type of proactive notification helps to minimize delays and improve response times.

One opportunity for improvement is to enhance communication capability at the work site. The E&I mechanics at the scene did not have Site radios and the work location did not have a nearby telephone. This forced the uninjured mechanic to make a choice regarding seeking help or tending to his injured coworker. While the delay and choices made in this case did not adversely impact the facility or the injured worker, the potential impact in a slightly modified scenario could have been much more severe.

In summary, the Board concluded that the actions taken to respond to the arc flash, fire and the injured mechanic were adequate.

2.4 Investigative Readiness and Accident Scene Preservation

DOE O 225.1A, *Accident Investigations*, requires contractors to establish and maintain readiness to respond to accidents, mitigate the consequences, assist in collecting and preserving evidence, and assist with the conduct of the investigation. This includes preserving the accident scene while it is under the contractor's control and documenting the accident scene through photography and other means. SRNS implements these requirements through a variety of documents, including:

- Manual 9B, *Site Item Reportability and Issue Management (SIRIM)*, Procedure 1-0, Rev. 4, effective September 7, 2007. This procedure requires actions to be taken to preserve conditions for continued investigation and documenting the accident scene, as appropriate, where these actions do not interfere with establishing a safe condition.
- Manual 2S, *Conduct of Operations*, Procedure 5.2, Rev. 9, effective September 2, 2008, outlines the procedure for issue investigation, including ensuring that equipment, systems or areas are quarantined as necessary in order to preserve evidence, minimize further equipment damage, and/or prevent personnel injury.
- Manual 8Q, *Employee Safety*, Procedure 8Q-18, Rev. 9, effective June 24, 2003, Attachment B, "General Investigating Guidance for Injuries/Illnesses." The attachment includes guidance on accident scene preservation, such as: "Safeguarding of evidence... is essential to the investigation."

- Manual SCD-7, *SRS Emergency Plan*, Section 9, Rev. 6, effective February 6, 2009, "Recovery and Reentry," contains requirements for control of the accident scene such that it will be preserved until the cognizant investigative authority concurs that recovery or normal operations can be resumed.

During the accident investigation, the Board noted the following facts regarding SRNS's investigative readiness:

- The scene was secured shortly after the fire event was terminated. A barricade was placed around the scene with strict entry conditions posted.
- During recovery planning activities, the Board granted permission to allow facility personnel to enter the area. However, prior to entry, facility management failed to adequately brief the staff on their limitations and responsibilities relative to scene preservation. During the entry, an individual entered the breaker cabinet and removed the level in question, inspected it, and then returned it to the cabinet. The Board observed the disturbed incident scene the following day and notified the facility. The Board interviewed the planners and facility management to determine the extent of activities performed and the source of the breakdown in communications. Based on the personnel interviews, the Board concluded the scene disturbance was minimal, sufficient photographic evidence of the original scene existed, and the movement of material did not impact the fact-finding phase of the investigation.

In summary, the Board concluded that the accident scene was adequately controlled.

3.0 ACCIDENT FACTS AND ANALYSIS

3.1 SRS Integrated Safety Management Processes

The Board considered the facts related to the accident and its analyses of the accident and has related this information to Integrated Safety Management (ISM) Core Functions. The ISM Core Functions comprise the fundamental DOE safety and health policies that should be incorporated into all work planning and execution activities. The five ISM Core Functions are designed to ensure that safety is effectively considered and implemented during all phases of work activities. The failure of any one of the core functions will result in the failure to effectively accomplish subsequent core functions. For example, if the specific work scope to be accomplished is not clearly and effectively identified, or if work scope changes are not recognized, the task-specific hazards associated with the specific work scope cannot be properly identified.

The DOE Integrated Safety Management System (ISMS) is described in DOE P 450.4, *Safety Management System Policy*. SRS's ISMS implementation is described in SRNS-RP-2008-00087 Rev. 1, *Integrated Safety Management System Description*, August 24, 2009. The ISMS Description document is part of the Standards/Requirements Identification Document (S/RID) which is part of DOE Contract DE-AC09-08SR22470. The SRS ISMS Description document was initially approved in 1997 and the certified system was adopted by the current Management and Operating contractor (SRNS) in 2008. The ISMS applies to work performed by SRNS and work performed by SRNS subcontractors when required by subcontract or applicable law.

The principal regulation associated with this event is 10 CFR 851, *Worker Safety and Health Program*, which requires implementation of National Fire Protection Association (NFPA) 70E, *Standard for Electrical Safety in the Workplace*. Both requirements are invoked by the SRNS contract and incorporated in the S/RID. S/RID 19.02.01.016 identifies the primary implementing procedures as Manual 18Q, *Safe Electrical Practices and Procedures*, and Manual 8Q, *Employee Safety Manual*. Manual 1Y, *Control of Maintenance*, is another key document governing

performance of work. The E2 contract Statement of Work (SOW #306464, Rev. 7) states, “All work associated with operations, maintenance, and engineering as outlined in the SOW shall be in compliance with all SRNS policies, procedures, and systems”.

In summary, the Board concluded that the commitment to comply with ISMS and regulatory requirements was adequately captured in contract documents and Site-level procedures.

3.2 Define the Scope of Work

Effective work execution begins with the development of a well-defined scope of work that translates mission and requirements into terms that those who are to accomplish the work can clearly understand. The definition of work scope must provide sufficient detail to support hazard analysis and subsequent development and implementation of controls at the task level. Line management must determine the work to be accomplished and be accountable for completely understanding the scope through every phase of the work cycle.

In this event, the definition of the afternoon work scope was broad and vague – determine what was wrong with the breaker and fix it. Given that troubleshooting is a work activity that requires flexibility, it is also a work activity that requires the clearest definition of what is not allowed, or definition of limitations, such that hazards can be bounded, controls can be established, and stopping points clearly understood by the workers. In this case, the work limitations were not clear. The use of a generic troubleshooting package further eroded the process of defining the scope because it eliminated review by key organizations in the process, including work planning and engineering. The generic work package described the afternoon work to be performed as: “Troubleshoot activities at 484-D Powerhouse and support facilities per Manual 1Y-8.03”. Manual 1Y, *Conduct of Maintenance*, Section 8.03, *Troubleshooting*, does not permit the use of a pre-approved troubleshooting work package for nonspecific work activities. Not only was the generic troubleshooting work package not in compliance with Procedure 1Y-8.03, the proposed troubleshooting of the 480 volt breaker was outside the limitations of the generic troubleshooting work package. The package was restricted to work that could be accomplished using standard personal protective equipment (PPE) – hearing protection, hard hats, safety glasses, leather gloves, and sturdy work shoes – which excludes almost all electrical work. Arc flash calculations for the breaker had been completed and labels had been clearly affixed to the front of the cabinet door in accordance with NFPA 70E, *Standard for Electrical Safety in the Workplace*, requirements. Based on the arc flash hazard of 87.6 calories/cm² and the requirements identified in Procedure 18Q-2, *Safe Practices On or Near Electrical Conductors or Live Parts*, this breaker should not have been worked in an energized state without required special reviews and authorizations. The required special reviews and authorizations were not considered or obtained. In addition, the scope definition identified in the work order and Safe Work Permit contradicts the hazard analysis prescreen description of work. The prescreen criteria allows electrical work to be performed by Qualified Electrical Workers (QEW) per Procedure 18Q-2, with the exception of work tasks requiring Energized Electrical Work Permits.

In summary, the Board concluded that the work in progress at the time of the event was poorly defined and outside the scope of Procedure 18Q-2 and the troubleshooting work package.

3.3 Analyze Hazards

The objective of the hazards analysis process is to develop an understanding of the task-specific hazards that may affect the worker, the public, or the environment. If appropriately followed, the Procedure 18Q-2 process would have prevented working this breaker energized without special authorizations, including the Senior Electrical Review Board (SERB). By error or intent, use of a generic troubleshooting work package allowed the supervisor and mechanics to exclude the SERB, facility work planning, and engineering from the process. The generic hazard analysis

and Safe Work Permit which supported the afternoon troubleshooting work package were based on a prescreen hazard analysis and limited electrical work to those activities covered by Procedure 18Q-2. The supervisor and mechanics did not verify the work scope met the prescreen conditions and did not uniquely identify and discuss the hazards associated with this work scope.

Although the prescreen hazard analysis discusses the use of electrical PPE in accordance with Procedure 18Q-2, the troubleshooting work package and Safe Work Permit limited work to activities that could be accomplished using standard PPE. During personnel interviews standard PPE was consistently identified as hearing protection, hard hats, safety glasses, leather gloves, and sturdy work shoes.

Procedure 8Q-122, *Hazard Analysis*, contains criteria for a prescreen hazard analysis that allows most electrical work to be performed by QEWs in accordance with Procedure 18Q-2, with the exception of work tasks requiring Energized Electrical Work Permits. The threshold level for prescreening of activities is illustrated in the following examples:

- Routine work performed in designated shop areas;
- Routine laboratory tasks performed in designated laboratories;
- General office work;
- Software loads and system management activities on process control systems;
- Routine operations activities;
- Operations support activities such as changing chart paper or replacing indicator lamps;
and
- Moving or maintaining protective clothing and/or building supplies.

While a complete list of all activities covered by prescreening would be impractical to generate, hands-on troubleshooting of an energized 480 volt breaker is not consistent with the examples provided in the procedure.

Arc flash calculations had been completed on the breaker and labels had been clearly affixed to the front of the cabinet door in accordance with NFPA 70E requirements. Based on the calculated arc flash hazard of 87.6 calories/cm² and the requirements set forth in the SRNS implementing procedure for NFPA 70E (Procedure 18Q-2), this breaker cubicle was not allowed to be worked in an energized state without special reviews and authorizations – which were not obtained. The Board reviewed the drawings and the arc flash study applicable to the electrical system under investigation and concluded that the methods used to estimate incident energy for the purpose of selecting appropriate arc flash PPE are conservative and consistent with generally accepted industry standards. However, the following opportunities for improvement in the accuracy of the estimates and the margin of safety were noted:

- The analysis did not consider the possibility of an arc flash event occurring in the main breaker cubicle while the breaker is open and the cabinet fed from two different sources. The engineer that completed the analysis stated that an arc flash while in this condition was considered incredible. In fact, this condition existed when the arc flash occurred. The line side of the main beaker was energized directly from Transformer 2 and the load side was energized via the tie-breaker fed from Transformer 1. An interlock is in place to prevent closing the main breaker with both sources energized. However, failure of the interlock or a short similar to the one that occurred in this event could result in an arc flash involving both sources and by industry standards must be included in the arc flash calculations.
- The clearing time considered the 2400 volt over-current device on the primary side of the alternate transformer. The assumed 7-second clearing time used in the calculation results

in a conservative incident energy calculation versus the 2-second clearing time recommended by NFPA 70E (i.e., arc flash hazard calculations need not consider fault durations longer than 2 seconds).

