

**Type A Accident
Investigation Board Report
July 11, 1996
Electrical Shock
at
Technical Area 53,
Building MPF-14
Los Alamos National Laboratory**



August 1996

Albuquerque Operations Office

This report is an independent product of an electrical shock accident investigation board appointed by Bruce G. Twining, Manager, Albuquerque Operations Office, Department of Energy.

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

The discussion of facts, as determined by the board, and the views expressed in the 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.

On July 12, 1996, I established a Type A Accident Investigation Board to investigate the electrical shock accident at Los Alamos National Laboratory that resulted in injury to a student employee.

The Board's responsibilities have been completed with respect to this investigation. The analysis process; identification of direct, contributing, and root causes; and development of judgments of need during the investigation were done in accordance with DOE 225.1, *Accident Investigations*.

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

Bruce G. Twining
Manager
Albuquerque Operations Office

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ACRONYMS AND INITIALISMS

AL	DOE Albuquerque Operations Office
AOT	Accelerator Operations and Technology Division
AR	Administrative Requirement
DOE	Department of Energy
HQ	DOE Headquarters
LAAO	Los Alamos Area Office
LANL	Los Alamos National Laboratory
MPF	Meson Physics Facility
OJT	On-the-Job Training
SOP	Standard Operating Procedure
SWP	Special Work Permit
TA	LANL Technical Area

TECHNICAL TERMS

Oscilloscope - an instrument that visually displays and may analyze electronic data.

Magnetron - an electron tube in which the flow of electrons is controlled by an externally applied magnetic field; component of a microwave oven which generates the microwaves

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PROLOGUE

INTERPRETATION OF SIGNIFICANCE

The non-fatal, electrical shock accident at Los Alamos National Laboratory (LANL) on July 11, 1996, occurred due to failures by the University of California and the accident victim (student employee). Incorrect grounding of a high voltage probe by the student employee during an electrical test was the principal cause of the electrical shock that he received. However, significant programmatic weaknesses in LANL's electrical safety and line management programs contributed to this accident, particularly inadequacies in work planning and controls, implementation of procedures, and training.

Applicable LANL work control procedures were not followed. The student employee was working alone, not implementing the required Two Person Rule, and did not have an approved Special Work Permit. Supervisory responsibility was not clearly defined in AOT-9, and requirements for electrical safety training for the student employee involved in this accident were unclear.

This accident highlights the importance of an integrated approach to safety that stresses clear goals and policies, individual and management accountability and ownership, implementation of requirements and procedures, and thorough and systematic oversight by the contractor and by Departmental management. There is also a need to ensure proper and uniform implementation of work planning and control procedures, including reviews and approvals.

DOE and LANL management systems have not been effective at resolving long standing, well-defined programmatic issues, or translating lessons learned into safe day-to-day operations. The similarity of this accident with other previous accidents at LANL, and the delay in execution of corrective actions by LANL management for previous accidents indicate a lack of management accountability and ownership for safety at LANL.

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EXECUTIVE SUMMARY

INTRODUCTION

An electrical shock accident at Los Alamos National Laboratory (LANL), Technical Area-53 (TA-53), Building MPF-14, was investigated in which a student employee conducting electrical measurements on a microwave oven received a 4000 volt shock. In conducting its investigation, the Accident Investigation Board (Board) used various analysis techniques including accident analysis, barrier analysis, change analysis, and event and causal factor analysis. The Board conducted electrical performance tests on key equipment, inspected and photographed the accident site, reviewed events surrounding the accident, and conducted extensive interviews and document reviews to determine the factors that contributed to the accident. Relevant management systems were evaluated, in accordance with the applicable Guiding Principles of Safety Management, that could have contributed to the accident.

ACCIDENT DESCRIPTION

The accident occurred at approximately 11:30 AM, on Thursday, July 11, 1996, at LANL, TA-53, Building MPF-14, when a student employee, working alone, improperly connected one of two probes while conducting electrical measurements on a microwave oven. Upon contact with an electrical component, energized due to the improper connection, the student employee received a 4000 volt electrical shock.

CAUSAL FACTORS

The **direct cause** of the accident was the student employee contacting electrically energized parts.

The **root causes** of the accident were (1) failure by contractor management to exercise authority, (2) failure by line management to implement electrical safety procedures, and (3) failure by the student employee to take individual responsibility for working in a safe manner.

