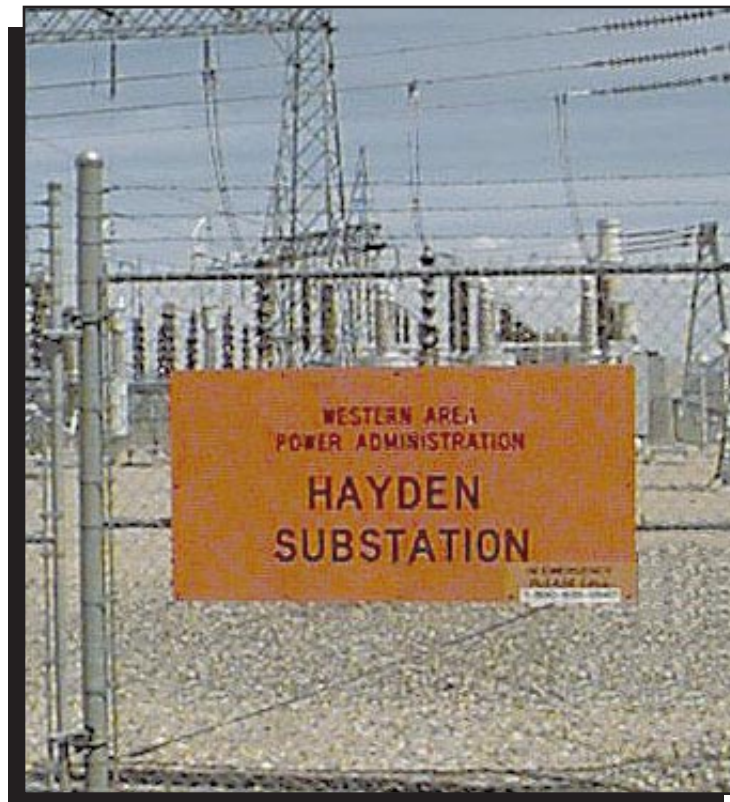


TYPE B

Accident Investigation Report

Serious Personal Injury While Doble Testing

May 19, 1999



***Hayden Substation
Hayden, Colorado***

Disclaimer

This report is an independent product of the Accident Investigation Board (Board) appointed by Michael S. Cowan, Chief Program Officer, Western Area Power Administration (Western), U.S. Department of Energy (DOE).

The Board was appointed to perform an investigation of this accident and to prepare a 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

On May 20, I established an Accident Investigation Board to investigate the May 19, 1999, electrical accident at Hayden Substation. The Board's responsibilities have been completed with respect to this investigation. The analysis, identification of contributing and root causes, and judgments of need reached during the investigation were performed in accordance with DOE Order 225.1A, Accident Investigations.

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

Michael S. Cowan, Chief Program Officer

Executive Summary

TYPE B ACCIDENT
INVESTIGATION BOARD REPORT
OF THE MAY 19, 1999
SERIOUS PERSONAL INJURY ACCIDENT
AT HAYDEN SUBSTATION, HAYDEN, COLORADO

Introduction

On May 19, 1999, at 10:31 a.m., four Western Area Power Administration (Western) employees were performing Doble testing on a circuit breaker at Hayden Substation in Routt County, Colorado. Three electricians were injured when the high-voltage lead (HVL) of the Doble test set encroached on the minimum approach distance to an energized part outside clearance boundaries, drawing arcing faults.

On May 20, 1999, Michael S. Cowan, Chief Program Officer for Western, appointed a Type B Accident Investigation Board (Board) to investigate the accident in accordance with DOE Order 225.1A, Accident Investigations. The Board began its investigation on May 20, 1999, and submitted its findings to the Chief Program Officer on July 2, 1999.

Accident Description

The accident occurred at 10:31 a.m. on Wednesday, May 19, 1999, while a crew was performing a complete service of equipment on two 138-kV circuit breakers. The crew had finished work on one breaker, and began work on the second breaker at about 10 a.m. Electrician 1 entered data into the Doble test set in a trailer. Electrician 2 was installing a test probe in bushings and attaching the low-voltage lead from an 8-foot stepladder. Electrician 3 was hanging the HVL from ground level using an 11-foot-long hotstick. The crew completed testing of bushings on one side of the breaker. Electrician 2 was on the fourth or fifth step of the ladder under a bushing, gathering tools and preparing to climb down. The Acting Foreman was crouched in front of the breaker cabinet on the west side of the breaker, which was open with the doors locked in place. He was checking the battery of the Meggar Unit. Electrician 3 was walking backward taking up slack on the HVL (which was still attached to the hotstick) as he was moving it to the opposite side of the breaker.

As Electrician 3 walked backward, he held the hotstick in a nearly vertical position. With the grounded HVL still attached to the top of the hotstick, the hook of the HVL got within 8 to 10 inches of the spark gap located on the top of a bushing of an adjacent energized 138 kV circuit breaker, initiating an arcing fault to ground. The fault current had a magnitude between 13,450 and 14,200 amperes that split, with the majority (10,700 – 11,300 amperes) traveling to ground through the spark gap. The remaining fault current (2,750 – 2,900 amperes) flashed down the HVL, which was against the hotstick and Electrician 3, causing his clothing to ignite.

The arc flashed down the HVL and launched the HVL's attachment hook from the end of the lead to approximately 120 feet from the fault location. Following the fault, Electrician 1 fell to the floor of the test trailer. Electrician 2 fell from the ladder to the ground and Electrician 3 fell to the ground engulfed in flames. The Acting Foreman saw Electrician 3 fall to the ground with his clothing on fire. He ran to Electrician 3 and put out the fire. Electrician 1 crawled from the smoke-filled test trailer and ran to assist the Acting Foreman in attending to Electrician 3.

The three injured employees were transported by ambulance to Routt County Community Hospital. Electrician 2 and the Acting Foreman were treated and released. Electrician 3 was transported to University Hospital in Denver, Colorado, for further treatment.

Root and Contributing Causes

Root Cause

The root cause of the accident was that Electrician 3 failed to maintain the minimum approach distance to energized parts.

Contributing Causes

The first contributing cause was inadequate procedures for Doble testing. The procedure did not address the safe use of a hotstick for placing and removing test leads in the vicinity of energized equipment. A change in work procedure had been developed and implemented to minimize exposure to fall hazards by requiring the use of a hotstick. Using a hotstick allows the worker to stand at ground level to attach and remove the HVL from the top of the bushing. However, the procedure was never studied to the extent necessary to determine if it would create other hazards.

On May 27, 1999, the Board issued a recommendation to maintenance personnel for an immediate corrective procedure addressing the safe use of a hotstick for placing and removing Doble test leads on equipment.

The second contributing cause was that the job hazard analysis did not address how the crew would avoid violating the minimum approach distance. During the walkthrough of the clearance boundaries, the surrounding energized boundaries were identified. Identifying the hazard is half the process; the other half is to develop solution(s) that would eliminate, modify, or prevent such hazards or accidents.

Judgments of Need

1. The job hazard analysis process needs to be examined and revised where necessary. Job hazard analyses must address minimum approach distances to energized equipment, identification of other hazards, and take appropriate actions to eliminate the hazards.
2. Management must communicate, abide by and enforce strict adherence to the *Power System Safety Manual*.

3. All managers (including supervisors) are accountable for the timely integration of all safety- and maintenance- related policies, procedures and programs, including but not limited to Judgments of Need identified in accident reports.
4. All new, changed or modified work procedures must be evaluated to determine if the new procedure creates new hazards and corrective measures must be incorporated in the appropriate manuals (all affected manuals must be cross-referenced).
5. When using a hotstick to place or remove the high voltage lead during Doble testing of breakers and transformers, a procedure should be developed such as the Board's immediate corrective procedure recommendation to ensure that all areas of safety are considered.
6. The following sections of the *Power System Safety Manual* –7.14, 8.7, 11.1.2 and 17.2– must be reviewed and discussed during a series of weekly craft safety meetings.
7. There is a need to ensure all posted emergency numbers are correct and periodically verified, such as during the annual safety inspections.
8. An engineering study shall be conducted to determine if spark gaps on the 138-kV breaker bushings are required. If it is determined that they are no longer required, they shall be removed.
9. The proper clothing must be worn for work in energized substations. The strict interpretation of OSHA 1910.269 (l) (6) (iii) would require, based on this accident, employees to be in flame-resistant clothing.

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Type B Accident Investigation Report
of the May 19, 1999
Serious Personal Injury Accident
at Hayden Substation, Hayden, Colorado

1.0 INTRODUCTION

1.1 Background

An agency of the U.S. Department of Energy (DOE), Western Area Power Administration (Western) markets Federal hydropower and operates and maintains nearly 17,000 miles of power transmission lines, 258 substations, and various related facilities in 15 central and western states. Western's Corporate Services Office (CSO) is in Golden, Colorado. Its service territory is divided into four customer service regions with the Upper Great Plains Region in Billings, Montana; the Rocky Mountain Region in Loveland, Colorado; the Sierra Nevada Region in Folsom, California; and the Desert Southwest Region in Phoenix, Arizona. The Colorado River Storage Project Customer Service Center in Salt Lake City, Utah, also markets power to Western customers. Each regional office manages a specific part of Western's service territory. The Hayden Substation is within the area served by Western's Rocky Mountain Region (RMR). The crew involved in the accident is stationed at the Western Colorado Maintenance Office in Montrose, Colorado, which reports to the RMR Office.

On May 19, 1999, at 10:31 a.m., four Western employees were performing Doble testing on a circuit breaker at Hayden Substation in Routt County, Colorado. Three electricians were injured when the high-voltage lead (HVL) of the Doble test set encroached on the minimum approach distance (MAD) of an adjacent energized circuit breaker outside the clearance boundaries, and drew arcing faults.