The morning of the event, the breakers had been racked in and out by the E&I supervisor and the two E&I mechanics in support of operations. The supervisor, during interviews, stated that he assumed that the arc flash hazard for all of the breakers in the entire switchgear panel was less than 40 calories/cm². Although several generic hazard analyses for racking breakers in and out were found in the Assisted Hazards Analysis (AHA) database, all of the analyses were prescreens based on the Procedure 18Q-2 exclusion criteria and none could be explicitly linked to this breaker. Additionally, the pre-job briefing for the afternoon troubleshooting activities failed to communicate the mechanics' specific tasks, the arc flash and shock hazards, appropriate tools, and the required PPE for the activity.

During this investigation, the Board questioned how a lockout can be established, as required by Procedure 18Q-2, on equipment with an arc flash hazard greater than 40 calories/cm² if absence of voltage checks are required prior to establishing a lockout (specifically, would a special Energized Work Permit be required and what PPE would be used). The SERB confirmed that no special energized work permits had been authorized to accomplish lockout verifications on equipment with an arc flash hazard greater than 40 calories/cm² anywhere onsite, and the only authorized method at this point would be to go upstream and isolate the power feeders. No evidence of upstream power feeds being taken out of service was found for the August 5, 2009, September 10, 2009, or September 23, 2009, breaker removal and reinstallation work. This further substantiates the Board's determination that there has been an ongoing practice in the powerhouse to work on or near this equipment without the required analysis or controls.

In summary, the Board concluded that the hazards associated with the work scope performed were not adequately analyzed. Analyses to support Procedure 18Q-2 work conditions and PPE requirements were limited to arc flash hazards less than 40 calories/cm² and required special reviews and approvals for work above 40 calories/cm². The required special reviews were not performed, and the supervisor and mechanics failed to verify the work intended to be performed was adequately encompassed by the generic prescreen hazard analysis attached to their troubleshooting package.

3.4 Develop and Implement Hazard Controls

The objective of developing and implementing hazard controls is to identify and provide all engineering, administrative, and PPE requirements consistent with the hazards to be encountered. To adequately develop and implement hazard controls, the work scope must first be well defined and the hazards thoroughly analyzed. In this accident, failure to adequately define the scope and then failure to properly analyze the hazards precluded effective development and implementation of hazard controls.

Application of Procedure 18Q-2 Requirements

During the investigation, the Board noted the following facts regarding the application of Procedure 18Q-2 requirements:

- The work scope related to the accident was performed in breaker cubicle AT2AL of 480 volt bus B2 with the arc flash label shown in Figure 3-1.
- The arc flash label on cubicle AT2AL was based on a calculation that assumed a 7-second fault time and did not consider a fault simultaneously fed by both the line and bus sources.

- The E&I First Line Manager (FLM) stated that he assumed the arc flash hazard was less than 40 calories/cm² in accordance with labels on the other breaker cubicles of bus B2.
- Work activities were conducted inside the breaker cubicle in the vicinity of unguarded energized live parts, contrary to Procedure 18Q-2.
- The FLM and both E&I mechanics involved in the accident stated that they thought arc flash protection was required only for racking the breaker in/out. The work activities resulting in the accident were performed assuming no arc flash PPE was required.
- According to Procedure 18Q-2, the intended work scope in the AT2AL cubicle could be performed only under one of the following two controls:
 - All hazardous energy sources are de-energized and placed in a safe energy state in accordance with Procedure 8Q-32, *Hazardous Energy Control. (Lockout/Tagout)*.
 - An Energized Electrical Work Permit is in place including the development and implementation of specific hazard controls for the work activities to be performed.

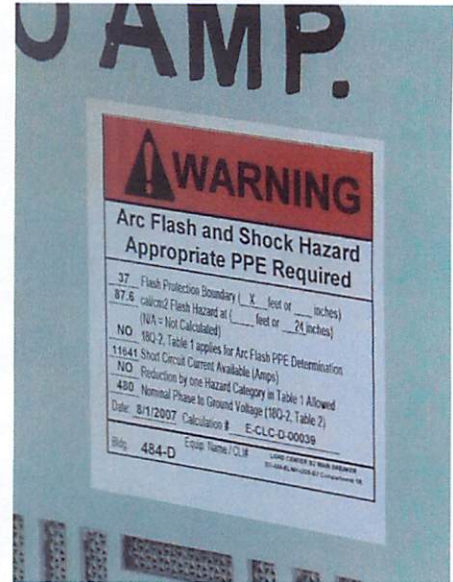


Figure 3-1: AT2AL Arc Flash Label

The Board found that neither of these two controls was applied to the work performed on the day of the event.

- Training requirements for QEWs include annual completion of the course “Safe Practices On or Near Electrical Conductors – training on understanding and applying the requirements of 18Q-2”. The FLM and both E&I mechanics were current on this training requirement and were documented as QEWs.

In the case of this accident, three experienced QEWs did not define the work scope or fully analyze hazards and applied an erroneous rule of thumb for hazard controls (that arc flash PPE is not required unless racking a breaker in or out).

As a result of misapplication of Procedure 18Q-2, the following NFPA 70E violations occurred:

- A conductive object (9-inch metal torpedo level) was placed within the Limited Approach Boundary where the object could make contact with energized parts, contrary to NFPA 70E 130.7(D);
- Arc-rated clothing was not worn inside the Arc Flash Protection Boundary, contrary to NFPA 70 E 130.7(C)(13) and 130.3;
- Exposed energized parts were not placed into an electrically safe work condition before personnel approached nearer than a safe distance, contrary to NFPA 70 E 110.8(A)(1) and 130.1; and
- Working within the Limited Approach boundary of exposed energized circuit parts was not justified, contrary to NFPA 70E 130.1(A)(1).

The Board found that Procedure 18Q-2 is cumbersome with respect to navigating between Table 1, Table 1 Notes, Table 2, and Table 3. The procedure starts with the basic rule that to work on or near electrical conductors, they must be locked out per Procedure 8Q-32, *Hazardous Energy Control*. However, Table 1, which makes up almost a third of the 35-page procedure, lists 25 types of work that are general categories of recognized exceptions to the basic rule, with numerous individual tasks and different levels and nature of hazards within each type of work. Table 1 also includes hazard controls, approval and attendance requirements, and references to supplemental notes elsewhere in the procedure that must be consulted for more detailed information regarding hazard controls. The 53 supplemental Notes to Table 1 cover 10 pages of the procedure. Further, because arc flash hazards must be addressed in addition to shock hazards, the arc flash label on equipment in the field must be interpreted in accordance with the instructions to determine whether the PPE requirements identified in Table 1 are applicable. If not applicable, QEWs must consult Table 3 for determination of the proper PPE. Depending on the specific situation, the PPE requirements in Table 3 may be more or less than the PPE listed in Table 1 for the specific work task.

The Board reviewed both the classroom and computer-based Procedure 18Q-2 training and found that in both cases, the training clearly explains and distinguishes between shock hazards and arc flash hazards. The training also adequately illustrates how to apply the procedure to various electrical work activities. Overall, the training is adequate to qualify electrical workers and the workers involved in the accident were qualified. However, the Board also noted that only three of the eleven practical exercises included in the Procedure 18Q-2 training involved arc flash hazards and no exercises included an example where the required PPE found in Table 3 exceeded the PPE in Table 1. Given that Table 1 has been included in the procedure since inception in the early 1990s, and Table 3 was added with the incorporation of NFPA 70E, the potential exists for long-term experienced electrical workers to erroneously conclude that Table 1 is the only significant table.

While Procedure 18Q-2 and the corresponding training could be improved, neither the procedure nor the training was determined to contribute to the accident. Even without consideration of Table 3, properly applying Table 1 for work within the limited space, but outside the restricted space, requires one pair of fire-resistant coveralls. The QEWs involved in the accident had extensive experience and no misinterpretation or misapplication of Procedure 18Q-2 or the associated training could credibly lead to the conclusion that no arc flash PPE was required for the work activity they initiated. The Board concluded that QEWs consciously chose to perform the work scope without appropriate consideration of the required safe electrical work practices by performing the work without arc flash PPE.

The Board concluded that Procedure 18Q-2 contains the necessary controls to safely perform electrical work and personnel were trained and qualified to the 18Q-2 requirements. The Board concluded that experienced QEWs disregarded proper implementation of hazard controls resulting in non-compliance with required safe electrical work practices.

Application of Work Planning and Control Requirements

During the investigation, the Board noted the following facts regarding the application of work planning and control requirements:

- The work scope related to the accident was troubleshooting to determine why breaker AT2AL of 480 volt bus B2 would not close and repairs to correct the problem.
- The pre-job briefing failed to communicate specific work scope, scope limitations, tasks, tools, hazards, and required controls (PPE).

- The work was initiated under the 484-D monthly troubleshooting work package (Work Order 968313).
- Previous use of this monthly troubleshooting work package in September 2009 was within the scope of the work order.
- The FLM and E&I Mechanic #2 retrieved the monthly troubleshooting work package without consulting or informing the work control group. Use of this package precluded specific work scope definition, development of a unique AHA, work planning and engineering involvement, and operations notification.
- The Shift Operations Manager and Control Room (Operations) were not notified that the troubleshooting work was being performed after lunch. Work authorization from the Shift Operations Manager was provided at the beginning of the month when the generic troubleshooting work package was signed.
- The generic monthly troubleshooting work package is limited to work scope requiring only standard PPE.
- The AHA associated with the monthly troubleshooting work package specifically excludes work that requires an Energized Electrical Work Permit. An Energized Electrical Work Permit was required to perform this work scope without lockout of all hazardous energy sources.
- Procedure 1Y-8.03, *Troubleshooting*, requires that troubleshooting be controlled by one of the following methods listed below. All three options require creation of an individual work order for specific troubleshooting activities.
 - The Fix-It-Now (FIN) process, which is limited to the activities listed in Section 3 of Procedure 1Y-8.03;
 - An approved work order with work instructions; or
 - A Formal Troubleshooting Plan with an approved work order.