Contributing causes of the accident were: (1) the training was inadequate, (2) LANL procedures were not followed, (3) supervision was inadequate, (4) the Two Person Rule was not used, and (5) the Two Person Rule was not understood.

CONCLUSIONS AND JUDGMENTS OF NEED

Table ES-1 presents the conclusions and judgments of need determined by the Board. Conclusions of the Board are those considered significant and are based upon facts and pertinent analytical results. Judgments of need are managerial controls and safety measures believed by the Board to be necessary to prevent or mitigate the probability or severity of a recurrence of this type of accident. They flow from the conclusions and causal factors and are directed at guiding managers in developing follow-up actions.

TABLE ES-1: Conclusions and Judgments of Need

Conclusions	Judgments of Need
An AOT-9 student employee did not assume individual responsibility for safety. Specifically, he did not use the Two Person Rule or prepare a special work permit.	AOT-9 needs to determine why procedures were not followed and implement necessary controls to prevent a recurrence.
A clear division of safety responsibilities within the AOT Division has not been established and communicated.	The AOT Division needs to establish, communicate, and implement safety roles and responsibilities.
AOT-9 electrical safety training was inadequate and inconsistent with LANL requirements.	The AOT Division needs to correct deficiencies in the AOT-9 group electrical safety training program and needs to review the status of training in other groups within the Division.
LANL does not have a comprehensive program in place to identify fitness for duty issues identified in this accident.	LANL needs to develop and implement a comprehensive fitness for duty program for personnel involved in hazardous operations and their supervisors.
AOT management failed to ensure that electrical safety and training programs were implemented in compliance with defined LANL requirements.	AOT management needs to develop a system to routinely monitor the implementation of safety and other programs in accordance with LANL requirements.
LANL oversight of the AOT Division was inadequate to identify programmatic issues identified in this accident.	Consistent with the conditions of the Pilot Oversight Program, AL and LANL need to conduct a for-cause review of electrical safety programs at LANL.
Application of lessons learned from previous Type A accidents related to this accident is not evident at LANL.	<p>LANL needs to promptly implement corrective actions to address the lessons learned from this and other accidents.</p> <p>LANL needs to assure that lessons learned are applied across all elements of the Laboratory.</p>

Type A Accident Investigation Board Report on the July 11, 1996 Electrical Shock at Technical Area 53, Building MPF-14, Los Alamos National Laboratory

1.0 INTRODUCTION

1.1 BACKGROUND

On July 11, 1996, at approximately 11:30 AM, a student employee of Los Alamos National Laboratory (LANL) received an electrical shock while working with a commercial microwave oven in Technical Area 53 (TA-53), Building MPF-14. The injured student employee was transferred to Los Alamos Medical Center where he underwent eight days of inpatient treatment. The student employee is now in an outpatient status and is expected to fully recover from his injuries.

On July 12, 1996, Tara O'Toole, M.D., M.P.H., Assistant Secretary for Environment, Safety, and Health, U. S. Department of Energy (DOE), delegated authority to Bruce G. Twining, Manager, Albuquerque Operations Office (AL) to form an investigation board for this accident. On July 12, 1996, Bruce G. Twining established a Type A Accident Investigation Board (Board) to investigate this accident in accordance with DOE 225.1, *Accident Investigations* (See Appendix A).

1.2 FACILITY DESCRIPTION

LANL, located in north-central New Mexico, is operated by the University of California under contract to DOE. Its primary mission is to apply its scientific and engineering capabilities to nuclear weapons technology to enhance national security. LANL also performs other work not related to nuclear weapons technology. LANL occupies 43 square miles and consists of 47 active technical areas.

TA-53, the scene of this accident, houses the Los Alamos Neutron Scattering Center, the accelerator production of the Tritium Project and numerous accelerator technology related projects. This 750-acre site encompasses 400

On July 11, 1996, a student employee of Los Alamos National Laboratory received an electrical shock while working in TA-53, Building MPF-14.

On July 12, 1996, a Type A Accident Investigation Board was established by Albuquerque Operations Office.

buildings and other structures, including the linear accelerator building, experimental laboratories, various support operations buildings, and other structures such as cooling towers, storage tanks, storage buildings, and craft shops. This complex is operated by a regularly assigned staff of 800. MPF-14, a 13,115 square foot building, is one of three radio frequency and high-power microwave laboratories used to house equipment and instrumentation for the research, development, and testing of advanced concepts for radio frequency power sources, high-power microwaves, and advanced accelerator and injection systems.