On May 20, 1999, Michael S. Cowan, Chief Program Officer (CPO) for Western, appointed a Type B Accident Investigation Board (Board) (see Appendix A) to investigate the accident in accordance with DOE Order 225.1A, Accident Investigations.

1.2 Facility Description

Located in Routt County in northwestern Colorado, Hayden Substation is owned and operated by Western. The substation consists of 138-kV and 230-kV switchyards. At the time of the accident, the crew was performing Doble testing in the 138-kV switchyard on circuit breaker (BK) 2872, which was under Clearance C99-242. Adjacent BK 2772 and BK 2972 were energized. (See Exhibit A.)

A test trailer was 13 feet, 6 inches from the cable tray. The trailer containing Doble test equipment was southwest of BK 2872, south and southeast of BK 2772. (See Exhibit A.) The trailer contained a table and chair, in addition to a Doble test set and other equipment. All equipment was properly grounded.

The accident occurred on the east side of BK 2772.

1.3 Scope, Conduct and Methodology

The accident site was immediately secured by RMR safety and maintenance staff. The Board began investigating the accident on May 20, 1999, and submitted its findings to the CPO on July 2, 1999.

The scope of the Board's investigation was to review and identify all relevant facts to determine the accident's cause(s). The investigation specifically addressed the role of management systems in the accident and the application of lessons learned from similar accidents within Western to prevent their recurrence.

In conducting its investigation, the Board:

- Conducted a site visit, interviewed witnesses and reviewed documents and evidence pertaining to the accident.
- Issued an immediate corrective procedure recommendation (Appendix B).
- Used event and causal factor charting, barrier analysis and Technique of Operations Review (TOR) analysis to correlate accident information and identify performance of management systems.
- Analyzed the data, reached conclusions and developed Judgments of Need to prevent future similar accidents.

2.0 FACTS AND ANALYSIS

2.1 Accident Description and Chronology

2.1.1 Background

The accident occurred at 10:31 a.m. on Wednesday, May 19, 1999, during Doble testing at Hayden Substation. Doble testing is a procedure to find the insulating value of a piece of equipment. During testing, the Doble equipment applies a voltage and the crew takes a reading of conductivity to measure how much current is leaking past the insulating medium. Using a hotstick, Electrician 3 was moving the HVL from bushing 5 to bushing 2 on BK 2872. He was taking up slack from the HVL by walking backward when the HVL encroached on the MAD and drew arcing faults near the top of bushing 5 of BK 2772. An Events and Causal Factors chart was developed to facilitate the following Chronology of Events. The chart has been catalogued as evidence.

Monday, May 17

The crew held a Monday morning safety meeting in Montrose and discussed the complete service of equipment (CSE) on BK 2872 and 2972 at Hayden Substation. An Acting Foreman was assigned to this job on May 13 because the Foreman II had other duties to perform. After the safety meeting, the crew traveled to Hayden Substation, arriving at about 2:30 p.m. Crewmembers held a tailgate meeting and reviewed a written job hazard analysis (JHA). The crew wore the required personal protective equipment for the job, which consisted of hard hats, safety-toed shoes, gloves and safety glasses. The Acting Foreman received Clearance C99-237 on BK 2972 at 2:34 p.m., discussed the boundaries of the clearance with the crew, and they started the CSE. The test trailer was positioned east of BK 2972. The Foreman II drove to the Craig Maintenance Facility, arriving at 5 p.m.

Tuesday, May 18

The Foreman II, Acting Foreman and crew held a morning tailgate meeting before continuing the CSE on BK 2972. Clearance on the breaker was released at 2:44 p.m., and BK 2972 was restored to normal service at 3:05 p.m.

The crew received clearance C99-242 on BK 2872 at 4:12 p.m. After discussing the boundaries of the clearance, the crew positioned the test trailer at the southeast corner of BK 2772 and installed personal grounds. (See Exhibit A). They then completed ductor tests and removed oil from all three tanks of BK 2872, storing it in the oil tanker. The Foreman II was at the substation and periodically at the worksite. The crew left the substation at 5:30 p.m.

Wednesday, May 19

The Acting Foreman and crew returned to the substation at 7:30 a.m. and began the day with a tailgate meeting. The Acting Foreman and crew opened all three tanks on BK 2872 and removed the remaining oil that had dripped overnight. The electricians inspected the three tanks, tightened hardware and performed tests. The Foreman II and Acting Foreman worked outside the tanks to support the electricians. They also began cabinet maintenance and cleaned up the work area. After completing work inside the tanks, making final checks and closing the tanks, the oil was pumped back into the tanks. The Foreman II then went to

the 230-kV switchyard to gather nameplate data from equipment, to be entered into Maximo (see Appendix C).

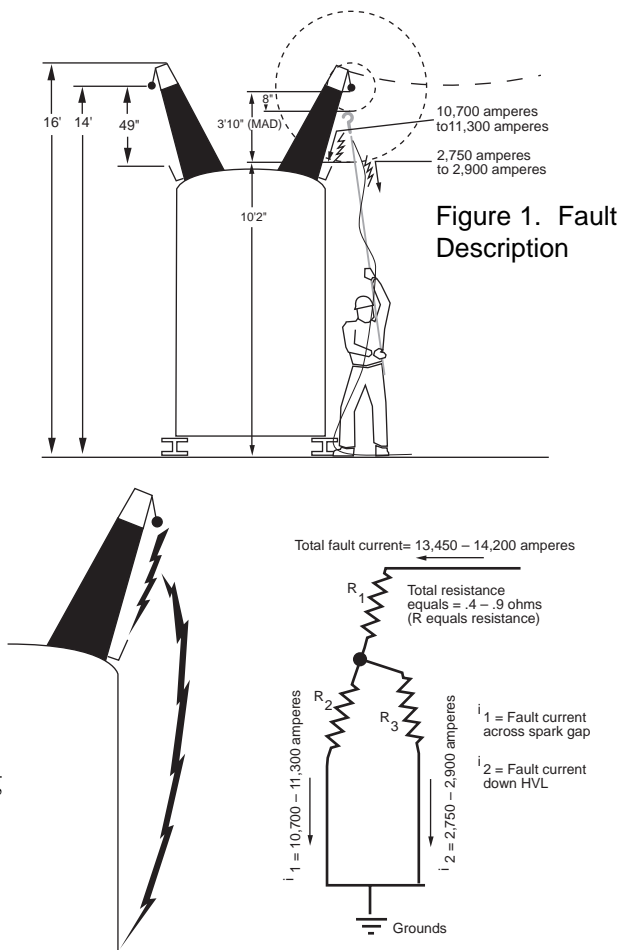
Upon completing the tank maintenance work on BK 2872, the crew began Doble testing at about 10 a.m., starting with bushing 1. Electrician 1 was entering data into the Doble test set in the trailer. Electrician 2 was installing a test probe in bushings and attaching the low-voltage lead from an 8-foot stepladder. Electrician 3 was hanging the HVL from ground level using an 11-foot-long hotstick. The crew completed testing of bushings 1, 3 and 5.

At the time of the accident, Electrician 1 was in the test trailer. Electrician 2 was on the fourth or fifth step of the ladder under bushing 5, gathering tools and preparing to come down. The Acting Foreman was crouched in front of the breaker cabinet, which was open with the doors locked in place. It is located on the west side of BK 2872. He was checking the battery of the Meggar Unit. Electrician 3 was walking backward taking up slack on the HVL, which was still attached to the top of the hotstick, with the hotstick in a vertical position. He was moving it from bushing 5 to bushing 2 on the opposite side of BK 2872 (see Exhibit E).

2.1.2 Accident Description

As Electrician 3 was walking backward taking up the slack of the HVL, he held the hotstick in a nearly vertical position. With the grounded HVL still attached to the top of the hotstick, the hook of the HVL got within 8 to 10 inches of the spark gap located on the top of bushing 5 of the energized 138-kV BK 2772. It initiated an arcing fault to ground. (See Exhibits B and G.) The fault current had a magnitude between 13,450 and 14,200 amperes that split, with the majority (10,700 – 11,300 amperes) traveling to ground through the spark gap. The remaining fault current (2,750 – 2,900 amperes) flashed down the HVL, which was against the hotstick and Electrician 3, causing his clothing to ignite. (See Exhibits C and F.)

The arc flashed down the HVL and launched the HVL's attachment hook from the end of the lead to approximately 120 feet from the fault location. The fault current down the HVL reached ground potential on the corner of the grounded circuit breaker, the grounded Doble test



See enlarged drawing on page 27

equipment (see Exhibit D) and the grounded test trailer (see Exhibit A). The blast from the arcs caused Electrician 2 to fall from the ladder from a height of about 5 feet above the ground. Immediately following the explosion, the Acting Foreman turned and saw Electrician 3 fall to the ground with his clothing on fire. Fault current within the ground shield and the conductor of the HVL overloaded the Doble test equipment located in the test trailer, creating an explosion and causing Electrician 1 to fall to the floor. The trailer immediately filled with smoke following the explosion (see Exhibit E).

Based on data received from digital fault recorders, sequence of events recorders and Schweitzer Engineering Laboratories relays, BK 2772 tripped open, clearing the majority of the fault current (12,600 to 13,300 amperes) in approximately 3.5 cycles (the AC high-voltage power system operates at 60 cycles per second). The remaining fault current (approximately 875 amperes) cleared when Gore Pass BKs 472 and 576 tripped open in 9.5 cycles at 10:30:56:288 a.m. A set time of 25 cycles after the fault began, BKs 472 and 576 automatically reclosed; and, 240 cycles after the fault was initiated BK 2772 automatically reclosed, restoring BK 2772 to full energization at 10:31:00:133 a.m. The entire process took approximately 4 seconds. (See Exhibit B.)