In the case of this accident, three experienced QEWs did not fully define the scope or analyze the hazards and improperly used a monthly troubleshooting work package with an inadequate AHA. The creation and utilization of a monthly generic troubleshooting package, in non-compliance with Procedure 1Y-8.03 requirements, is an illustration of a work environment focused on streamlined execution, with less than adequate attention to proper work planning and hazard analysis.

Based on evaluation of interviews and analysis of evidence at the accident scene, the Board determined that the troubleshooting activity to identify the condition to be corrected was actually conducted in the morning of the day of the event, before the afternoon work that resulted in the accident. It was during morning activities that the need to correct breaker alignment in the cubicle via adjustment of the cubicle rails was determined. The work to correct the alignment was also initiated in the morning, before any maintenance work package was in use. The Board discovered that personnel used a hammer and a wrench while they were attempting to adjust the rail (during the course of the investigation, the Board noted that the rail support bolt was broken.). At this point, the troubleshooting work package was initiated. By the time the troubleshooting work package was invoked, the job had progressed beyond troubleshooting into repair and adjustments to correct the problems identified during morning activities. The actual work required a corrective maintenance work order with a fully defined work scope, thorough analysis of hazards, and specifically developed hazard controls.

The Board concluded that the monthly troubleshooting work package was non-compliant with Procedure 1Y-8.03. All troubleshooting activities are required to be controlled by a task specific work order and associated hazard controls. Section 3 of 1Y-8.03 states, "In addition to activities performed using 18Q, Procedure 2, qualified trained mechanics may also perform the following activities as required..." and then a number of low hazard electrical work activities are listed. This wording could be misinterpreted to mean that any electrical work activities performed using Procedure 18Q-2 fit within the scope of troubleshooting activities.

While the wording in Procedure 1Y-8.03 could be improved, the Board determined it did not contribute to the accident. The work resulting in the accident was beyond troubleshooting and should have been performed under a corrective maintenance work order that included all appropriate controls. The FLM and mechanics involved in the accident engaged in troubleshooting and repairs in the morning with no maintenance work package. They continued repairs in the afternoon with the troubleshooting work package which did not cover the actual work scope, without involvement or notification of operations, work control, or engineering.

The Board concluded that experienced FLM and E&I mechanics, who were Qualified Electrical Workers, disregarded proper implementation of hazard controls and failed to comply with required work planning and control practices by beginning corrective maintenance with no specific authorization or work package and later continuing corrective maintenance with a work package that did not cover the scope of the activities being conducted. The Board also concluded that the 484-D generic monthly troubleshooting work package is non-compliant with the requirements of Procedure 1Y-8.03, *Troubleshooting*.

3.5 Perform Work within Controls

The five ISMS Core Functions are designed to ensure that safety is effectively considered and implemented during all phases of work activities. The failure of any one of the core functions will result in the failure to effectively accomplish subsequent core functions. For example, if the specific work scope to be accomplished is not clearly and effectively identified, or if work scope changes are not recognized, the task-specific hazards associated with the specific work scope cannot be properly identified.

During the morning of the incident, an odor and excessive heat emanating from Transformer #1 in the switchgear room was noticed and communicated to operations. Based on concerns related to Transformer #1 overheating, the facility and operations managers decided to reconfigure the electrical system and transfer some of the load from Transformer #1 to Transformer #2. This required opening the bus tie breaker and closing the main breaker (AT2AL). The main breaker had been removed and calibrated in August 2009 and was reinserted in the cubicle on September 10, 2009, but was not closed. After the Control Room operator unsuccessfully attempted to remotely close the main breaker at 1020 hours, the E&I FLM was contacted to "check out the breaker". Additional attempts to remotely and manually close the breaker were made with the assistance of the FLM and E&I Mechanics #1 and #2. The Control Room maintained communications with the E&I FLM via cell phone during attempts to close the breaker. The 484-D Facility Manager, Operations Manager, and E&I FLM collectively decided to remove the original breaker and insert a spare breaker located in the switchgear room. The E&I FLM and Mechanics #1 and #2 replaced the original breaker with the spare. Within approximately 90 minutes, at least three remote attempts and one manual attempt to close the breaker failed. The final attempt to close the breaker was at approximately 1142 hours, after which the maintenance crew went to lunch.

During the attempts to close the spare breaker, the FLM and mechanics discovered that the left track in which the breaker traverses was misaligned, causing the breaker to tilt forward and to the

left. Through interviews, the Board discovered that the work crew engaged in unauthorized repair work prior to lunch. The E&I FLM used a hammer in attempts to align the left track so that the breaker contacts and stabs would properly engage. Additionally, the Board investigation and interviews revealed that a wrench was used in efforts to align the track. The work crew decided to break for lunch and create a technical work document to continue working on the breaker. The technical work document consisted of an authorized generic monthly troubleshooting work package and a pre-screen hazard analysis. The work package described the work to be performed as “troubleshoot activities at 484-D Powerhouse and support facilities per Manual 1Y-8.03.”

After the crew’s lunch break, the FLM and Mechanic #2 performed a less than adequate “pre-job briefing” and signed the work documents. Discussions regarding required PPE were minimal at best. The focus of the “pre-job” was to “troubleshoot” the breaker. After the pre-job briefing, E&I Mechanic #2 found E&I Mechanic #1 at his work station and requested his help in repairing the breaker. Mechanic #1 signed the Safe Work Permit but was unsure of the exact work scope and his specific task. E&I Mechanic #2 obtained a 9-inch metal torpedo level from the shop on the way to the switchgear room. E&I Mechanic #2 planned to use the level to identify how much adjustment would be required to properly align the breaker track. After the mechanics arrived in the transformer room, E&I Mechanic #2 placed the level on the “A” phase arc chute of the breaker and walked east of the breaker to record information in the work package. E&I Mechanic #1 observed the level wobble and thought that it may fall. He reached in the cubicle with his left hand to grab the level but was too late in his effort to prevent the level from falling. Through the investigation process, the Board determined that the level most likely fell to the left of the breaker into the breaker “A” phase moving contact and the cubicle wall creating a path-to-ground which resulted in the arc flash. E&I Mechanic #1 raised his arms in a protective motion to guard his face against the arc flash. E&I Mechanic #2 was not affected by the arc flash since he was several feet away from the breaker. Neither mechanic had donned any arc flash PPE. E&I Mechanic #1 sustained second and third degree burns to the arms and first and second degree burns to his face.

When the damaged breaker was removed from the cubicle during recovery actions on October 3, 2009, wooden shims were found on the right track. The Board determined that attempts to level the breaker via wooden shims were made during the unauthorized work on the morning of the event.

During the morning work activities (attempted adjustments), two other E&I Mechanics (#3 and #4) were performing authorized work, replacing a breaker test station cable, approximately 20 feet from the AT2AL breaker cubicle. E&I Mechanics #3 and #4 were interviewed and provided written statements to the Board. The mechanics testified that they observed E&I Mechanic #1 donning an arc flash suit during some of these activities, but they did not observe the FLM or E&I Mechanic #2 don an arc flash suit or leave the area. Mechanics #3 and #4 stated that they left the area when E&I Mechanic #1 began donning the arc flash suit. When the FLM used the hammer, E&I Mechanics #3 and #4 also left the room because they felt they were in danger of being “hit by flying metal”. E&I Mechanics #3 and #4 also discussed that hammering a breaker was not normal procedure but since the work involved a supervisor, they assumed he had appropriate documentation and that the equipment was de-energized. During lunch, E&I Mechanics #3 and #4 told E&I mechanic #1 to be safe and don’t let anyone “get you killed”. E&I Mechanics #3 and #4 did not call a time-out during the observed activities or brief management on their concerns until after the event.

The Board determined that neither the morning nor the afternoon troubleshooting work activities were performed within the required controls. The FLM and E&I Mechanics #1 and #2 were

QEWs indicating knowledge of SRS electrical procedures and basic electrical safety. However, they failed to comply with general safe work practices and electrical procedures.

Procedure 1Y-8.03, *Troubleshooting*, does not permit the use of pre-approved troubleshooting work packages for nonspecific work activities. The monthly troubleshooting work package, although not in compliance with 1Y, limited work scope to those activities requiring only standard PPE. Standard PPE was identified by employees (during Board interviews) to consist of hard hat, safety glasses, safety shoes, hearing protection, and leather gloves. The scope definition identified in the work package and Safe Work Permit contradicts the hazard analysis prescreen description of work. The prescreen criteria allows electrical work performed by QEWs per Procedure 18Q-2 with the exception of work tasks requiring Energized Electrical Work Permits.

The AT2AL breaker has the required NFPE 70E arc flash label affixed to the breaker door. The information on the label indicates a flash protection boundary of 37 feet and an 87.6 calories/cm² flash hazard at 24 inches. There was some discussion regarding the arc flash hazard between the FLM and E&I Mechanic #2 but work proceeded based on the assumption that the arc flash hazard was less than 40 calories/cm². A time-out was not implemented at this point to verify the information on the label. E&I Mechanic #1 donned the arc flash suit rated for 40 calories/cm² or less based solely on information from the E&I FLM. E&I Mechanic #1 only wore the suit during racking in or out of the breaker. The FLM and E&I Mechanic #2 did not don arc flash protective equipment during any of the work activities performed the day of the incident.

The Board concluded that supervision failed to exercise leadership and oversight to ensure work was performed safely. Specifically, the E&I FLM personally engaged in unauthorized work. In attempts to adjust the breaker track, he used a hammer and wrench on the track. He also pried the breaker up with a make-shift pry bar (racking bar) in attempts to engage the electrical control contacts.