1.3 SCOPE, PURPOSE, AND METHODOLOGY

The Board began its investigation on July 15, 1996, completed the investigation on July 31, 1996, and submitted its findings to the AL Manager on August 1, 1996.

The scope of the Board's accident investigation included all activities required to review and analyze the circumstances surrounding the accident in order to determine the cause(s) or probable cause(s). During the investigation, the Board inspected and photographed the accident scene, reviewed documentation presented by LANL, reviewed the critical events leading to the accident, reviewed the emergency response, conducted extensive interviews with appropriate individuals, tested key equipment, and performed causal analysis. The Board evaluated the adequacy of the contractor's safety management system and work control practices, and made appropriate recommendations.

The purpose of the investigation was to identify causal factors of the accident, including deficiencies, if any, in safety management systems. The investigation report will inform the DOE community of lessons learned to promote program improvement and to reduce the potential for similar accidents.

The Board conducted its investigation, with a focus on management systems, using the following methodology.

- The Board gathered facts relevant to the accident.

The scope of the accident investigation included all activities required to identify the cause or causes of the accident.

The purpose of the investigation was to identify causal factors in order to inform the DOE community of lessons learned.

- The Board evaluated relevant management systems and factors.
- The Board then analyzed event and causal factors to determine the causes of the accident.

2.0 FACTS AND ANALYSIS

2.1 ACCIDENT DESCRIPTION AND CHRONOLOGY

2.1.1 Accident Background

The accident occurred while a student employee was conducting tests on a commercial microwave oven to characterize the high voltage power supply to the magnetron. (The magnetron is the component of the microwave oven which generates the microwaves.) The student employee is an undergraduate student from Cornell University, majoring in Applied and Engineering Physics, and is expected to graduate in August, 1996. He was employed full time at LANL at the time of the accident. He had worked at LANL at various times over a three year period and had worked at LANL continuously for approximately the last year. He was considered by his coworkers and management to be a serious, careful experimenter with demonstrated ability in safely working with high voltage equipment.

The microwave oven involved in the accident was a General Electric Model JE1425L with a built-in timer. It had been previously modified for use in another experiment in late 1993 or early 1994. The modification consisted of inserting one-inch copper tubes through the oven sides to provide ports for the insertion of test materials. The modification was designed to prohibit microwave radiation leakage. During subsequent testing requested and observed by the Board, LANL Industrial Hygienists verified that the microwave leakage from the oven was well below accepted safe limits. The cover of the microwave oven had been removed to allow access to the magnetron high voltage terminals, but no safety interlocks were defeated.

The accident occurred while a student employee was conducting tests on a commercial microwave oven.

The microwave oven was modified to facilitate experimental activities.

The characterization tests being conducted at the time of the accident involved measuring the high voltage power supply to the magnetron and displaying its waveform on a Hewlett Packard Model 54111D or 54510A digital oscilloscope. To conduct the tests, one or two (depending on the measurement being made) Tektronix Model P6015 high voltage probes were connected from the magnetron filament to an oscilloscope. These high voltage probes also have compensator boxes attached by ten foot coaxial cables. Compensator boxes are used to tune the waveform, using a calibrated signal, so that the test waveform will be accurately displayed on the oscilloscope. Compensator boxes also provide the connection to the oscilloscope.

Normally, the tests were to be conducted by attaching all test leads; plugging in the oven; placing a beaker of water into the oven to absorb the microwave energy during tests; setting the timer to automatically turn the oven off after a preset time, usually five to 10 seconds; and then turning on the oven. After each measurement, the waveform data could be saved using the internal functions of the digital oscilloscope and/or plotted to an external plotter connected to the oscilloscope. Figure 2-1 shows a view of the overall accident scene, including the workbench, microwave oven and oscilloscopes.

Due to the nature of the work to be performed, LANL procedures required a number of administrative safety controls to be in place. These controls for hazardous work are contained in the LANL *Environment, Safety and Health Manual*.

Administrative Requirement 1-3 (AR 1-3), *Standard Operating Procedures and Special Work Permits*, requires either a Standard Operating Procedure (SOP) or a Special Work Permit (SWP) for any potentially hazardous operation. The SOP or SWP must “identify the hazards and specify the controls selected to eliminate or mitigate those hazards.” SOP’s are intended for long term activities and must undergo reviews on a periodic basis. SWP’s are intended for a limited-term or one-time, potentially hazardous operation or activity.