2.1.3 Post-accident Chronology of Events

Following the fault, Electrician 1 fell to the floor in the test trailer. Electrician 2 fell from the ladder to the ground, and Electrician 3 fell to the ground engulfed in flames. The Acting Foreman saw Electrician 3 fall with his clothing on fire. The Acting Foreman responded to the accident immediately, extinguishing the fire on Electrician 3's clothing. Electrician 1 crawled from the smoke-filled test trailer and ran to assist the Acting Foreman in attending to Electrician 3. Electrician 2 ran around the east end of BK 2872 to assist Electrician 1.

The Acting Foreman saw Electrician 1 coming to assist, so he went to call 911. As he left the accident scene, he saw the Foreman II and told him Electrician 3 was down. The Acting Foreman drove to the control house to call 911 for emergency medical and ambulance assistance.

The Acting Foreman placed an emergency call to the West Routt Fire Protection District and then continued to Highway 40 and County Road 51 to meet the ambulance. The call from the Acting Foreman was received at 10:35:03 and the ambulance departed for the accident scene at 10:37:41.

Electrician 2 went to the control house to confirm emergency help was on the way. As he reached the control house, he encountered the Acting Foreman who said he was going to meet the ambulance. Electrician 2 also called RMR Dispatch.

Two volunteer emergency medical technicians (EMTs), who were working at the Hayden Powerplant, north of the substation, heard the radio dispatch and responded to provide emergency assistance. They arrived on the scene before the ambulance and began emergency treatment. The Foreman II assisted the EMTs by cutting the red lead from the reel to make room for the EMTs to work. The ambulance arrived at the scene at 10:46:00 and prepared Electrician 3 for transport to Routt County Hospital, Steamboat Springs,

Colorado. The ambulance left the scene at 10:59:49. It was determined that Electrician 2 and the Acting Foreman would also be transported to the hospital for medical attention. A second ambulance, which is on permanent assignment at the powerplant, arrived on the scene at 11:15:44 to transport Electrician 2 and the Acting Foreman to the hospital. That ambulance departed at 11:15:53.

Electrician 3 received emergency treatment at Routt County Hospital and was transferred by air ambulance to University Hospital, Denver, Colorado. Electrician 2 and the Acting Foreman were examined, treated for minor injuries and released.

2.1.4 Emergency Response and Investigative Readiness

The Foreman II called the Field Maintenance Manager at about 10:40 a.m. to notify him of the accident. He then called the RMR Safety Manager, the RMR Regional Manager, the Western Colorado Maintenance Manager and support staff in Montrose at approximately 10:45 a.m. He also notified all Western Montrose crews and Electrician 3's family of the accident. The RMR Safety Manager called the CSO Safety and Security Office at 10:50 a.m. The RMR Regional Manager and CSO Safety and Security Manager notified the Chief Program Officer in Golden at about 10:55 a.m.

The emergency notification was timely, and the emergency response and dispatch of the ambulance was within 3 minutes. Despite the quick notification, the response time could have been delayed. The West Routt Fire Protection District is a volunteer department with one paid employee. That employee happened to be at the fire station when the emergency call was received. He placed the emergency call to 911 and dispatched the ambulance. The fire district is not staffed to receive emergency calls. The emergency number posted at the substation and used by Western personnel to request emergency assistance was outdated.

The accident site was immediately secured. Proper notifications were made and regional maintenance and safety staff were dispatched to the site. Electrician 1, Electrician 2, Acting Foreman and Foreman II were administered drug tests. The Chief Program Officer, Corporate Services Office, Golden, Colorado, named an Accident Investigation Board within 24 hours. The Board's members included a senior manager who served as chairperson, a trained investigator, two technical advisors and a legal advisor. The Chairperson and one technical advisor arrived on the scene at 5 p.m., May 20, 1999. The investigation began and continued as other team members arrived.

2.2 Hazards, Controls and Management Systems

2.2.1 Work Planning and Controls

Before beginning work at Hayden Substation, the Acting Foreman completed a written JHA, performed a walkthrough of the clearance boundaries, and conducted a tailgate meeting. During the tailgate meeting the written JHA was reviewed by all crewmembers. No major changes or additions were made, and it was initialed by all crewmembers. The crew twice conducted a walkthrough of the clearance boundaries: once before starting the CSE of BK 2972 and once before starting the CSE of BK 2872. The crew held its first tailgate meeting the afternoon of May 17, 1999. Subsequent tailgate meetings were conducted on Tuesday and Wednesday morning before starting the day's work.

Interviews with the crew indicate that the specific issue of working in close proximity to energized parts was never discussed as a potential hazard. Due to the location of the test trailer, the hazard was mitigated during the CSE on BK 2972. The trailer was parked on the east side of the breaker, which allowed relocating the HVL from one side of the breaker to the other while attached to the hotstick and maintaining minimum approach distances of energized equipment. However, for the CSE on BK 2872, the trailer was relocated to the southeast corner of BK 2772. Given the location of BK 2872 (between two adjacent energized bays), it would be extremely difficult to move the HVL around BK 2872 with the HVL attached to a hotstick held in the vertical position while maintaining minimum approach distances to energized parts. (See Exhibit H.)

A review of previous accidents and Judgments of Need at Western reveals that a leading contributing factor has been poor job planning with respect to the JHA process. The JHA process for this job involved:

- One written JHA that was reviewed by the crew.
- A walkthrough of the clearance boundaries by the crew, performed before each CSE.
- Tailgate meetings at the start of each workday.

The written JHA was predeveloped (canned) and addressed CSEs that specified both BK 2972 and BK 2872 as one job, although there were hazards unique to BK 2872. BK 2972 was only surrounded on three sides by energized equipment, while BK 2872 was completely surrounded by energized equipment. The CSE on this breaker would have to be performed between two energized bays, which further limited the work area. The walkthrough of the clearance boundaries by the crew on both breakers involved identifying the points of protection; therefore, the hazards posed by the energized bays may have been identified, but the crew did not develop solutions to eliminate, modify or prevent the hazard. Tailgate meetings were held at the start of each workday. The CSE on BK 2872 began toward the end of a day (Clearance C99-242 was issued at 4:12 p.m. May 18, 1999). Although there was discussion concerning who had supervisory control over this equipment, no tailgate meeting was held at the start of the CSE to address specific hazards associated with this piece of equipment.

All three parts of the crew's JHA process failed to develop corrective measures to eliminate the hazards associated with working in close proximity to energized parts.

2.2.2 Policies and Procedures

Western has a well-defined safety program, with requirements for specific types of work spelled out in the *Power System Safety Manual* (PSSM) and Occupational Safety and Health Administration (OSHA) Code of Federal Regulations (CFR) 1910.269.

The following applicable safety rules are from the PSSM:

Section 7.14.c. Test procedures and facilities. When testing equipment such as transformers, circuit breakers, etc., under a Clearance, the person holding the Clearance shall be responsible for overseeing the safe testing activities.

Section 8.7.b. Protective clothing. When working on or near energized equipment, you shall wear clothing that, when exposed to flames or electric arcs, will not increase the extent of injury that could be sustained. In these situations wearing of clothing that contains acetate, nylon, polyester and rayon either alone or in blends is prohibited. Natural fabrics such as cotton, wool or silk and synthetic fabrics that are marked as flame resistant apparel are acceptable.

Section 11.1.2.a. Working near energized equipment by electrical workers. Maintain at least the minimum approach distance shown in Appendix A from exposed energized high-voltage (600 volts and above) components of substation equipment. Appendix A: Minimum approach distances to live parts by electrical workers. (This minimum approach distance is 3 feet, 10 inches at a 6,000-foot altitude.)

Section 11.1.2.b. The clearance holder is responsible for preventing access to adjacent energized equipment. Normally, identification of energized equipment during a JHA by reviewing the boundaries of the clearance and walkthrough will suffice. If because of the close proximity to energized equipment (distances between Appendix B Table B-1 and Table Appendix A) or potential encroachment by unauthorized personnel, prevention cannot be assured, one of the following methods shall be used:

- (1) Use visible warning devices, such as cones, tape, rope, or portable fence sections with minimum ground-to-top height of 42 inches, with warning signs reading “DANGER–DO NOT PASS UNDER THIS BARRIER,” “DANGER–HIGH VOLTAGE,” or similar notice placed at intervals of not more than 20 feet. Yellow tape (4-inch wide) with imprinted wording meets this criteria.
- (3) Using a designated person to be a “safety observer” while work is in progress. The “safety observer” shall not perform any other work.

Section 17.2.a. A JHA is a study of a job or activity to (1) identify hazards or potential accidents associated with each step or task and (2) develop solutions that will eliminate, modify or prevent such hazards or accidents. For simple tasks, the JHA may be a thought process for a single employee task; it may be an oral discussion as part of a tailgate safety meeting; or it may be an oral discussion among a supervisor and employees when work is assigned at the shop prior to departure.

The following are OSHA requirements:

CFR 1910.269(l)(2). Minimum approach distances. The employer shall ensure that no employee approaches or takes any conductive object closer to exposed energized parts than set forth in Table R-6 through Table R-10, unless:

- (i) The employee is insulated from the energized part (insulating gloves or insulating gloves and sleeves worn in accordance with paragraph (l)(3) of this section are considered insulation of the employee only with regard to the energized part upon which work is being performed), or

- (ii) The energized part is insulated from the employee and from any other conductive object at a different potential, or
- (iii) The employee is insulated from any other exposed conductive object, such as during live-line bare-hand work.

CFR 1910.269 (l) (6) (iii). The employer shall ensure that each employee who is exposed to the hazard of flames or electric arcs does not wear clothing that, when exposed to flames or electric arcs, could increase the extent of injury that would be sustained by the employee.