The Board also concluded that an effective process had not been implemented to control equipment (material and tools) introduced into energized electrical components. Procedure 18Q-2 does not specifically restrict un-insulated tools or combustible materials from being used around energized equipment. Procedure 18Q-2 simply states that specific tools and equipment must be inspected prior to use and determined to be safe for use on the task being performed.

The Board noted that as of October 15, 2009, a cause for the main and spare breakers failing to close had not been confirmed. On October 4, 2009, the bus was re-energized using the tie breaker in the cabinet directly below the cubicle in which the arc flash occurred.

Conduct of Operations and Maintenance

The Board determined that formal Conduct of Operations had not been effectively implemented for 484-D activities, as demonstrated by the actions, or lack thereof, described below.

The work crew, including the supervisor, neglected to notify the Control Room prior to performing the work. The Safe Work Permit was pre-authorized by the Shift Manager at the first of the month but required Control Room notification prior to performing troubleshooting activities after lunch. In interviews, maintenance personnel stated that contacting the Control Room to perform work under the troubleshooting work package was not a requirement but a "good idea". However, Manual 2S, *Conduct of Operations*, Alternate Implementation Method (2S AIM) requires facility personnel performing functions that may affect process operation or control area indication (in the form of alarms, signal light indications, or instrumentation response) to obtain permission from the responsible qualified person before initiating such action.

Operations personnel exhibited minimal interest and involvement in identifying the breaker deficiency and development of a path forward for troubleshooting and repairs. For example,

operations did not have a questioning attitude about the breaker issues nor did they follow-up on the E&I crews' planned path forward when the crew stopped work for lunch. Neither the Operations Manager nor the Shift Manager reported to the switchgear room during attempts to operate the breaker even though they understood there were issues with the breaker alignment.

The Board also found that 484-D Control Room log entries were not made in accordance with the 2S AIM. Operating log entries should be made in such a manner that each provides sufficient detail to be understood by personnel who were not present during the shift. Entries should adequately describe the situation or event, its significance and cause, and any corrective or follow-up actions taken or required. There was no entry concerning the odor and heat emanating from Transformer #1 that was identified the morning of the event. Entries regarding the operator's attempts to close the breaker prior to E&I involvement were not completed. Entries were not made that provided details regarding the decision to insert the spare. An entry was not made when the activities were deferred for lunch. No time-outs were recorded in the log. However, after the incident, personnel involved stated that time-outs were taken on two occasions during the morning activities. In summary, log entries did not adequately describe the situation, its significance and potential causes, and follow-up actions taken in order to accurately reconstruct the time-line of the event.

Operations and testing were not conducted in an orderly and professional manner following approved procedures as required by the 2S AIM. Specifically, an approved procedure was not utilized during the morning work activities and an operational post maintenance test on the breaker was not officially performed as required per Procedure 1Y-9.01, *Post Maintenance Testing*. The Board also identified that there was no functional testing of the breaker interlocks to ensure proper operation. Additionally, legacy operations procedures from 1991 describing electrical activities to be performed by operators remain active, even though the use of operators to perform electrical operations has been discontinued.

The unauthorized maintenance work activities performed by the FLM and E&I Mechanics #1 and #2 demonstrated that formal Conduct of Maintenance has not matured.

The morning activities were not authorized through work control or operations. Interviews with mechanics and managers did not indicate a consistent understanding of proper work authorization and requirements to notify the Control Room prior to performing work in the facility.

The Board concluded that perfunctory pre-job briefing was conducted for troubleshooting activities. The pre-job briefing failed to communicate the mechanics' specific tasks, the arc flash and shock hazards, appropriate tools, or the required PPE for the troubleshooting. Interviews with the affected mechanics indicated that the expected tasks were ambiguous. The E&I FLM dated the Pre-job Briefing Checklist 9/23/2009 and recorded the time as 1230 hours. The Control Room log indicated that the arc flash occurred at 1246 hours. Insufficient time was available to perform an adequate briefing. Additionally, the pre-job briefing form used was not the latest revision: the completed form was dated November 14, 2008, while the most recent revision was effective August 5, 2009.

Safety Culture is defined as an organization's values and behaviors—modeled by its leaders and internalized by its members—that serve to make safety the overriding priority. Based on the values and behaviors of the employees described in this report, the Board concluded that the safety culture at 484-D has not fully matured. Out of the five individuals that observed the unauthorized work, no one stepped forward and questioned the unsafe work. Mechanics performed work without technical work documents and outside of safety boundaries.

The Board noted that recent positive actions had been taken by SRNS to improve Conduct of Operations in 484-D. Most recently, a contractor Facility Evaluation Board Assist visit was

requested and performed in August 2009. The Facility Evaluation Board Assist visit focused on the effectiveness of implementation of 2S AIM. The Facility Evaluation Board report noted that conduct of operations appears to be improving. However, they also identified opportunities for improvement in management's field presence, Control Room activities, shift turnover, documentation, pre-job briefs, and labeling.

In summary, the Board concluded that management failed to exercise leadership/oversight to ensure work was performed safely, experienced Qualified Electrical Workers failed to comply with general safe work practices and electrical procedures, Conduct of Operations and Maintenance has not been effectively implemented in 484-D, and the safety culture has not fully matured.

3.6 Provide for Feedback and Improvement

Feedback and improvement processes should be designed and implemented to provide information on the adequacy of work controls, to identify and implement opportunities for improving the definition and planning of work, and to utilize line and independent oversight processes to provide information on the status of safety. The feedback and improvement function is intended to identify and correct processes or conditions that lead to unsafe or undesired work outcomes, confirm that desired work outcomes were arrived at in a safe manner, and provide managers and workers with information to improve the quality and safety of subsequent, similar work.

In evaluating how DOE and SRNS had analyzed performance information as part of lessons learned, feedback, and improvement, the Board reviewed feedback provided by DOE and SRNS assessments and Site Occurrence Reporting and Processing System reports.

Site Occurrence Reporting and Processing System (ORPS) Reports

On November 14, 2008, a DOE-SR Facility Representative observed a vendor retrieve an instrument from the low voltage (24 volt) area of an electrical panel at the 784-7A Steam Plant. The same vendor was also observed looking into the open door of a 480 volt electrical panel, which was arc flash labeled. Proper PPE was not worn to access the panels in either case. The scope of work was to troubleshoot, with vendor guidance, electrical anomalies between the two electrical panels. The vendor scope was to perform consultation and not to perform any hands on work. This was verbally communicated to the vendor by the Subcontract Technical Representative prior the vendor's arrival on Site. The hands-on troubleshooting work was to be performed by Site Infrastructure Utilities & Operations E&I mechanics in accordance with an approved work package. The vendor did not receive work authorization or a pre-job briefing from 784-7A facility personnel prior to accessing the electrical panels. A Fact Finding Meeting was held at 1230 on November 17, 2008, to evaluate the significance of the electrical safety concern. Additional investigation revealed that on several occasions, the electrical panel doors had been opened by non-qualified electrical workers from within the Site Infrastructure Utilities & Operations organization to observe the status of various starters/components in the low voltage section of the panel. Proper PPE was not worn while opening the main panel door as required by the arc flash label located near the 480 volt disconnect.

Site Infrastructure Management, with assistance from the SRS Electrical Safety Subject Matter Expert, decided to report these multiple safety violations of Procedure 18Q-2 as a 10(2), Management Concern, Significance Category 3 (documented in Occurrence Report EM-SR-SRNS-SIPS-2008-0004). The root cause of the occurrence was identified as a breakdown in the work release process. Contributing causes included unclear roles and responsibilities, habit patterns, and interpretation of requirements. The apparent cause of the facility operations personnel accessing the electrical panels without proper PPE was a misunderstanding of

Procedure 18Q-2 requirements. There was confusion over arc flash PPE requirements for opening the 480 volt panel door (which was arc flash labeled) to gain access to the 24 volt electrical panel on the far end of the electrical cabinet which was not arc flash labeled but was interlocked to the 480 volt panel door. This panel configuration was unique at SRS. An additional contributing cause was a lack of QEWs on shift who could replace low voltage fuses and reset breakers within the electrical panel.

Details of the corrective actions taken as a result of this event were documented in the SRNS Site Tracking and Reporting System (STAR) as item 2008-CTS-015661. Corrective Action 17 states, "Evaluate need for Utility & Operations 18Q-2 refresher training for mechanics and operators." The closure statement for this action states, "Evaluation of the need for 18Q-2 refresher training for mechanics and operators revealed that the mechanics and operators are familiar with 18Q-2, they know how to access the procedure via ShRINE and that whenever they are involved in an electrical task, the requirements of 18Q-2 is (sic) reviewed in the Pre-Job Briefing (PJB). Any questions that may arise involving 18Q-2 is (sic) resolved in the PJB prior to the execution of the task. If they have questions after they have begun execution of the task, they understand that they can initiate a time-out after they have first ensured that the work has been placed in a safe state and involve the proper personnel for issue resolution before continuing. Re-qualification on 18Q-2 is an annual requirement for all personnel who perform electrical work in order for them to retain their Qualified Electrical Worker qualifications." The remainder of the corrective actions were narrowly focused on work authorization and electrical safety issues at 784-7A.

The Board determined that the contractor missed an opportunity to ensure that safe work practices were understood by all QEWs and to reduce the excessive reliance on QEWs as the single line of defense to identify controls.

DOE-EM Headquarters Oversight

SRS Electrical Safety Review, dated June 25, 2009

In response to an electrocution near miss at the East Tennessee Technology Park, DOE's Environmental Management (EM) organization directed actions to be carried out by both Headquarters and field sites. This direction was transmitted via Dr. Robert Goldsmith's memo, *Electrical Practices Assessment Guidance*, dated May 6, 2009. The guidance contained a Criteria and Review Approach Document which delineated suggested areas to be assessed.

DOE-SR formed a DOE-led assessment team that included Subject Matter Experts from both SRNS and the prior M&O contractor (the liquid waste operating contractor at the time of the assessment). The final report was approved on June 25, 2009, and transmitted to EM Headquarters on June 30, 2009.