The tests being conducted at the time of the accident involved high voltage measurements.

Routine practice minimized the potential for an accident.

LANL procedures required a number of administrative safety controls, due to the hazardous nature of the work.

Figure 2-1



Figure 2-1: Overall View of the Accident Scene

AR 7-1, *Electrical Safety*, and AR 1-8, *Working Alone* require the presence of a second individual when work of this type is conducted. The second individual is required to:

- Be certified in cardiopulmonary resuscitation (CPR),
- Remain clear of the hazard, and
- Be only a consulting observer.

Technical Bulletin TB-701, *Electrical Safety*, is a supplement to AR 7-1 and contains additional safety precautions and design recommendations for electrical work, including research. The use of the guidance in TB-701 is not mandatory.

LANL requirements for fitness for duty are contained in LANL Director's Policy 119 (DP-119), *Occupational Medicine*. DP-119 requires the Laboratory's occupational medicine program to "identify and correct or prevent any instance for which employee physical and mental health is incompatible with safe and reliable performance of job tasks" and "to provide employee assistance services to employees with ... personal problems."

In summary, these policies and procedures require hazard identification, management review and approval of the controls identified to eliminate or mitigate the identified hazards, and the presence of a second, qualified individual when work is conducted. In addition, the LANL occupational medicine program, managers, and workers are expected to act in consonance to assure that personnel performing hazardous duties are mentally and physically fit to perform those duties.

2.1.2 Accident Description and Chronology of Events

The project to characterize the magnetron began sometime in March 1996, and was suspended later the same month. During the brief period of work in March, the microwave oven was partially disassembled to examine various components, including the magnetron, and reassembled. When the project was suspended the student employee was assigned to work on other projects. The project restarted on July 9, 1996. On the morning of July 10, 1996, the student employee identified to several coworkers and the Deputy Group Leader the possibility that he might

LANL administrative controls include hazard identification, management review and approval, the presence of a second, qualified individual during test activities, and fitness to perform duties.

Active testing resumed on July 9, after a suspension of several months. On July 10, the student employee experienced a stressful emotional experience, but continued to conduct tests.

experience an emotionally stressful event. At about midday, the anticipated event did occur. Later that day he performed some high voltage measurements on the microwave oven using a single probe without incident. He stopped work at approximately 5:00 PM because he was having difficulty concentrating on the testing. During the performance of these measurements, a second person was present, although no Special Work Permit was approved.

On the morning of July 11, 1996, the student employee visited with several coworkers, and met with his mentor and Deputy Group Leader. At approximately 11:20 AM, the student employee proceeded to MPF-14 where the magnetron tests were to be conducted. No direct account of the subsequent accident is available, since no other personnel were in the immediate vicinity at the time of the accident and the student employee did not recall the accident when interviewed by the Board.

Shortly after 11:20 AM, the student employee, without the benefit of the second person required by LANL procedure for work of this kind, apparently resumed the testing suspended the previous afternoon. A second probe had been obtained for use in performing differential voltage measurements. In order to perform these measurements, both high voltage probes were attached to the magnetron. One of the probes was later found to be incorrectly connected. The tip of this probe was connected to one side of the magnetron filament and the grounding clip was attached to the other side of the filament. This resulted in the application of 4000 volts to the associated compensator box which is normally safe to touch. Figure 2-2 shows a simplified representation of the test configuration as discovered after the accident. Note that the microwave oven high voltage power supply transforms the 120 volts of alternating current from a standard electrical receptacle to 4000 volts of pulsed direct current for use by the magnetron. Figure 2-3 is a photograph of the high voltage probe connections to the microwave oven.

At approximately 11:30 AM the student employee apparently contacted the high voltage (probably at the compensator box) and received a severe electrical shock. Subsequently, the automatic timer functioned to terminate oven operation. The student employee was found almost

At approximately 11:20 AM, on July 11, 1996, the student employee proceeded to MPF-14 to resume testing.

Investigation of the scene after the accident revealed that a grounding clip was incorrectly connected, creating an unexpected 4000 volt electrical shock hazard.

At approximately 11:30 AM, the student employee contacted the high voltage and received a severe electrical shock.