A memorandum from the Deputy Assistant Secretary for the Department of Labor, OSHA, dated August 10, 1995, states the following: Paragraph 1910.269 (l) (6) (iii) shall be cited when employees who are exposed to electric arcs are found to wear the following apparel: a. Any clothing that is not flame resistant or flame-retardant-treated, if the clothing can ignite under the electric arc and flame exposure conditions found at the workplace.

Based upon a review of the above policies and regulations, the following safety rules were not complied with:

- Section 7.14.c was not complied with when the test procedures were not properly overseen.
- Section 8.7 of the PSSM and CFR 1910.269 (l) (6) (iii) were not complied with. Not all of Electrician 3's clothing was 100-percent cotton. His shirt was 35 percent cotton and 65 percent polyester. His pants were 36 percent polyester and 64 percent cotton. Electrician 3 was also wearing bib Carharts (100 percent cotton) over his clothing. All layers of clothing ignited. (See Exhibit C.) Since the 100-percent cotton coveralls ignited, the coveralls also contributed to the employee's injuries; therefore, wearing cotton clothing in this situation is in violation of OSHA (see above).
- Section 11.1.2.a and CFR 1910.269 (l) (2), were not complied with when the MAD was encroached, causing the arc faults. The electrical clearance to ground was lowered by two feet (from 16 feet to 14 feet) by spark gaps located on the top of the bushing (see Exhibit G). The reduced electrical clearance contributed to the probability of encroachment of the MAD.
- Section 11.1.2.b was not complied with when the crew was performing work in proximity to energized equipment (distances between Appendix B Table B-1 and Table Appendix A) without the use of visible warning devices or a safety observer.
- Section 17.2 was not complied with when no procedures for removing or dealing with corrective measures were developed to address the hazard of encroaching on the MAD.
- All other policies and procedures were fully complied with. All equipment used in the job was properly grounded, including the test trailer which was parked under an energized bus. The switching procedure was properly performed. The required personal protective equipment for this job was used.

2.2.3 Human Factors, Training and Qualifications

Human Factors

Based on a review of interviews with crewmembers, there were no mental or physical distractions or other factors that contributed to the accident.

Training

Training is a major focus of Western's management systems. Reviewing the past three years of RMR training records revealed that the crew was current with all mandatory safety training. All crew members received Doble training. In addition, Electrician 2 and Electrician 3 attended a Doble conference in Boston, Mass., in April 1998. The Acting Foreman and Electrician 3 received Doble training in Loveland, Colo., on December 7, 1998, and the Foreman II and Electrician 3 attended similar training in Loveland on March 1, 1999. All four employees were equally and adequately trained and were proficient in Doble testing. However, Doble testing is not considered mandatory training and the training is not intended to address other hazards such as working in close proximity to other energized equipment.

Qualifications

The crew consisted of journeymen with lengthy craft experience and training in Western's policies and work procedures. The crew had a combined total of 69 years of Federal Government experience as electricians. Each crew member met the agency qualifications, including experience and training, as outlined in the Supplemental Questionnaire and Crediting Plan for Electrician WB-2808. Individual electrician's experience ranged from 13 years to 23 years.

2.2.4 Management Systems

Western's safety and maintenance organizations work together to develop rules, guidelines and procedures to promote a safe work environment. These are two completely different organizations within Western, and they sometimes view safety requirements differently. Safety's role is to develop and promote goals, objectives, policies and procedures. Maintenance oversees implementation and enforcement of safety procedures at job sites.

While Western has investigated past accidents and issued reports, the organization has not taken action to ensure full discussion and implementation of Judgments of Need from these reports. A list of Judgments of Need from Western's history of accident investigations was developed. This list demonstrates that Western has not fully carried out corrective actions in response to Judgments of Need. Indicators of incomplete action and integration include previous accidents at Flaming Gorge Substation in Dutch John, Utah, in 1985 and a 1995 Shoo-fly Removal Operation Accident at Laramie, Wyoming. These two accidents contained elements similar to the accident at Hayden Substation, yet corrective actions and modified work procedures responding to these judgements of need were not fully integrated and therefore did not prevent the Hayden accident.

When Western changes procedures to improve safety, the change is often isolated, without being integrated into all related areas. For example, changes to Western's fall protection

procedures (Fall Prevention Implementation Group Report, March 1993) led to the use of hotsticks in Doble testing of circuit breakers. However, Western's procedures for Doble testing (PSSM, Chapter 6) do not address the safe use of hotsticks for attaching and removing test leads while Doble testing.

2.3 BARRIER ANALYSIS

A barrier analysis was conducted to facilitate the findings of this section. The chart has been catalogued as evidence. Barriers currently in place that could have played some part in preventing the accident were addressed by the Accident Investigation Board. A barrier analysis identifies the purpose of each barrier, and how each barrier failed to perform. The Board identified and addressed 10 barriers, and through this analysis a root cause was determined, as well as two main contributing causes.

Root Cause

The root cause of the accident was that Electrician 3 failed to maintain the MAD to energized parts defined in the PSSM, Appendix A, and OSHA CFR 1910.269, Table (1) (2).

Contributing Causes

The first contributing cause was inadequate procedures for Doble testing. The procedure did not address the safe use of a hotstick for placing and removing test leads in the vicinity of energized equipment. This change in work procedure was developed and implemented to minimize exposure to fall hazards by requiring the use of a hotstick. However, the procedure was not fully studied to determine if it would create other hazards. The Board issued a recommendation to maintenance personnel for an immediate corrective procedure addressing the safe use of a hotstick to place and remove Doble test leads on equipment.

The second contributing cause was that the JHA did not address how the crew would avoid violating the MAD. During the walkthrough of the clearance boundaries, the surrounding energized boundaries were identified. Identifying the hazard is half the process; the other half is to develop solution(s) that would eliminate, modify or prevent such hazards or accidents.

2.4 TECHNIQUE OF OPERATIONS REVIEW ANALYSIS

The TOR Analysis performed by the Board focused on management systems that may be deficient and which could have prevented or lessened the likelihood of this or similar accidents from occurring. The TOR analysis pointed to six areas where management systems were deficient:

Management:

- Hazard or problem – not properly evaluated. This relates to the issue of management addressing fall hazards, and more specifically while installing Doble test leads on equipment using a hotstick. Although one hazard was properly addressed (exposure to fall hazards) another hazard had been created and overlooked (encroachment of MADs in adjacent energized bays) during the implementation of the new procedure. While addressing hazards in one area, careful analysis shall be performed to evaluate the overall impact to safety.

Supervision:

- Unsafe act. Failure to correct before accident occurred. This applies to supervision at the job site. An electrician was allowed to carry a conductive object above his head near energized bays. Strict adherence to the PSSM must be enforced at the jobsite.
- Initiative. Failure to see problems and exert an influence on them. This applies to the clearance holder performing work at the job site, rather than overseeing the safe testing activities as required by the PSSM, Section 7.14.c,

Responsibility:

- Hazard or problem – not recognized. This applies to Western management either not fully understanding or recognizing the arc exposure hazards for work in substations yet, allowing employees to be exposed to this (unknown) hazard without wearing the proper apparel or enforcing the existing apparel requirement. Electrician 3 was wearing cotton/polyester blend pants and shirt that ignited and 100 percent heavy cotton bib-overalls (Carharts) that also ignited, contributing to an increase in his injuries.

Decision and Direction:

- Failure to investigate and apply the lessons of similar mishaps. A similar accident occurred in 1985 at Flaming Gorge Substation in Dutch John, Utah. A recommendation in that investigation report states: “Clearance boundaries must not be violated.” This recommendation did not prevent the most recent accident. In addition, the 1995 accident during a shoo-fly removal operation stated as a Judgment of Need: “A dedicated observer must remain on the jobsite in non-work status during work in the proximity of energized equipment.” These two accidents contained elements similar to the accident at Hayden Substation, yet corrective actions and modified work procedures responding to these judgements of need were not fully integrated and therefore did not prevent the Hayden accident.
- Hazard or problem – controls not developed. With regard to the 1985 accident and recommendation, controls should have been developed, such as the corrective procedure recommendation that was issued by the Board on May 27, 1999 (refer to Appendix B). No such control was developed after the 1985 accident.

2.5 SEQUENCE OF EVENTS AND CAUSAL FACTORS ANALYSIS

The root cause of the accident was that Electrician 3 failed to maintain the required MAD to energized parts defined in the PSSM, Appendix A and OSHA CFR 1910.269. The board also identified contributing causes, which are defined as issues that increased the likelihood or severity of the accident without individually causing the accident.

Contributing causes include the following:

- Although the JHA process identified the clearance boundaries, which were in close proximity to energized parts, the process did not adequately develop controls or corrective measure(s) to maintain the MAD, which would reduce or eliminate the hazard of encroaching on energized parts.

- Encroachment within the MAD of energized equipment while Doble testing was not a recognized hazard as mentioned in section 2.4.
- The job supervisor allowed, or did not see, the manner in which Electrician 3 was relocating the HVL from bushing 5 to bushing 2, as required in section 7.14.c of the PSSM, and as indicated in section 2.4 (Supervision).
- The safe procedure for using a hotstick for installing and removing the HVL was not properly addressed as indicated in sections 2.3 and 2.4.
- The employee was not practicing safe work procedures when he walked backward toward an energized bus while holding a conductive object in the air.
- The manner in which the crew was performing its work required a designated safety observer, or a warning device such as tape. Neither of these safeguards were in place.
- Electrician 3's clothing ignited, which contributed to his injuries.