Although no findings were identified during the assessment, ten Opportunities for Improvement (OFI) were documented. The corrective actions developed to address these OFIs are documented in STAR 2009-CTS-007538. Three of the relevant OFIs and associated corrective actions are documented below in Table 3-1 below.

The Board noted that the actions included in STAR-7538 differ from those documented in the assessment report, are less prescriptive than those in the report, and therefore may not address the issues identified in the OFIs.

Table 3-1: Selected Opportunities for Improvement Identified in the June 2009 DOE-SR SRS Electrical Safety Review

Opportunity for Improvement	Actions	Due Date
The method for conveying arc flash information to the workers appeared to be inconsistent among the areas visited. (OFI-5)	Implement site process to meet the NFPA 70E-2009 requirement for arc flash hazard information labeling on electrical equipment (Action 7 of STAR-7538)	10/30/09
Arc Flash Labeling and interpretation of the information was not clearly understood by all workers resulting in some instances where workers “over dressed” for the arc flash hazard. (OFI-6)	Develop and implement training for the interpretation, use and application of arc flash data from the installed arc flash labels. (Action 6 of STAR-7538)	4/30/10
Arc Flash hazard category was not always included in safe work permit during the work planning process. Workers would have to identify arc flash requirement in the field prior to work. (OFI-7)	Review work control process and evaluate the planner’s role for providing arc flash information. (Action 7 of STAR-7538)	10/30/09

The Board determined that these corrective actions, if effectively completed and implemented, will relieve the QEW from the burden of self-identifying the applicable controls from Procedure 18Q-2 necessary to conduct electrical work safely.

DOE-SR Assessment Activities

The DOE-SR Assistant Manager for Closure Project (AMCP) uses an annual assessment plan to schedule assessments. The FY2009 Annual Assessment Plan identifies 15 assessments scheduled for Facility Representatives (shown in Table 3-2). DOE-SR AMCP Facility Representative assessments from the annual plan that are documented in the DOE-SR Site Integrated Management Total Assessment System (SIMTAS) for FY2009 include:

- Work Planning and Control (9 completed);
- Operations Activity Observation (11 completed),
- Maintenance Activity Observation (10 completed);
- ORPS (draft not finalized);
- Lockout/Tagout (1 completed), and
- Subcontractor Technical Representative Program Review (1 completed).

An additional 145 Facility Representative assessments were documented in SIMTAS for FY2009.

SIMTAS also documents 148.5 hours of management walk-throughs related to DOE-SR AMCP activities by the four managers responsible for oversight of Area Closure Projects and Site Infrastructure, resulting in an average of 3.08 hours per month per manager.

Table 3-2: DOE-SR Assistant Manager for Closure Project, FY2009 Annual Assessment Plan, Facility Representative Assessments

Frequency	Topic	Type	Area/Facility	Schedule
Quarterly	Work Planning/Control	Scheduled	Any AMCP Facility*	Quarterly
Quarterly	Operations Activity Observation	Scheduled	Any AMCP Facility*	Quarterly
Quarterly	Maintenance Activity Observation	Scheduled	Any AMCP Facility*	Quarterly
Annual	OP-07 ORPS	Scheduled	Any AMCP Areas*	Sept. 2009
Annual	Lockout/Tagout	Scheduled	D-Area (E2), EO, Water & Steam Teams	June 2009
Annual	STR Program Review	Scheduled	Any AMCP Areas*	Sept. 2009

* Target Facilities in AMCP include:

D-Area Powerhouse	A-Area Powerhouse – Biomass	Central Sanitary Waste Facility	DUS
SREL Facilities	USFS Projects (e.g., Phytoremediation Pond)	Central Shops – Cx	CMP ERH
ARRA Project	Infrastructure Projects		

Notes:

- (1) Reactive assessments will be performed as conditions warrant.
- (2) Daily Facility Tours of AMCP projects/facilities are not included in this list.

The Board determined that DOE-SR AMCP Facility Representatives are conducting assessments of the contractor's activities that provide the contractor with meaningful feedback through the Monthly Assessment Report.

Contractor Assessment Activities

The Board conducted a search of the contractor's Site Tracking, Analysis and Reporting (STAR) system to identify issues related to arc flash events, conditions, or concerns. The following recent items were analyzed by the board and are summarized as follows.

STAR 2008-CTS-16672 – Senior Management Assessment – Conduct of Maintenance

Issue: F Tank Farm E&I mechanics and FLMs need a Procedure 18Q-2 refresher.

Action 1: F Tank Farm E&I mechanics and FLMs need a Procedure 18Q-2 refresher. The maintenance manager will communicate the expectation to complete the arc flash information on the Safe Work Permit prior to sending the mechanics to perform field work. Completed 2/26/2009

STAR 2009-CTS-2835 – Facility Evaluation Board Opportunity for Improvement

Issue: Inconsistencies were noted with arc flash warning labels installed on electrical components. Calculations had been completed for all labels observed. However, some of the labels indicated that Procedure 18Q-2 Table 1 applied while others were marked as "N/A". A

consistent approach to labeling would assist the electrical maintenance personnel in determining the required arc flash protective equipment to be worn.

Action 2: Prepare and give a briefing to the Solid Waste Management Maintenance Qualified Electrical Workers on how to read procedure 18Q-2 Arc Flash Warning Labels. Completed 6/24/09

STAR 2009-CTS-006380 – Facility Evaluation Board Issue at K Area.

Issue: Unsafe conditions were observed in K Area that had the potential to cause injury to personnel and/or create a negative impact on equipment and operations. The facility actively worked to correct a majority of unsafe conditions during the assessment (20.09.00.00). The following electrical safety items were identified by the Facility Evaluation Board:

- An electrical wire was protruding from a conduit coiled up in the -14 Purification level with the exposed wire end loosely taped with electrical tape.
- Arc flash labeling was inconsistent in the +34 level and the Purification wing and corridor. Some Square D breaker boxes were labeled and others were not.
- An open ended conduit was in the -14 Purification level adjacent to door 302.
- An electrical pull box cover on the south end of +34 level had one screw missing.
- A metal multi-powered electrical strip on a table in 910-A did not have a Factory Mutual (FM) or Underwriters Laboratory (U/L) label or listing.
- An electrical circuit breaker panel box was not labeled in the MAC Center (west side) in accordance with NFPA 70E.
- Inadequate lighting was observed in the Purification wing. Some stairwells were dark in some parts of the Purification area. Facility safety personnel had not recently monitored the lighting levels of the stairwells.

Action taken: The cognizant manager briefed the Local Safety Improvement Team on the findings during the July 2009 meeting and requested members to be observant for these kinds of behaviors and to correct them if seen. The Safety Improvement Team members were also encouraged to focus future Behavior-Based Safety observations around these kinds of activities. Completed 7/8/09

STAR 2009-CTS-006868 – Procedure 18Q-2 Assessment

Issue: Issues were identified regarding compliance with arc flash PPE when the calories/cm² exceeds 1.2 and Table 1 PPE is not applicable. Personnel were not using PPE required per Table 3. Exact requirements were discussed with the Senior Electrical Review Board (SERB) Co-Chairman, who confirmed that additional PPE per Table 3 is required based on arc flash labels.

The probable cause for non compliance was determined to be a lack of understanding in the interpretation of the information in the procedure as provided in the training that personnel received.

Action 3: Develop and implement documented training to all Operations, Maintenance and E&I personnel on proper understanding of arc flash labels and proper PPE per Procedure 18Q-2 tables. Due 10/30/09.

Common among these STAR items is that the requirements for implementing Procedure 18Q-2 are not well understood and/or enforced. The recurring corrective action is to retrain the workers and their supervisors on Procedure 18Q-2 requirements and application of those requirements.

The Board concluded that corrective actions taken as a result of numerous issues related to implementation of Procedure 18Q-2 requirements have been not been effective in ensuring personnel understand and properly apply electrical safety requirements.

Other Contractor Actions

Over the last 13 years, the 484-D facility has not operated consistently under the direct control of the SRS Management and Operating (M&O) contractor. As a result, DOE Conduct of Operations and Conduct of Maintenance programs have not been emphasized on a regular basis. Issues in these areas were noted during the powerhouse turnover to the current M&O contractor in 2008, and resulted in development of the "Infrastructure & Services E2 Contract for D-Area Transition Plan". This plan included Engineering Program actions (including arc flash calculations and Design Authority Designation); preventive and predictive maintenance programs; transfer of all operating procedures; training and qualification of personnel to Site standards; and Programmatic Issues including Baseline Conduct of Operations Assessments and transition to 2S-AIM (Operations), Manual 8Q (Safety), Manual E7 (Engineering), Manual 1Y (Work Control), and Manual 4B (Training & Qualification). In addition to this plan, numerous Conduct of Operations and Safety briefings were conducted in an effort to bring the powerhouse operating staff up to Site standards.

The powerhouse was also included in the M&O assessment program within the STAR database. This resulted in the performance of Self-Assessments and Management Field Observations, in addition to safety walkdowns conducted by the area safety professional. This process has resulted in the identification of numerous deficiencies and is the primary data feed for the organization's Corrective Action Board.

At the request of the SRNS President, a review of 484-D improvement actions was conducted during July 2009. Although the report focused on material conditions, it offers a view of the positive impact on material conditions that have been made which in turn will have a positive impact on Conduct of Operations. The activities being conducted are proactive and predictive in nature, such as non-destructive evaluation of high energy piping systems and installation of electronic plant master pressure controllers.

Recognizing the need for an independent assessment of progress, the Manager of Utilities Operating Services requested an assist visit from the contractor's Facility Evaluation Board. The Facility Evaluation Board stated, "It was clear to the assessors that Site Infrastructure, Utilities and Operating Services personnel were performing work in a more disciplined manner than previously. Based on interviews with the management team and employees, conduct of operations appears to be improving."

The Board concluded that 484-D powerhouse initiatives involving facility improvement, management presence in the field, and aggressive re-enforcement of expectations, although immature, were having a positive impact in some areas.

3.7 Summary of Analytical Methods and Results

Barrier Analysis

Barrier Analysis is based on the premise that hazards are associated with all tasks. A barrier is any management or physical means used to control, prevent, or impede the hazard from reaching the target (i.e., persons or objects that a hazard may damage, injure or harm). Appendix B contains the Board's complete Barrier Analysis of the physical and management barriers that did not perform as intended and thereby contributed to the accident. The results of the barrier analysis were integrated into the Events and Causal Factors Analysis to support the development of causal factors.