Figure 2-2

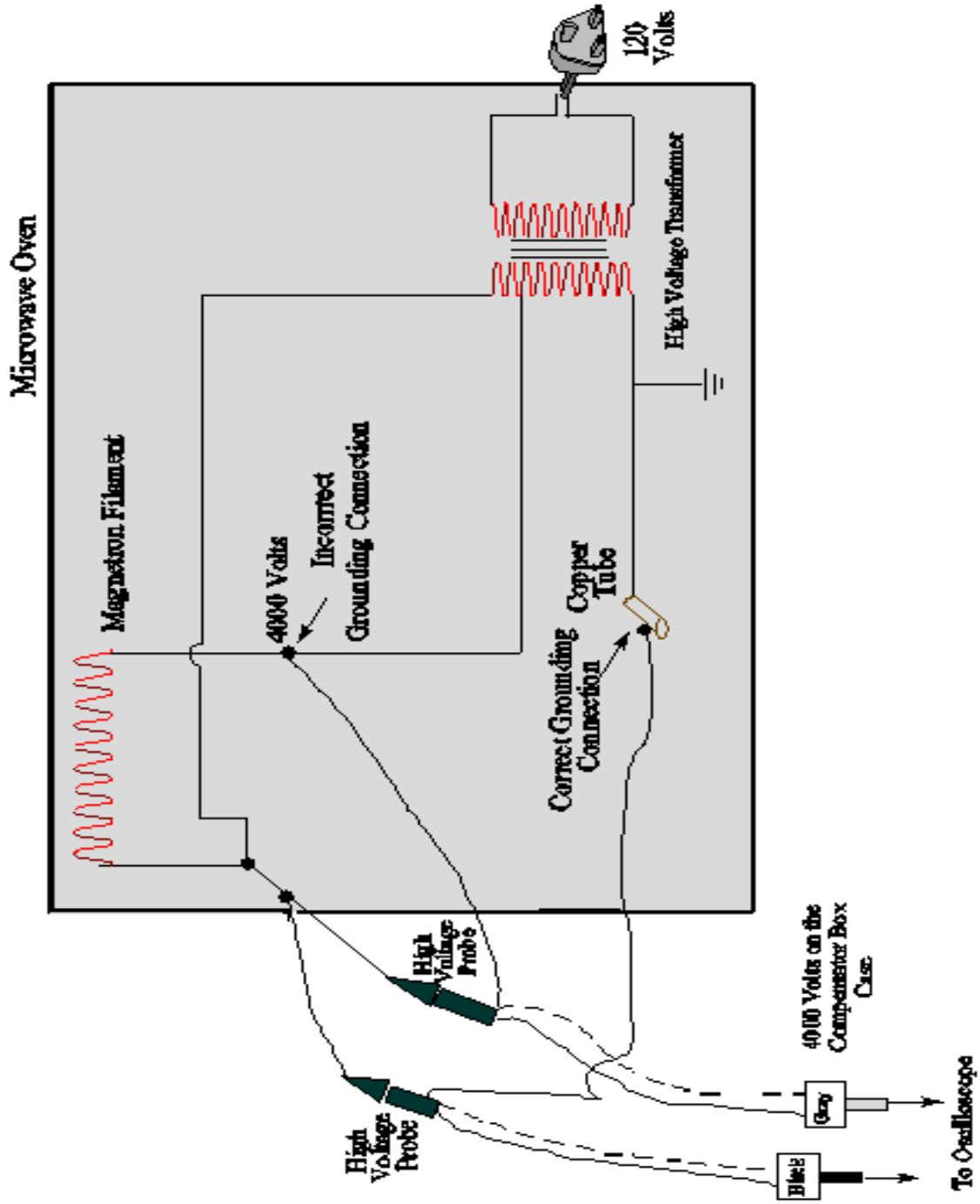


Figure 2-2: Test Set-Up at Time of Accident (Simplified)