3.0 CONCLUSIONS AND JUDGMENTS OF NEED

3.1 CONCLUSIONS

- The fault was the result of encroachment of the minimum approach distance (MAD) on energized equipment near the top of bushing 5 on BK 2772.
- Neither the written job hazard analysis nor the tailgate meeting(s) properly addressed close working distances to energized parts, as adequate controls were not established to ensure that the electrician maintained the MAD to energized parts.
- The spark gap on the top of the bushings of the 138-kV breakers at the Hayden substation lowers the electrical clearance to ground by two feet, from 16 feet to 14 feet.
- Management has not fully carried out corrective actions in response to previous Judgments of Need.
- Work was performed in “close proximity” to energized equipment. This requires use of visible warning devices such as cones, tape, rope or portable fence sections, or use of a designated person to be a “safety observer” while work is in progress. The “safety observer” shall not have any other duties. These requirements were not met.
- Almost all work involved in a complete service of equipment on BK 2872 would have to be performed in “close proximity” to energized equipment.
- The safe procedure for using a hotstick for Doble testing was not addressed.
- Employee was not wearing the proper clothing for the job. Improper clothing for this job includes any clothing that is not flame resistant or flame-retardant-treated, if the clothing can ignite under the electric arc and flame exposure conditions found at the workplace. The PSSM allows clothing to be worn that is made of natural fabrics as long as the clothing will not contribute to the injury that could be sustained.
- Although the test trailer was parked under an energized conductor, it was properly grounded.
- The switching procedure for the job was properly performed.
- All four employees were equally proficient in Doble testing.
- The crew wore the required personal protective equipment for the job, which consisted of hard hats, safety-toed shoes, gloves and safety glasses.
- Emergency numbers located in the substation had not been updated.
- EMTs responded to the accident site in a timely manner.
- Assigning an Acting Foreman for routine maintenance is a common practice for this crew.

3.2 JUDGMENTS OF NEED

1. The job hazard analysis process needs to be examined and revised where necessary. Job hazard analyses must address minimum approach distances to energized equipment, identification of other hazards, and take appropriate actions to eliminate the hazards.
2. Management must communicate, abide by and enforce strict adherence to the *Power System Safety Manual*.
3. All managers (including supervisors) are accountable for the timely integration of all safety- and maintenance- related policies, procedures and programs, including but not limited to Judgments of Need identified in accident reports.
4. All new, changed or modified work procedures must be evaluated to determine if the new procedure creates new hazards and corrective measures must be incorporated in the appropriate manuals (all affected manuals must be cross-referenced).
5. When using a hotstick to place or remove the high voltage lead during Doble testing of breakers and transformers, a procedure should be developed such as the Board's immediate corrective procedure recommendation to ensure that all areas of safety are considered.
6. The following sections of the Power System Safety Manual –7.14, 8.7, 11.1.2 and 17.2– must be reviewed and discussed during a series of weekly craft safety meetings.
7. There is a need to ensure all posted emergency numbers are correct and periodically verified, such as during the annual safety inspections.
8. An engineering study shall be conducted to determine if spark gaps on the 138-kV breaker bushings are required. If it is determined that they are no longer required, they shall be removed.
9. The proper clothing must be worn for work in energized substations. The strict interpretation of OSHA 1910.269 (l) (6) (iii) would require, based on this accident, employees to be in flame-resistant clothing.

4.0 BOARD SIGNATURES

Richard Gallegos

Accident Investigation Board Chairperson
Western Area Power Administration
Golden, CO

Date: _____

Leo Wandler

Trained Investigator
Western Area Power Administration
Bismarck, ND

Date: _____

John Quintana

Technical Advisor
Western Area Power Administration
Golden, CO

Date: _____

Robert Yniguez

Technical Advisor
Western Area Power Administration
Phoenix, AZ

Date: _____

Betty London

Legal Advisor
Western Area Power Administration
Golden, CO

Date: _____

5.0 BOARD MEMBERS, ADVISORS AND STAFF

Chairperson	Richard Gallegos
Member	Leo Wandler
Member	John Quintana
Member	Robert Yniguez
Member	Betty London
Technical Writer	Judy Farrell, Remtech Services Inc.
Design Support	Michael Dawson and Connie Edwards, Remtech Services Inc.

APPENDICES

Appendix A

Appointment Letter for Type B Accident Investigation

Appendix B

Memorandum on Handling Doble High-Voltage cable with a Hotstick

Appendix C

Acronyms, Initialisms and Definitions

Acronyms and Initialisms

Definitions of Technical Terms

Appendix D

Exhibit A Diagram of Accident Scene with Trailer

Exhibit B Fault Description

Exhibit C Photos of Victim's Burnt Clothing

Exhibit D Doble Test Equipment After the Fault

Exhibit E Diagram of Victim Locations

Exhibit F Photo of Accident Site

Exhibit G Photo of Bushing

Exhibit H Diagram of Approach Distances

APPENDIX A

MAY 20 1999

A3700

Accident Review Board - Serious Personal Injury, Hayden Substation -
May 19, 1999, Hayden, Colorado

L. Juarez, A0200, Golden, CO
J. Wegner, B0000.BL, Billings, MT
T. Carlson, G0000, Phoenix, AZ
J. Bladow, J0000, Loveland, CO

This memorandum establishes an Accident Investigation Board to investigate the subject accident. The following Western employees will serve as Chairperson and members until the review is closed.

Richard Gallegos, Economic Impact and Diversity Manager, Golden, Colorado,
Chairman

Leo Wandler, Safety Specialist, Bismarck, North Dakota, Trained Investigator

Bob Yniguez, Foreman I, Page, Arizona, Technical Advisor

John Quintana, Electrical Engineer, Golden, Colorado, Technical Advisor

Betty London, Attorney, Golden, Colorado, Legal Advisor

The scope of the board's investigation will include, but is not limited to identifying all relevant facts, analyzing those facts to determine the direct, contributing, and root causes of the accident, developing conclusions, and determining the judgments of need that, when implemented, should prevent the recurrence of the accident. The investigation will specifically address the role of management systems as they may have contributed to the accident and the application of lessons learned from similar accidents within Western.

The Board members may charge their time and expenses to work order number HDN----WES-M 92701.

The report shall be forwarded by memorandum, which states the Board's recommendations, to me within 30-calendar days of this correspondence.

Please keep me advised of your progress and solicit the assistance of the Office of Safety and Security or the technical assistance of any others that you need.

Michael S. Cowan

Michael S. Cowan
Chief Program Officer

cc:

A0000

A0204, B. London

A0300, R. Gallegos

A3000

A3700

A3700 J. Quintana

R. Fettig, B0700.BL, Billings, MT

L. Wandler, B0720.BS, Bismarck, ND

S. Spencer, G5200, Phoenix, AZ

B. Yniguez, G5220.PA, Page, AZ

A3000:MCowan:x2000:tlp:5/20/99:o:/a39sec/a3000/accident.wpd

United States Government

Department of Energy

memorandum

Western Area Power Administration

DATE: May 27, 1999

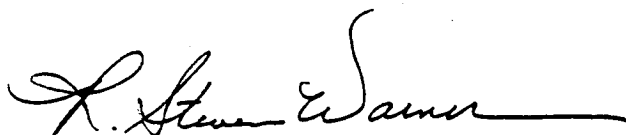
REPLY TO
ATTN OF: A3000

SUBJECT: Handling Doble High-Voltage Cable with a Hot-Stick

TO: Distribution

The following recommendation of the Hayden Accident Investigation Board is directed towards maintenance operations that involve the use of a hot-stick to place or remove the high-voltage lead of the Doble test set while testing power circuit breakers and power transformers that are adjacent to energized equipment. Maintenance staffs are strongly encouraged to review their procedures and consider the following work practice.

When using a hot-stick to place or remove the high-voltage lead during Doble testing of breakers and transformers, it is recommended that the test lead be removed from the hot-stick and hand carried to the opposite side of the equipment to continue the testing. Once the worker is in a safe position, the test lead can be reattached to the hot-stick for continuation of the test on the opposite bank of bushings. This work practice will reduce/eliminate the risk of encroachment of the minimum approach distance to adjacent energized equipment.


for Michael S. Cowan
Chief Program Officer

Distribution

M. Hacskaylo, A0000
 L. Juárez, A0200
 R. Gallegos, A0300
 T. Meeks, A0500
 L. Kyriss, A0600
 R. Fullerton, A0600
 V. Ponce, A1000
 K. Maxey, A8000
 G. Wegner, B0000.BL, Billings, MT
 R. Fettig, B0700.BL, Billings, MT
 B. Stone, B0701.BL, Billings, MT
 C. Hanson, B0710.HU, Huron, SD
 R. Boyer, B0730.FP, Fort Peck, MT
 S. Gliko, B5000.HU, Huron, SD
 T. Carlson, G0000, Phoenix, AZ
 K. Kendall, G0701, Phoenix, AZ
 B. Berg, G5000, Phoenix, AZ
 J. Bladow, J0000, Loveland, CO
 T. Henry, J0705, Loveland, CO
 B. Marsh, J0700.Q1, Loveland, CO
 J. Belleau, J0710, Loveland, CO
 G. Causer, J0715.MT, Montrose, CO
 J. Keselburg, J6000, Loveland, CO
 D. Sabo, L0000, Slat Lake City, UT
 J. Toenyas, N0000, Folsom, CA
 H. Schumacher, N0700, Folsom, CA
 B. Thomas, N0710, Folsom, CA
 T. Boyko, N5000, Folsom, CA

cc:

Gary Mai, 9114 Capullo Circle, LaGrange, CA 95329

Accident Investigation Board:

R. Gallegos, Chairman, A0300
 J. Quintana, Technical Advisor, A3700
 B. London, Legal Advisor, A0200
 L. Wandler, Trained Investigator, B0720.BS, Bismarck, ND
 B. Yniguez, Technical Advisor, G5220.PA, Page, Arizona
 A0300 (Gallegos)
 A3700 (Dembrowski) (Quintana)
 A3900 (Davis) (Romero) (Schurman)

APPENDIX C-ACRONYMS, INITIALISMS AND DEFINITIONS

Acronyms and Initialisms

AC	Alternating current
BK	Circuit breaker
CFR	Code of Federal Regulations
CSE	Complete service of equipment
CSO	Corporate Services Office
DOE	U.S. Department of Energy
EMT	Emergency medical technician
HVL	High-voltage lead
JHA	Job hazard analysis
kV	Kilovolt
MAD	Minimum approach distance
OSHA	Occupational Health and Safety Administration
PSMM	Power System Maintenance Manual
PSOM	Power System Operations Manual
PSSM	Power System Safety Manual
RMR	Rocky Mountain Region
TOR	Technique of Operations Review

Definitions of Technical Terms

ARCING FAULTS: The process of current inadvertently leaping the gap from an energized object to a grounded object.