Change Analysis

Change analysis examines planned or unplanned changes that cause undesirable results related to the accident. This process analyzes the difference between what is normal, or expected, and what actually occurred before the accident. Appendix C contains the Board's detailed Change Analysis. The results of the Change Analysis are integrated into the Events and Causal Factors to support the development of causal factors.

Events and Causal Factors Analysis

An Events and Causal Factors Analysis was performed following the processes described in the DOE Workbook *Conducting Accident Investigations, Revision 2*. The Events and Causal Factors Analysis is a systematic process that uses deductive reasoning to determine which events and/or conditions contributed to the accident. Causal Factors are significant events and conditions that produced or contributed to the accident and include direct, contributing, and root causes. The direct cause is the immediate event or condition that caused the accident. Root causes are causal factors that, if corrected, would prevent recurrence of the same or similar accidents. Contributing causes are events or conditions that collectively with other causes increased the likelihood of the accident, but that individually did not cause the accident. The Events and Causal Factors Table is included as Appendix D of this report.

- The **direct cause** of the September 23, 2009, accident was that a metal torpedo level fell and came into contact with Phase "A" of an energized 480 volt breaker.
- The **root cause** was that experienced Qualified Electrical Workers (QEW) failed to comply with required and expected safe electrical work practices.
- **Contributing causes** were identified as follows:
 - Degraded equipment and facility conditions necessitated frequent reactive maintenance.
 - Past operating practices fostered an environment conducive to shortcuts and work-arounds being used without proper analysis.
 - Management had not effectively enforced requirements and reinforced expectations regarding procedural compliance and personal accountability to perform electrical work safely.
 - It was an accepted practice in 484-D for the main breakers to be worked without Procedure 18Q-2 being properly implemented (i.e., a lockout or special energized electrical work permit was not used).
 - QEWs had an incomplete understanding of Procedure 18Q-2 requirements and did not refer to the procedure for the specific work application.
 - A QEW placed an unauthorized tool (9-inch metal torpedo level) into the restricted space near exposed energized 480 volt electrical components.
 - Lack of effective 484-D work planning and control process, including use of a monthly troubleshooting work package that was non-compliant with Procedure 1Y-8.03 requirements, allowed electrical work to occur without appropriate identification of specific scope, hazards, and controls.
 - Operations did not demonstrate a sense of ownership and responsibility for facility electrical activities.
 - Conduct of Operations and Maintenance requirements had not been effectively implemented in 484-D and the safety culture had not fully matured.
 - The pre-job briefing failed to address specific scope, hazards, and controls.

- Corrective actions resulting from previously identified deficiencies did not ensure that safe electrical work practices were understood by all QEWs or reduce the excessive reliance on QEWs as the single line of defense to identify needed controls.

4.0 CONCLUSIONS AND JUDGMENTS OF NEED

Judgments of Need are managerial controls and safety measures believed necessary to prevent or minimize the probability of a recurrence. They flow from the causal factors and are designed to guide managers in developing effective corrective actions. The Board’s Conclusions and Judgments of Need are provided below in Table 4-1. Additional opportunities for improvement are documented in Appendix E.

Table 4-1: Conclusions and Judgments of Need

Conclusions	Judgments of Need
(2.3) Actions taken to respond to the arc flash, fire and the injured mechanic were adequate.	N/A
(2.4) The accident scene was adequately controlled.	N/A
(3.1) The commitment to comply with Integrated Safety Management and regulatory requirements was adequately captured in contract documents and Site-level procedures.	N/A
(3.2) The work in progress at the time of the event was poorly defined and was outside the scope of Procedure 18Q-2 and the troubleshooting work package. (3.3) The hazards associated with the work scope performed were not adequately analyzed. (3.4) Experienced Qualified Electrical Workers (QEWs) disregarded proper implementation of hazard controls and failed to comply with required work planning and control practices by beginning corrective maintenance with no specific authorization or work package and later continuing corrective maintenance with a work package that did not cover the scope of the activities being conducted.	SRNS needs to ensure that technical work documents contain specific activities that are defined in sufficient detail to allow for proper identification of hazards and implementation of hazard controls. SRNS needs to ensure that 484-D work is reviewed, authorized, supervised and performed by personnel that clearly understand the work scope, limitations, hazards, and controls prior to work execution.
(3.3) The arc flash calculations provided a conservative safety envelope.	N/A
(3.4) The 484-D monthly troubleshooting package did not comply with Procedure 1Y-8.03 requirements for troubleshooting.	SRNS needs to ensure that troubleshooting work is controlled by a job-specific work order in compliance with Procedure 1Y-8.03, <i>Troubleshooting</i> .

Conclusions	Judgments of Need
(3.4) Procedure 18Q-2, <i>Safe Practices On or Near Electrical Conductors or Live Parts</i> , contained the necessary controls to safely perform this work and personnel were trained and qualified to the 18Q-2 requirements.	N/A
(3.5) An effective process had not been implemented to control equipment (material and tools) introduced into energized electrical components.	SRNS needs to develop a process to ensure adequate control of tools and equipment used on or near energized electrical components.
(3.5) A perfunctory pre-job briefing was conducted for troubleshooting activities. The pre-job briefing failed to communicate the mechanics' specific tasks, the arc flash and shock hazards, appropriate tools, or the required personal protective equipment for the activity.	SRNS needs to ensure that 484-D powerhouse personnel perform effective pre-job briefings in accordance with Manual 2S, <i>Conduct of Operations, Alternate Implementing Method (2S AIM)</i> , including, but not limited to, discussing specific work scope and limitations, associated hazards, and controls necessary to perform work safely.
(3.5) Experienced QEWs failed to comply with general safe work practices and electrical procedures.	SRNS needs to reinforce individual responsibility to comply with safe work practices and electrical procedures.
(3.5) Management failed to exercise leadership/oversight to ensure work was performed safely.	SRNS needs to ensure that management and supervision set and enforce the expectation that activities are conducted in accordance with Site policies and procedures. This includes, but is not limited to, setting a good example with their actions, maintaining awareness of work activities under their cognizance, and maintaining an effective presence at the work site.
(3.5) Conduct of Operations and Maintenance had not been effectively implemented in 484-D and the safety culture had not fully matured. (3.6) 484-D powerhouse initiatives involving facility improvement, management presence in the field, and aggressive re-enforcement of expectations, although immature, were having a positive impact in some areas.	SRNS needs to take prompt action to implement a step change in Conduct of Operations and Maintenance practices at the 484-D powerhouse. This includes, but is not limited to, near-term compensatory measures prior to completion of final corrective actions.
(3.6) The corrective actions taken as a result of numerous issues related to implementation of Procedure 18Q-2 requirements have not been effective in ensuring that personnel understand and properly apply electrical safety requirements.	SRNS needs to reduce the excessive reliance on QEW knowledge as the single line of defense in identifying needed controls for electrical work.

5.0 BOARD SIGNATURES

Signature on File

10/22/2009

Carl Everatt
DOE Accident Investigation Board Chairperson
Trained Accident Investigation Board Chair
U.S. Department of Energy Savannah River Operations Office
Deputy Assistant Manager for Nuclear Material Stabilization Project

Date

Signature on File

10/22/2009

Mark A. Smith
Trained Accident Investigator/Analyst
U.S. Department of Energy Savannah River Operations Office
Nuclear Safety Program Manager

Date

Signature on File

10/22/2009

Michael J. Thomas
Trained Accident Investigator
U.S. Department of Energy Savannah River Operations Office
Senior Operations Advisor

Date

Signature on File

10/22/2009

Teresa Tomac
Trained Accident Investigator
U.S. Department of Energy Savannah River Operations Office
Facility Representative, Assistant Manager for Closure Projects

Date

6.0 BOARD MEMBERS, ADVISORS, AND STAFF

Board Chair	Carl Everatt U.S. Department of Energy Savannah River Operations Office Deputy Assistant Manager for Nuclear Material Stabilization Project
Member (Investigator/Analyst)	Mark A. Smith U.S. Department of Energy Savannah River Operations Office Nuclear Safety Program Manager
Member (Investigator)	Michael J. Thomas U.S. Department of Energy Savannah River Operations Office Senior Operations Advisor
Member (Investigator)	Teresa Tomac U.S. Department of Energy Savannah River Operations Office Facility Representative Assistant Manager for Closure Projects
Advisor	Brian Sautter U.S. Department of Energy Savannah River Operations Office Nuclear Materials Engineering Division
Advisor	Jack Bernard President, E2 Consulting Engineers, Inc.
Advisor	Bobby Gray Electrical Subject Matter Expert (Retired, Fluor)
Liaison/Advisor	Jack Goldenberg Savannah River Nuclear Solutions, LLC Manager, ARRA Portfolio Logistics
Editor/Coordinator	Lauren Wabbersen National Nuclear Security Administration NA-262 Site Engineering & Project Integration Division

Board Appointment Memorandum

DATE 11/23/09

United States Government

Department of Energy (DOE)

Savannah River Operations Office (SR)

memorandum

DATE: SEP 25 2009

REPLY TO

ATTN OF: Allison (MGR, 2-6337)

SUBJECT: Type B Investigation of Employee Burn Injury at the D Area Powerhouse (484-D) on September 23, 2009

TO: Carl Everett, Deputy Assistant Manager for Nuclear Materials Stabilization Project

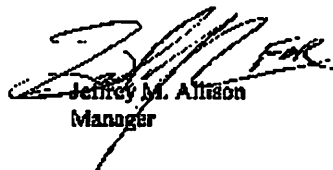
You are hereby appointed Chairperson of the Type B Accident Investigation Board I have convened to investigate the subject incident. The investigation and report shall conform to requirements detailed in the Department of Energy (DOE) Order 225.1A, *Accident Investigations* and DOE G 225.1A-1, *Implementation Guide for Use with DOE O225.1A, Accident Investigations*. The Board will be comprised of the following members:

- Mark A. Smith, DOE-SR – Investigator/Analyst
- Michael Thomas, DOE-SR – Investigator
- Teresa Tomac, DOE-SR – Investigator

The scope of the Board's investigation is to include, but not limited to, identifying all relevant facts; analyzing the facts to determine the direct, contributing, and root cause of the incident; developing conclusions; and determining judgments of need that, when implemented, should prevent the recurrence of the incident. The Board will focus on and specifically address the role of DOE and contractor organizations and Integrated Safety Management Systems, as they may have contributed to the overall accident. The scope will also include an analysis of the application of lessons learned from similar accidents within DOE. If additional resources are required to assist you in completing this task, please let me know and it will be provided.