Figure 2-3

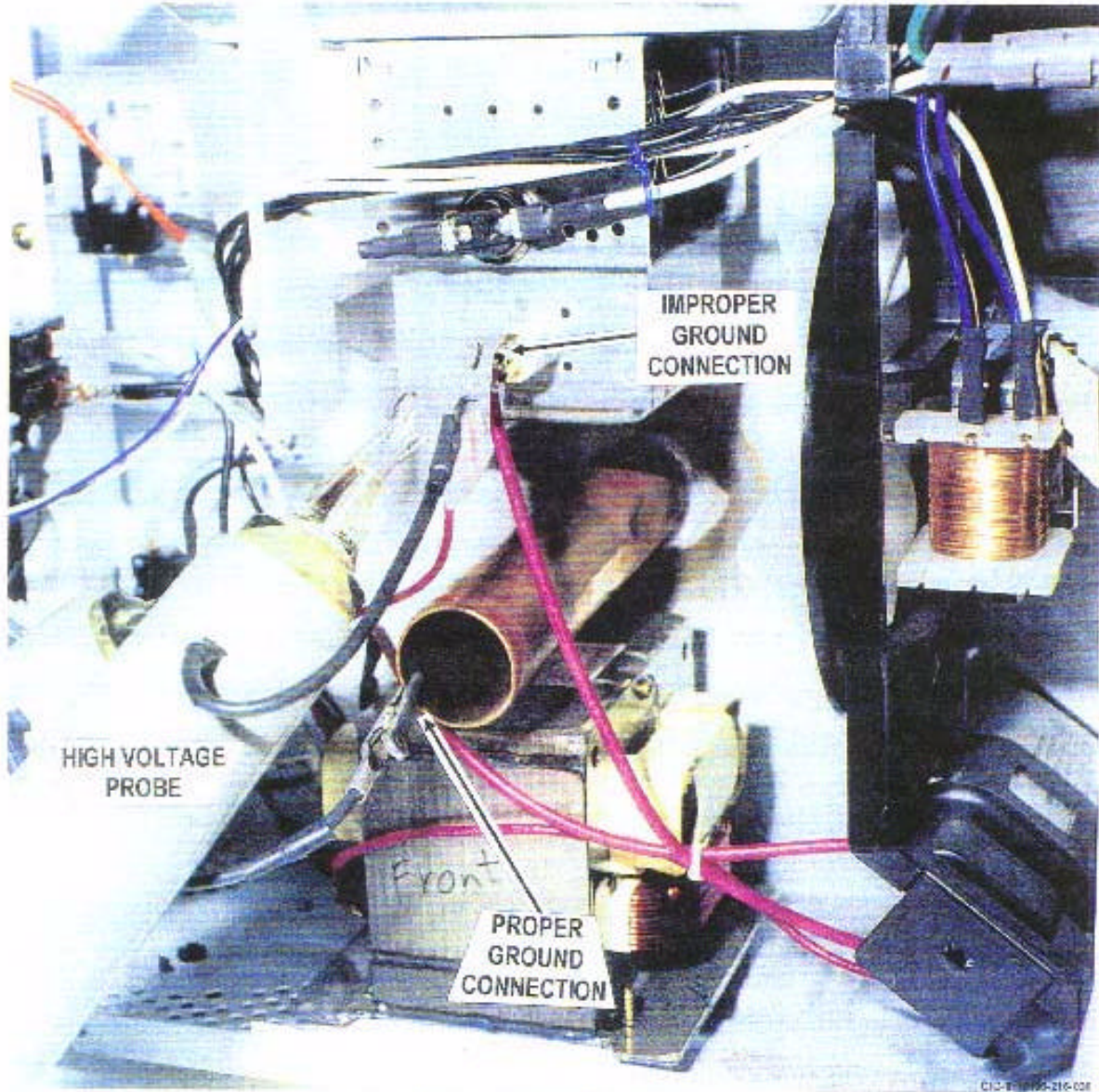


Figure 2-3: High Voltage Probe Connections to the Microwave Oven

immediately by a coworker who was passing near the scene. The coworker summoned additional assistance from other staff members working in the building. First aid was given to the student employee by a nearby coworker and a call placed to 911. Section 2.3, Accident Analysis, contains a more detailed discussion of specifically how the shock was probably received, based on reconstruction of the accident from the physical evidence, interviews, and the results of equipment testing requested by the Board. Figure 2-4 summarizes the chronology of the accident.

2.1.3 Emergency Response and Investigative Readiness

The student employee was transported by ambulance to Los Alamos Medical Center. No deviations from LANL or DOE policies and procedures were noted during the accident response. Proper notifications were made, electrical equipment in the immediate vicinity was de-energized, and appropriate first aid was rendered to the affected student employee. The Los Alamos Fire Department was on the scene within 12 minutes after the accident, and the student employee was enroute to Los Alamos Medical Center within 25 minutes after the accident.

LANL and DOE Los Alamos Area Office (LAAO) actions to preserve the integrity of the accident scene and to prepare for accident investigation were effective. The following LANL and LAAO actions were key to investigation support.