BUSHING: An extremely low conductive post-support for a conductor.

CIRCUIT BREAKER: Generally any switching device that is capable of closing under normal load conditions or interrupting an electrical circuit under overload or short circuit conditions.

CLEARANCE: A statement with documentation from the System Operator to the clearance holder declaring that the equipment to be worked on has been deenergized and isolated from all sources of primary system energy.

COMPLETE SERVICE OF EQUIPMENT (CSE): A set of test and maintenance procedures performed on all high-voltage circuit breakers.

CURRENT: The movement or flow of electrons in a circuit, measured in amperes.

CYCLE: 60 cycles = 1 second.

DOBLE TESTING: A procedure to find the insulating value of a piece of equipment using test equipment developed by Doble Engineering Co.

DUCTOR: Equipment used for testing the resistance of the contacts in high-voltage breakers in micro-ohms.

ENERGIZED: Any ungrounded piece of equipment.

HIGH-VOLTAGE LEAD: Conductive cable used in a Doble test set for applying voltage to the equipment (usually circuit breaker and transformer bushings) being tested. The HVL runs from the Doble test set to the piece of equipment while in use.

HOTSTICK: A fiberglass pole normally used for performing work on energized equipment or installing personal grounds on deenergized equipment because of its high insulating value. When used to apply the HVL during Doble testing, all equipment is grounded; therefore, its application is strictly to allow the procedure to be performed from the ground level (to avoid fall hazards).

JOB HAZARD ANALYSIS: A study of a job or activity to (1) identify hazards or potential accidents associated with each step or task and (2) develop solutions that will eliminate, modify, or prevent such hazards or accidents. For simple tasks, the JHA may be a thought process for a single employee task; it may be an oral discussion as part of a tailgate meeting; or it may be an oral discussion among a supervisor or employees when work is assigned at the shop prior to departure.

JUDGMENTS OF NEED: Managerial controls and safety measures necessary to prevent or minimize the probability or severity of a recurrence of an accident.

MANAGEMENT: Refers collectively to the operating office head and his/her staff, and/or the regional manager and staff, including the person (supervisor) directly in charge of personnel at the worksite, regardless of payroll or operating title.

MAXIMO: A computerized maintenance management system used to track and improve inventory, maintenance, operations and productivity.

MEGGAR UNIT: A portable device used to check the insulation value of the wire in the cabinet.

MINIMUM APPROACH DISTANCE: The closest distance an employee is permitted to approach an energized object.

RESISTANCE: Measured in ohms. The element in a circuit that limits the flow of current.

SUBSTATION: An assembly of equipment, such as transformers, circuit breakers, and so on, for the purpose of switching, changing, or regulating the voltage of electricity.

SWITCHYARD: The outdoor portion of a substation.

TAILGATE MEETING: An on-the-job briefing, usually not documented, about the job to be done.

TECHNIQUE OF OPERATION REVIEW (TOR) ANALYSIS: A tool used for investigating accidents which is a form of Root Cause Analysis. The TOR analysis focuses on eight managerial elements: Decision and Direction; Training; Responsibility; Supervision; Control; Work Groups; Management; and Personal Traits. Each element has a list of items on a worksheet in which the investigator must determine if they are contributing causes to the accident.

VOLTAGE: Measured in volts. The work or force required to move electrons to create current.

Exhibit A

Diagram of Accident Scene with Trailer.

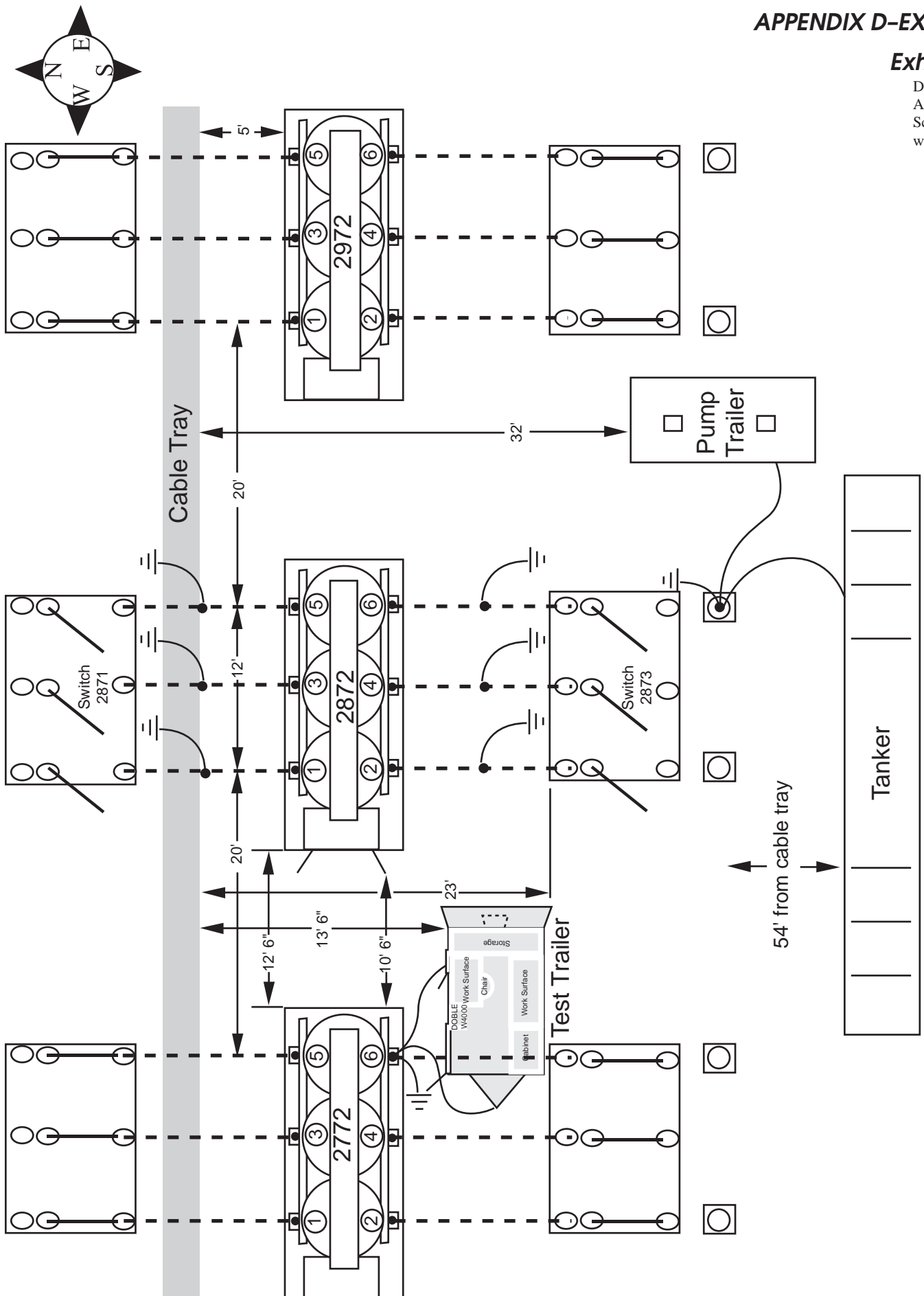


Exhibit B

Fault Description.