The Board will provide my office with weekly reports on the status of the investigation but will not include any findings or arrive at any premature conclusions until an analysis of all the causal factors has been completed. Draft copies of the factual portion of the investigation report will be submitted to my office and to Savannah River Nuclear Solutions, IJC for factual accuracy review prior to the report finalization.

The final investigation report should be provided to me by October 23, 2009. Any delay in the date shall be justified and forwarded to this office. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report.



Jeffrey M. Allison
Manager

MGR:MT:dmy

MGR-09-035

Barrier Analysis

Hazard: Arc FlashTarget: E&I Mechanic (worker)

What Were the Barriers?	How Did Each Barrier Perform?	Why Did the Barrier Fail?	How Did the Barrier Affect the Accident?
Qualified Electrical Workers	Qualified Electrical Workers failed to apply knowledge of Procedure 18Q-2 requirements to the task.	The supervisor and mechanics failed to overcome prior operating practices and did not exercise personal responsibility as qualified electrical workers.	Allowed workers to be in the vicinity of energized electrical components without proper controls and PPE.
Lockout – Hazardous Energy Control	Not Used	Personnel did not consider use of a lockout.	Allowed hazardous energy to be present.
Proper Personal Protective Equipment	Not Used	Qualified Electrical Workers failed to exercise appropriate responsibilities.	Allowed arc flash to contact the worker.
Work Authorization and Control of Troubleshooting (Procedure 1Y-8.03)	An appropriate troubleshooting work order was not generated.	484-D Facility Work Control had a non-compliant generic monthly troubleshooting package in place and the supervisor failed to recognize activities were outside the scope of the monthly package.	Specific scope, hazards and controls applicable to the task were not identified.
Pre-Job Brief for Troubleshooting	The pre-job brief did not include discussion of work scope, hazards, controls and PPE.	There was inappropriate reliance on skill of the craft.	Resulted in failure to identify controls commensurate with the hazards.
Material (Tool) Control	Not Used	Qualified Electrical Workers failed to exercise appropriate responsibilities.	Allowed non-insulated tool to contact energized electrical equipment.
Material Condition (functional breaker)	The breaker would not close remotely or manually.	Unknown	Resulted in need to troubleshoot the breaker.
Arc Flash Labeling	Appropriate labeling was in place and readily visible.	Qualified Electrical Workers failed to exercise appropriate responsibilities.	Allowed work on or near energized electrical components without appropriate controls.

What Were the Barriers?	How Did Each Barrier Perform?	Why Did the Barrier Fail?	How Did the Barrier Affect the Accident?
Supervisory Oversight	Supervisor set inappropriate expectations and was not present during performance of the troubleshooting task.	The scope was categorized as routine electrical work (to rack out breaker and set it on the floor) with the hazard stated to be less than 40 calories/cm ² rather than 87.6 calories/cm ² . The supervisor was acting for other supervisors in addition to his normal duties (i.e., he had conflicting priorities).	Encouraged work in the vicinity of energized high-hazard electrical components without appropriate controls.
Management Oversight	Management failed to exercise leadership to ensure work was performed safely.	The 484-D safety culture had not fully matured due to continuous operating pressure and holdover of prior operating philosophy.	Allowed inappropriate work practices to be implemented in the field.
Electrical Training	The training program was adequate but the qualified electrical workers did not apply material from training to the task.	Supervisor and mechanics failed to overcome prior operating practices and did not exercise personal responsibility as qualified electrical workers.	Allowed workers to be in the vicinity of energized electrical components without proper controls and PPE.
Self-Assessment	Failed to ensure effective corrective actions in response to similar issues.	Corrective actions identified in response to previous issues were narrowly focused on the facility in question.	Allowed weaknesses in Procedure 18Q-2 implementation to continue in 484-D.
Work Planning	Work planners were not involved in the task.	The supervisor failed to consult with work planners.	Allowed inappropriate use of monthly troubleshooting work package.
Engineering Involvement	Engineering was not involved in the task.	The supervisor failed to involve engineering.	Task initiated without engineering expertise involved in identifying task scope and the associated hazards.
Assisted Hazard Analysis (AHA)	A full AHA not used.	There was complacent use of the pre-screen/routine reliance on Manual 18Q in place of a full AHA	Allowed work to occur without identification of hazards and associated controls.

What Were the Barriers?	How Did Each Barrier Perform?	Why Did the Barrier Fail?	How Did the Barrier Affect the Accident?
Safe Work Permit	The permit did not address specific work activities.	The generic monthly package served as monthly blanket approval to cover troubleshooting activities.	Did not ensure appropriate authorization of troubleshooting work.
Disciplined Conduct of Operations	Conduct of Operations was Less Than Adequate	There was not a fully implemented Conduct of Operations program due to continuous operating pressure and holdover of prior operating philosophy.	Allowed work in the vicinity of energized high-hazard electrical components without appropriate controls.
Maintenance	Routine equipment failures result in frequent time-critical reactive maintenance to keep the plant on line.	More than ten years of a run-to-failure maintenance strategy has resulted in significant deferred maintenance and reliability issues.	Contributed to a work environment conducive to short cuts.
Procedure 18Q-2 Energized Work Permit	Not Used	Personnel did not consider use of an energized work permit.	Allowed hazardous energy to be present without proper controls.

Change Analysis

Accident Situation	Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect on this Accident
Qualified Electrical Workers did not implement requirements	Qualified electrical workers implement requirements	All electrical safety requirements were not implemented as expected	Arc flash and burn injury
No lockout (L/O) or energized work permit	L/O installed or approved Energized Work Permit in place	Work occurred on or near energized electrical components	Less Than Adequate controls over work taking place on or near energized electrical components
Appropriate PPE not used	Appropriate PPE used	Workers not protected by appropriate PPE	Burn injury
Generic monthly troubleshooting work package in place	Job-Specific troubleshooting work package developed including engineering and operations reviews	Specific work scope was not described, specific hazards and controls were not identified Engineering not involved No operations review of the specific task	Reliance on skill of the craft and monthly troubleshooting work package resulted in inadequate PPE, tools, and additional controls for work on energized electrical components.
Inadequate Pre-Job Brief was provided to workers	Adequate Pre-Job Brief provided to workers	Specific scope, individual task assignments, work limitations, hazards and controls were not communicated to the workers	Work occurred near energized electrical components with unauthorized tools and without adequate PPE
No maintenance procedure in place	Comprehensive maintenance procedure in place	No specific guidance provided to workers on repairs, troubleshooting or post-maintenance testing	Reliance on skill of the craft and monthly troubleshooting work package resulted in inadequate Personal Protective Equipment (PPE), tools, and additional controls for work on energized electrical components.
Breaker would not work	Functioning Breaker	Breaker not operating as expected	Non-functioning breaker was an initiating condition for the event

Accident Situation	Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect on this Accident
Pre-screened Assisted Hazard Analysis used	Full Assisted Hazard Analysis conducted	Specific hazards and controls were not identified	Inadequate PPE, tools, and controls were used for work on or near energized electrical components.
Generic Safe Work Permit used	Specific Safe Work Permit developed and used	Specific scope was not described, specific hazards and controls were not identified, and supervisory review of specific scope, hazards and controls was not obtained	Reliance on skill of the craft and monthly troubleshooting work package resulted in inadequate PPE, tools, and additional controls for work on energized electrical components.
Un-insulated tools used	Only authorized tools used	Metal tools were used on or near energized electrical equipment	Arc flash
No engineering or management oversight in the field	Engineering and management oversight of task	Engineering support and management guidance were not provided to workers in the field	Reliance on skill of the craft and monthly troubleshooting work package resulted in inadequate PPE, tools, and additional controls for work on energized electrical components.
Less Than Adequate Conduct of Operations	Disciplined Conduct of Operations	Less Than Adequate operational formality and rigor	Inadequate control of work activities resulting in improper work practices
Lack of ownership by operations of all work in facility	Operational ownership of all work in facility	Operations not fully aware of specific work scope	Potential to have prevented the event

Events and Causal Factors Chart

Date/Time	Event	Comments/Conditions	Causal Factors (see Key below)
8/31/2009	484-D under SRNS Site procedures (DOE conduct of Operations, Safety, etc.)	Previous 484-D Operational Philosophy used commercial practices	CC-1, 2
8/5/2009	Breaker removed for preventive maintenance (PM), spare installed	<ul style="list-style-type: none"> • Breaker is labeled 87.6 calories/cm² arc flash hazard • Improper Personal Protective Equipment (PPE) • No procedure for racking breaker • Skill of the craft used to rack the breaker • No lockout used 	CC-4, 5, 9, 11
8/5/2009	Breaker in Shop for PM		
8/31/2009	Breaker preventive maintenance completed		
9/10/2009	Breaker returned from shop and re-installed but not closed in	<ul style="list-style-type: none"> • Breaker is labeled 87.6 calorie/cm² arc flash hazard • Improper PPE • No procedure for racking breaker • Skill of the craft used to rack the breaker • No lockout used 	CC-4, 5, 9, 11
9/23/2009			
Morning	Report of 484-D Transformer #1 overheating/burning smell. Operations management decides to return electrical distribution system to its normal operating alignment	Shift Operations Manager initiated electrical distribution realignment	CC-1
1020 hours	484-D Control Room (CR) attempt to close breaker fails, Shift Operations Manager calls E&I for assistance	Shift Operations Manager tells E&I to check out the breaker	CC-1
Morning	Three E&I personnel (First Line Manager and two E&I mechanics, who are Qualified Electrical Workers (QEW)) go to inspect breaker and request CR to close breaker	<ul style="list-style-type: none"> • QEWs are satisfactorily trained and qualified per site requirements • CR attempt to close breaker fail 	
Morning	E&I personnel request CR to close breaker again while they observe the breaker	CR attempt to close breaker fails	
Morning	E&I personnel attempt to rack the breaker out and tries to close in the breaker, asks CR to try and close breaker again.	<ul style="list-style-type: none"> • E&I attempt to close breaker fails • CR attempt to close breaker fails • Breaker is labeled 87.6 cal/cm² arc flash hazard • Improper PPE • No procedure for racking breaker • Skill of the craft used to rack the breaker • No lockout used 	CC-3,4,5,7, 8, 9, 11
1100 hours	Operations directs E&I personnel to rack original breaker out, rack spare in	<ul style="list-style-type: none"> • Breaker is labeled 87.6 cal/cm² arc flash hazard • Improper PPE • No procedure for racking breaker • Skill of the craft used to rack the breaker • No lockout used 	CC-2, 3, 4, 5, 7, 8, 9, 11