- Careful preservation of the accident scene was accomplished to the extent consistent with treating and preparing the student employee for transport to Los Alamos Medical Center. The area was clearly bounded with caution tape, and guards were posted at the door to the building to prevent unnecessary personnel from entering the area. LAAO formally took custody of the accident scene pending determination of the investigation type. Accelerator Operations and Technology (AOT) Facility Management controlled access to the accident scene. Evidence tape was obtained from the Los Alamos Police Department for use in sealing the doors to the accident scene.

LANL emergency response was effective.

LANL and LAAO were effective in preserving the accident scene.

Figure 2-4

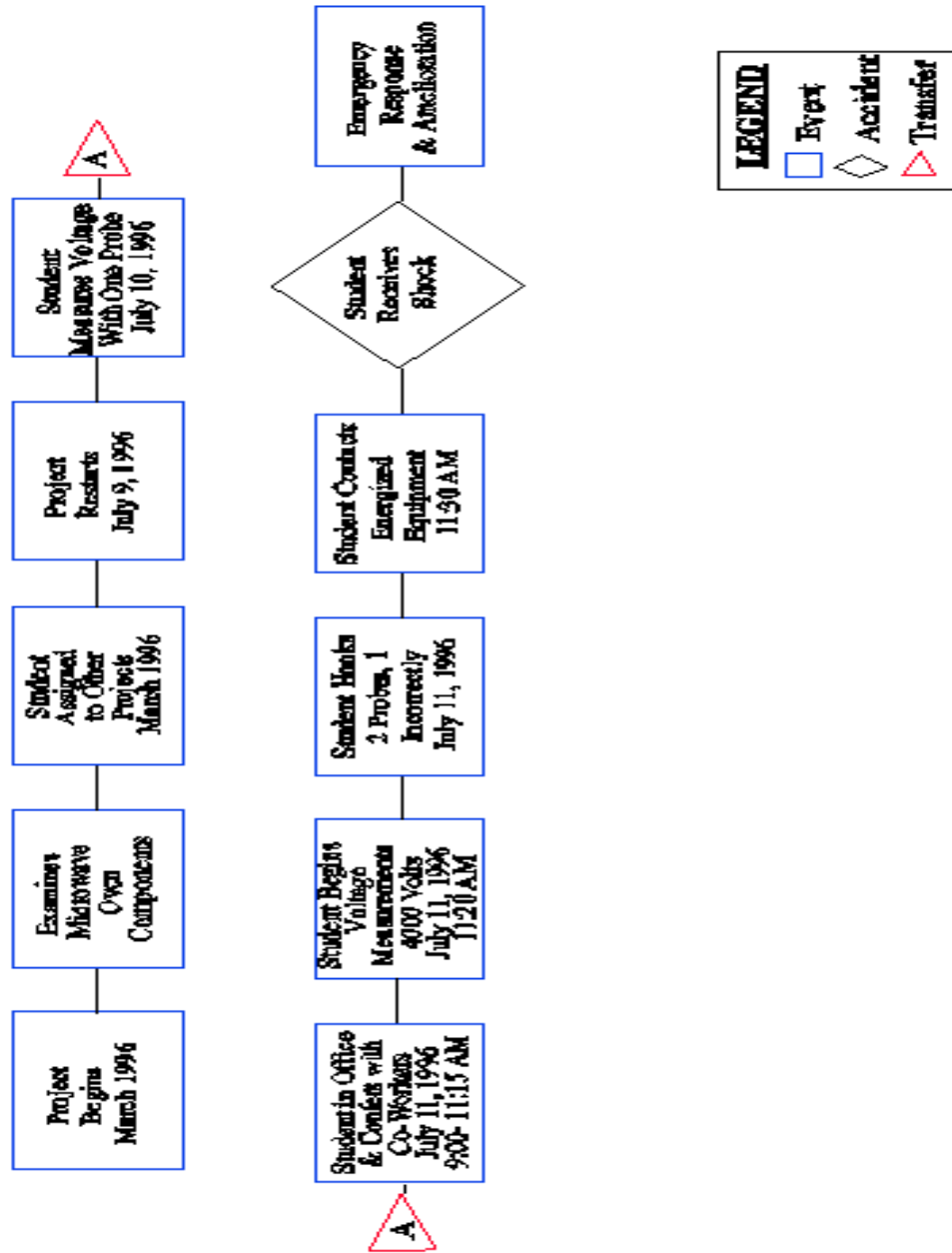


Figure 2-4: Summary Events Chart and Accident Chronology

- Prompt arrangements were made for both still and video photography of the accident scene. Photography was initiated 1 hour and 10 minutes after the accident and completed by 2 hours and 30 minutes after the accident. Follow-up photographic support provided to the team during the investigation was cooperative and professional.
- Prompt clean-up of biohazards resulting from the student employee's injuries was conducted by trained personnel immediately following initial photography of the accident scene and after obtaining permission from LAAO representatives at the scene.
- Accurate logs were kept by the LANL Emergency Operations Center and Incident Commander, and included a list of all notifications, personnel allowed into the area, and times of significant events.
- Written statements of all personnel involved in the immediate response to the accident were completed as soon as practical to minimize the opportunity for witnesses to discuss the accident. A critique was held within three hours of the accident that included all personnel knowledgeable of the circumstances, including the LANL Deputy Director, occurrence investigation personnel, health and safety specialists, and representatives from LAAO.
- An initial briefing, all available photographs, and access to the accident scene were provided to the Board on July 15, 1996. The evidence presented to the Board included the student employee's clothing, photographs, and videotape of the accident scene. Photographs were identified by a unique file number, but did not contain complete identification data as to time, date, and photographer's name.

Additional photographs were taken on several occasions during the investigation at the request of the Board. All personnel contacted by the Board, either as a witness or to provide logistical support, were cooperative and professional, although some medical evidence provided to the Board was neither accurate nor timely.

The Board found the investigative preparedness of both the contractor and LAAO to meet the requirements of DOE 225.1. The minor deficiencies noted above did not affect the outcome of the investigation nor did they reduce the efficiency of the investigation.

2.1.4 Medical Report