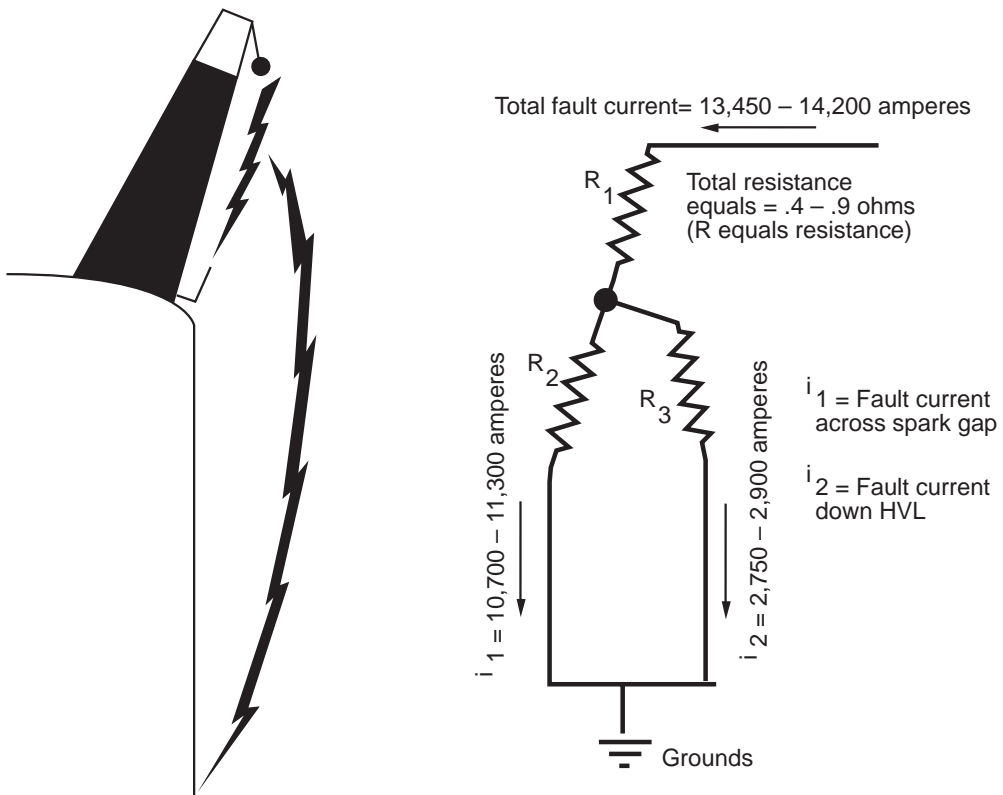
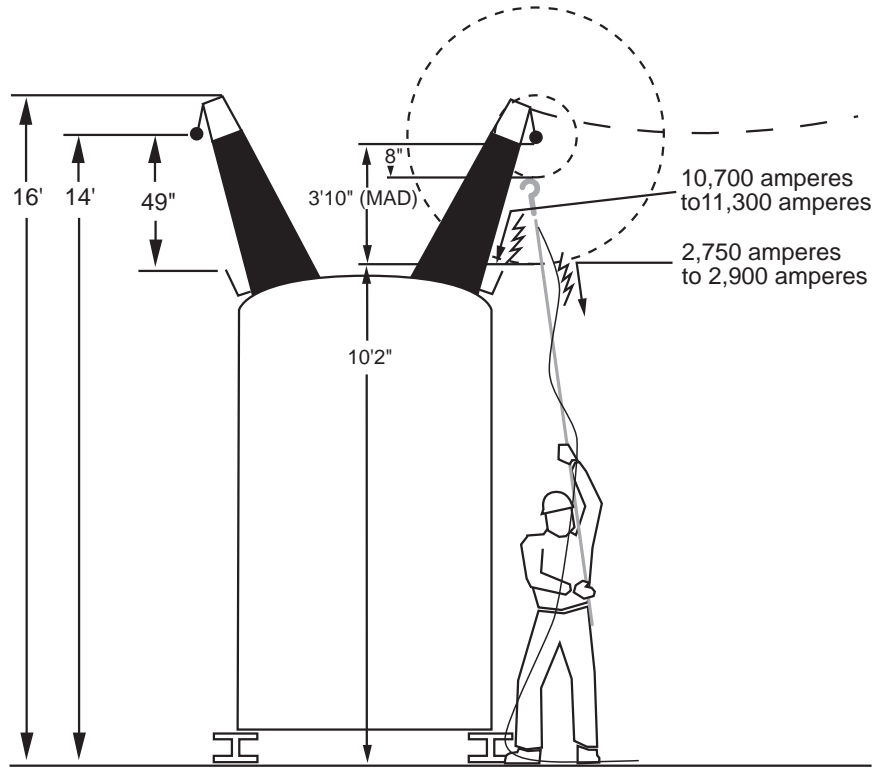


Exhibit C

Photos of Victim's Burnt Clothing.

Electrician 3's pants
64 percent cotton
36 percent polyester



Electrician 3's shirt
35 percent cotton
65 percent polyester



**Electrician 3's bib
overalls (Carharts):**
100 percent cotton



Exhibit D

Doble Test Equipment After the Fault.



Exhibit E

Diagram of Victim Location.

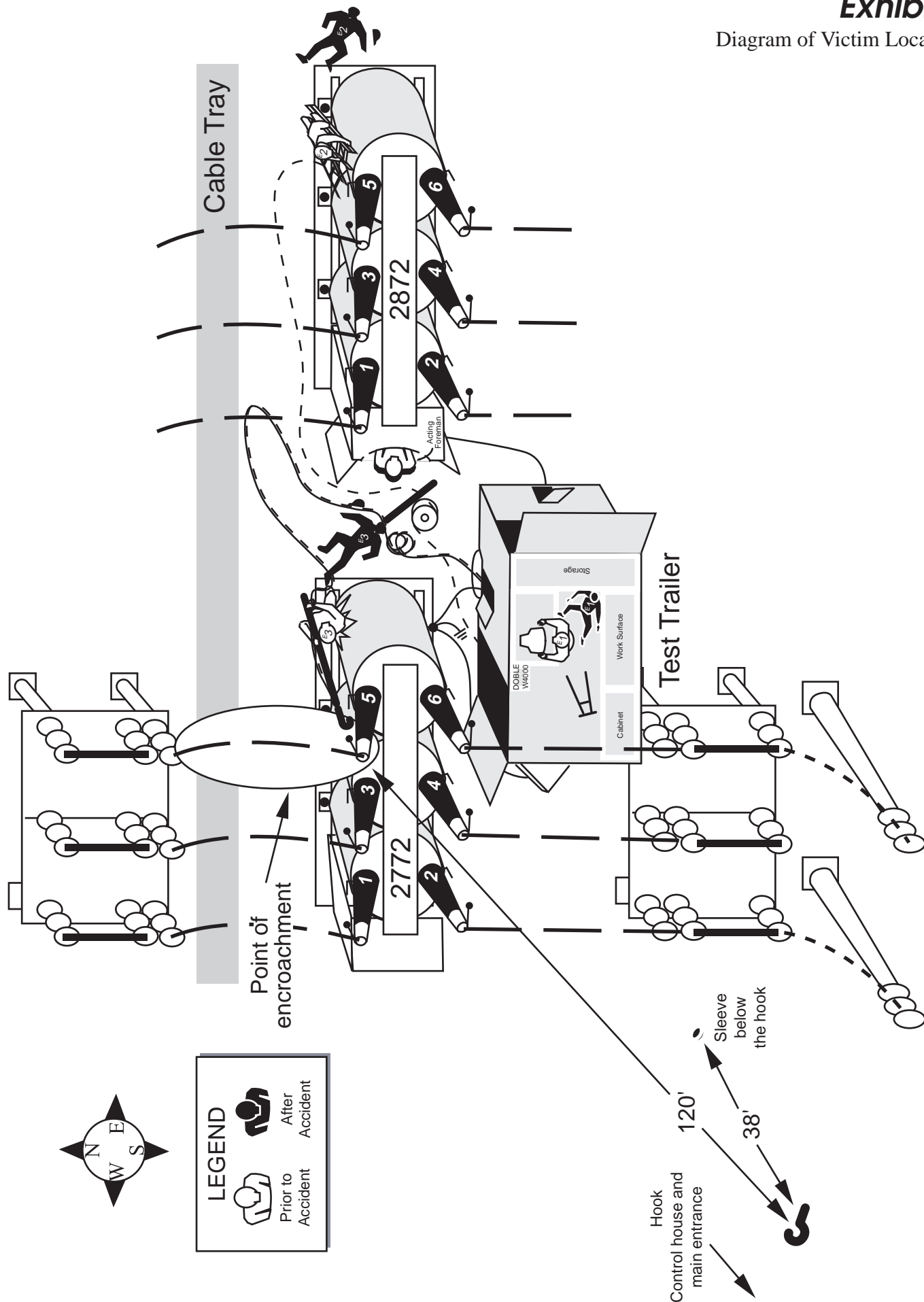


Exhibit F

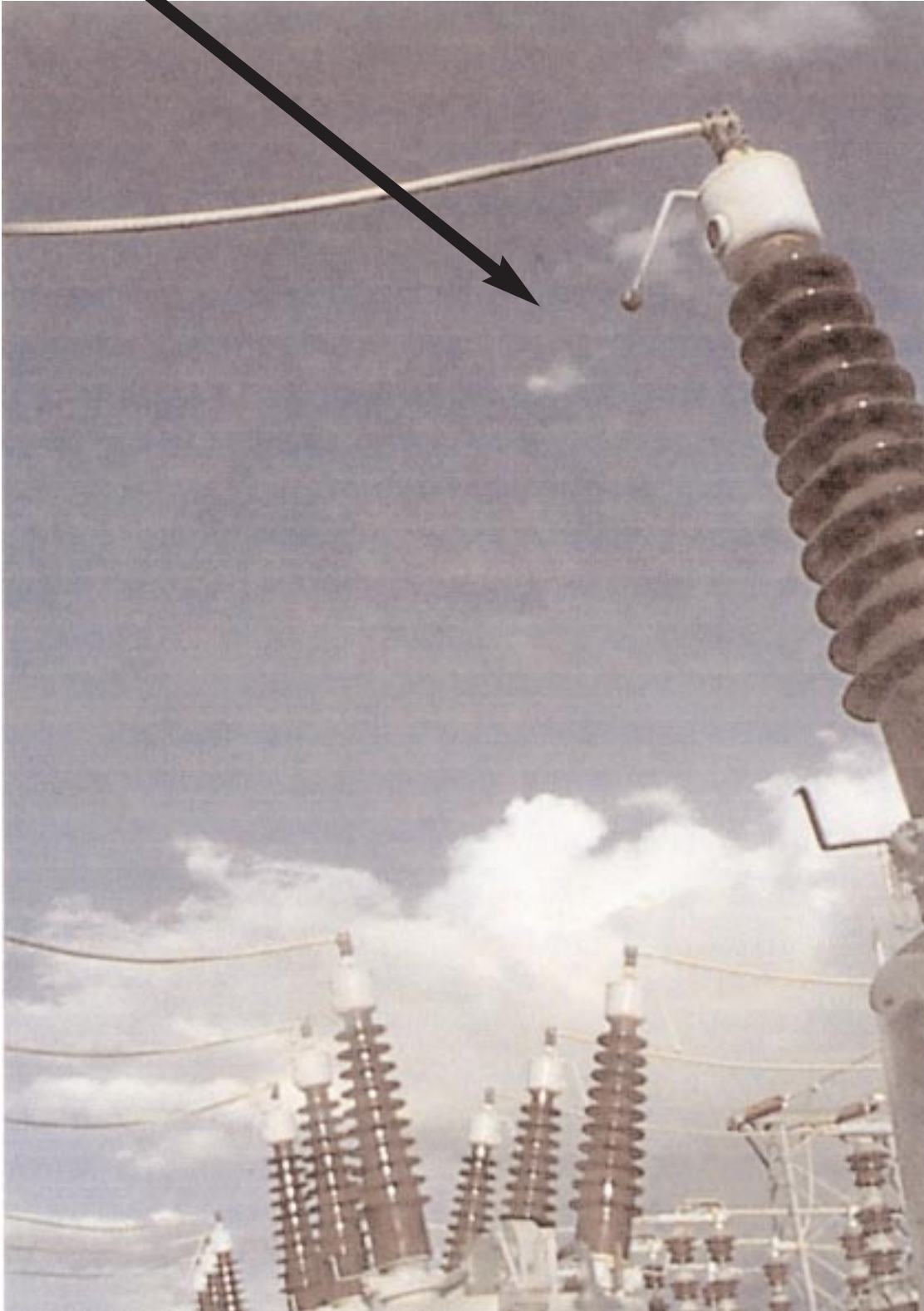
Photo of Accident Site.