Date/Time	Event	Comments/Conditions	Causal Factors (see Key below)
1100 hours 1122 hours 1139 hours	Control Room attempts to close breaker	All three CR attempts fail	CC-3, 4, 5, 7, 8, 9, 11
1142 hours	E&I personnel attempt to manually close in breaker	<ul style="list-style-type: none"> • E&I attempt to close breaker fails • E&I FLM uses hammer to readjust the breaker support rails • Wood shims are placed between the breaker and support rails • Breaker is labeled 87.6 cal/cm2 arc flash hazard • Improper PPE • No procedure for racking breaker • Skill of the craft used to rack the breaker • No lockout used 	CC-3, 4, 5, 7, 8, 9, 11
Midday	E&I personnel break for lunch		
1230 hours	E&I First Line Manager conducts Pre-Job Brief for breaker troubleshooting activities	<ul style="list-style-type: none"> • Decided to enter troubleshooting mode after lunch to determine the extent of the breaker problem • Very sparse discussion about scope of work limitations, hazards, controls, PPE and tool control. • E&I FLM assumed breaker was <40 cal/cm2 • AHA was prescreened out, a safe work permit was used • E&I were complacent about their personal accountability with understanding the scope of work, hazards, and controls. • Troubleshooting package did not meet requirements of SRNS 1Y-8.03 • Work planning was not used 	CC-2, 3, 4, 5, 6, 7, 9, 10, 11
Unknown	E&I Mechanic #1 and Mechanic #2 begin troubleshooting breaker	<ul style="list-style-type: none"> • No PPE worn by either E&I mechanic • Energized electrical work permit is not utilized as required by 18Q.2 • No supervisory oversight is present at job site • E&I failed to notify Control Room of the troubleshooting to be performed • Scope of the troubleshooting performed exceeds the scope of the troubleshooting package 	RC-1 CC-2, 3, 4, 5, 8, 9, 11
1245 hours	E&I Mechanic #2 places metal torpedo level on breaker in cubicle and walks away	Tool control is less than adequate, an un-insulated tool is placed inside the breaker	RC-1 CC-3, 4, 5, 6, 11
1246 hours	Metal torpedo level falls in breaker while E&I Mechanic #1 is attempting to stabilize it; Arc Flash occurs, E&I Mechanic #1 injured	Breaker cubicle is energized	DC-1

Date/Time	Event	Comments/Conditions	Causal Factors (see Key below)
1246 hours	D2 boiler tripped	Initiates CR response	
1247 hours	Fire reported in switchgear room / SRS Fire Department (SRSFD) called	E&I 2 proceeds to CR for assistance because no communication is present near the job site	
1249 hours	SRSFD dispatched to 484-D		
Unknown	E&I Mechanic #1 (injured) walking toward nearby shop to obtain medical assistance; E&I Mechanic #2 proceeding to Control Room to report event and seek help		
1250 hours	Control Room orders evacuation of non-essential personnel to rally point		
Unknown	Panel verified de-energized (post-event - contractor discovered 125 volt Direct Current breaker control power was not de-energized)		
1253 hours	Responding personnel and E&I Mechanic #1 (injured) approach Barricade 7 in government vehicle		
Unknown	484-D Operations Manager puts out fire using ABC extinguisher prior to SRSFD responding to scene		
1257 hours	Ambulance/Medical and Emergency personnel arrive at Barricade 7, location of E&I Mechanic #1)		
1300 hours	SRSFD Battalion Chief assumes command of 484-D incident scene		
1301 hours	Medical personnel and E&I Mechanic #1 en route to Doctors Hospital Burn Unit in Augusta, Georgia		
1302 hours	SRSFD enters facility to verify fire is out		
1335 hours	Ambulance/E&I Mechanic #1 arrive at hospital	Distance from Barricade 7 to Doctors Hospital in Augusta, Georgia, is 32 miles (approximately 50 minutes)	
1338 hours	Facility personnel with PPE and meter verify power is off		
1423 hours	All Clear is given		
1440 hours	SRSFD returns command to 484-D		

Causal Factors Key:

DC = Direct cause = Metal torpedo level fell and came into contact with Phase "A" of an energized 480 volt breaker.

RC = Root cause = Experienced Qualified Electrical Workers (QEW) failed to comply with required and expected safe electrical work practices.

CC = Contributing Causes:

CC-1: Degraded equipment and facility conditions necessitated frequent reactive maintenance.

CC-2: Past operating practices fostered an environment conducive to shortcuts and work-arounds being used without proper analysis.

CC-3: Management had not effectively enforced requirements and reinforced expectations regarding procedural compliance and personal accountability to perform electrical work safely.

CC-4: It was an accepted practice in 484-D for the main breakers to be worked without Procedure 18Q-2 being properly implemented (i.e., a lockout or special energized electrical work permit was not used).

CC-5: QEWs had an incomplete understanding of Procedure 18Q-2 requirements and did not refer to the procedure for the specific work application.

CC-6: A QEW placed an unauthorized tool (9-inch metal torpedo level) into the restricted space near exposed energized 480 volt electrical components.

CC-7: Lack of effective 484-D work planning and control process, including use of a monthly troubleshooting work package that was non-compliant with Procedure 1Y-8.03 requirements, allowed electrical work to occur without appropriate identification of specific scope, hazards, and controls.

CC-8: Operations did not demonstrate a sense of ownership and responsibility for facility electrical activities.

CC-9: Conduct of Operations and Maintenance requirements had not been effectively implemented in 484-D and the safety culture had not fully matured.

CC-10: The pre-job briefing failed to address specific scope, hazards, and controls.

CC-11: Corrective actions resulting from previously identified deficiencies did not ensure that safe electrical work practices were understood by all QEWs or reduce the excessive reliance on QEWs as the single line of defense to identify needed controls

Opportunities for Improvement

- An opportunity exists to improve the clarity and guidance of Procedure 18Q-2, *Safe Practices On or Near Electrical Conductors or Live Parts*, in that:
 1. Procedure 18Q-2 is cumbersome with respect to navigating between Table 1, Table 1 notes, Table 2, and Table 3;
 2. There is no specific guidance in the procedure tables for situations where the arc flash hazard exceeds 40 calories/cm²; and
 3. The potential for dropping tools from beyond the restricted or limited space boundaries into energized electrical conductors is not addressed.
- An opportunity for improvement exists to enhance Qualified Electrical Worker (QEW) knowledge of Procedure 18Q-2 by adding exercises that emphasize the differing practical applications of the arc flash table requirements (Table 3) to the required training.
- An opportunity for improvement exists in the wording of Procedure 1Y-8.03, *Troubleshooting*. Section 3 of 1Y-8.03 states, “In addition to activities performed using 18Q, Procedure 2, qualified trained mechanics may also perform the following activities as required.....” This can be interpreted to mean that any electrical work activities performed using Procedure 18Q-2 fits within the scope of troubleshooting activities.
- An opportunity for improvement exists in the communication methods between workers and the Control Room in 484-D. In this event, the mechanics had no method to quickly communicate with the Control Room.
- An opportunity for improvement in the accuracy of the estimates and the margin of safety in arc flash calculations was noted in that:
 1. The analysis did not consider the possibility of an arc flash event occurring in the main breaker while the breaker is open and energized from two different sources; and
 2. The clearing time considered the 2400 volt over-current device on the primary side of the alternate transformer. The assumed 7-second clearing time used in the calculation results in a conservative incident energy calculation when compared to the 2-second clearing time recommended by the National Fire Protection Association (NFPA) 70E, *Standard for Electrical Safety in the Workplace*.
- An opportunity for improvement in the control of 100 calorie suits exists in that even though 100 calorie suits are not authorized for use at the Savannah River Site, a procurement action for additional 100 calorie suits was approved in September 2009. The safeguards identified in Procedure 7B-1.1, *Purchase Requisitioning*, did not prevent the procurement from being processed. Suits currently on Site should be strictly controlled.
- An opportunity for improvement exists in understanding why the main breaker failed to close on September 23, 2009.
- An opportunity for improvement exists to improve the post-maintenance testing of breakers. The maintenance work packages that removed breakers for shop calibration had no Post-Maintenance Tests identified.
- An opportunity for improvement exists for operations and maintenance to involve engineering in work efforts.

- An opportunity for improvement exists to enhance the hazards analysis process by reevaluating the current blanket prescreen for 18Q-2 electrical work activities. Procedure 8Q-122, *Hazards Analysis*, contains criteria for a prescreen hazard analysis that allows most electrical work to be performed by QEWs in accordance with Procedure 18Q-2, with the exception of work tasks requiring Energized Electrical Work Permits. The hands-on troubleshooting of an energized 480 volt breaker is not consistent with the threshold examples provided in the procedure.
- An opportunity for improvement exists to ensure that Site Tracking, Analysis and Reporting (STAR) corrective actions accurately reflect the source document. For example, actions documented in STAR-2009-CTS-7538 differ from those documented in the SRS Electrical Safety Review assessment report, are less prescriptive than those in the report, and therefore may not address the Opportunities for Improvement identified in the report.
- An opportunity for improvement exists to ensure that revisions to Manual 2S, *Conduct of Operations*, are evaluated for incorporation into existing 2S-AIM documents.