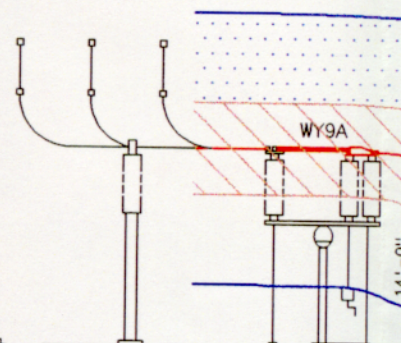
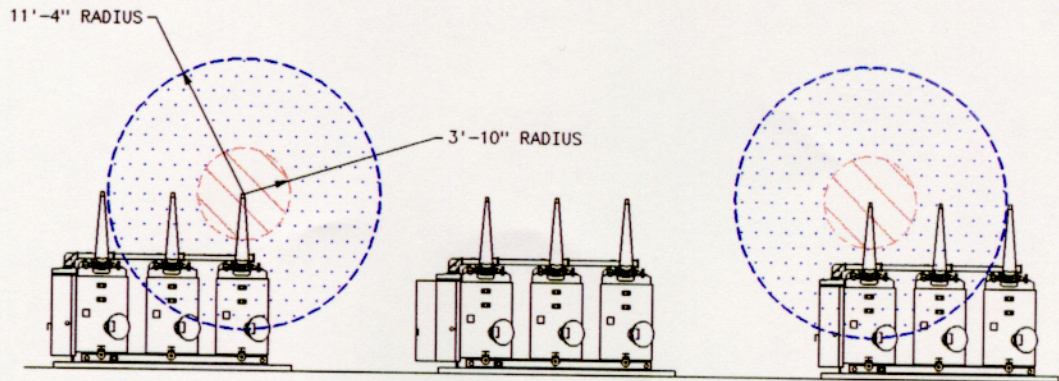
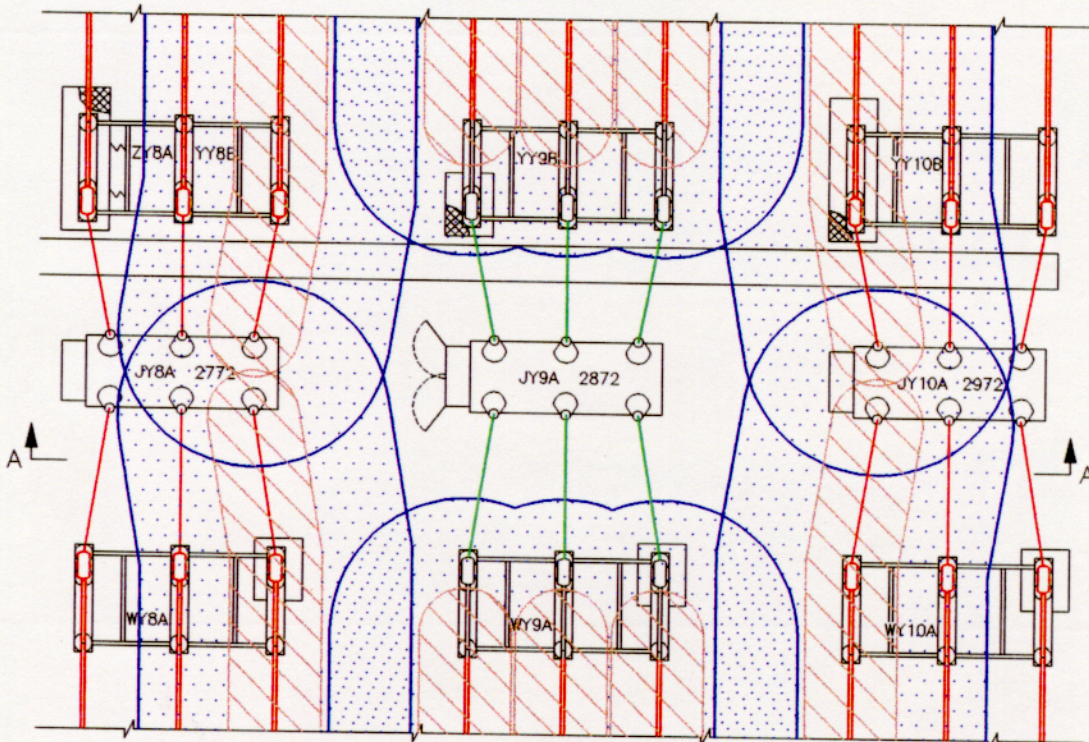
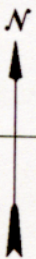


Exhibit G

Photo of Bushing.

Bushing 5 BK2772
Spark Gap

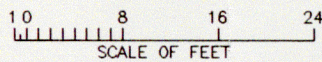
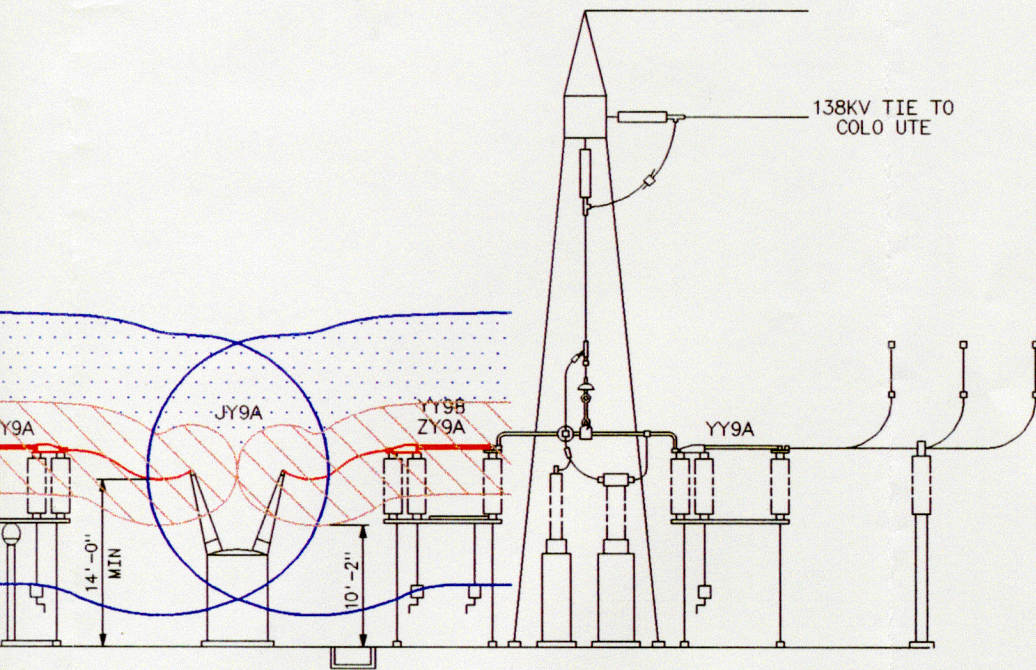
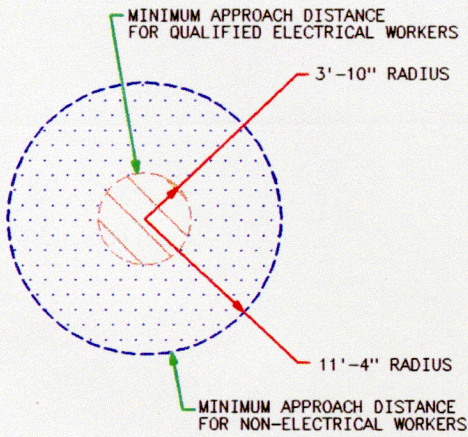




SECTION A-A

Exhibit H

Diagram of Approach Distances.



UNITED STATES DEPARTMENT OF ENERGY WESTERN AREA POWER ADMINISTRATION CORPORATE SERVICES OFFICE - GOLDEN, COLORADO			
HAYDEN SUBSTATION COLORADO			
138KV BUS STRUCTURE			
DESIGNED	-----	APPROVED	-----
CAE	MAY 28, 1999	HDN	T0001