The Board interviewed the student employee and obtained a statement from the LANL Medical Director to determine the medical assistance rendered to the student employee. It was reported by those first on the accident scene, that the student employee appeared to have difficulty breathing, and a first-aid-trained co-worker rendered assistance. Upon arrival of the ambulance, the emergency medical technicians placed the student employee on a backboard prior to moving him for transportation to the Los Alamos Medical Center. During this time, the student employee was uncontrollably thrashing and required restraint. After admission to the hospital, he was sedated, and placed on a respirator in intensive care. Approximately seven hours after the accident, he awoke, was mentally intact, and was removed from the respirator. He remained mentally intact and alert during the remainder of his hospitalization.

During interviews with the student employee, the Board observed the injuries sustained by him, including burns to the back and tips of his index and middle fingers on his right hand, burns to the back of his right hand, several small burns on his upper back, small burns on his left hand, and larger burns on his left upper arm. Medical information provided to the Board indicated that he also dislocated both shoulders, the left one requiring surgical repair on July 13, 1996. He was discharged in the late afternoon of July 18, 1996, and will be followed as an outpatient. It was reported to the Board that he is expected to fully recover, but may require physical therapy for his dislocated shoulders. There was no reported medical evidence of internal injuries and there was no indication that substance abuse was a factor in the accident.

The student employee, who had been sedated, awoke approximately seven hours after the accident.

The Board later interviewed the student employee and was able to observe the nature and location of his burns.

2.2 MANAGEMENT SYSTEMS

In the past nineteen months, LANL has experienced four serious accidents, one of which was fatal, and three potentially fatal. In two of the non-fatal accidents, the injured persons are expected to fully recover. In the other case, the employee has been in a coma for seven months.

On December 20, 1994 a fatal shooting accident occurred at the live fire range at LANL during a routine training exercise. A participant in the exercise accidentally carried live ammunition into the exercise. Systems and supervisors that should have detected this error failed to do so. The root causes of the event were determined to be failure to comply with procedures and inadequate management systems. Two additional non-fatal serious accidents occurred on November 22, 1995 and January 17, 1996. In the November accident, a LANL employee who was not qualified to operate a forklift, attempted to do so and caused the machine to tip over. The employee was pinned beneath the machine and received serious injuries. The direct cause of this accident was determined to be the failure of the employee to follow LANL forklift safety policy. The root cause was attributed to a lack of management controls to ensure that only licensed operators are permitted to operate forklifts. In the January accident, a LANL subcontractor employee jackhammered into a 13.2 kV primary power line and received a severe electrical shock. The worker remains in a deep coma. Although many factors contributed to this event, non-compliance with requirements and inadequate management systems were major contributors.

In addition to the Type A accident investigations conducted by the DOE, the University of California sent a fact finding team to LANL to independently investigate the three accidents and to determine corrective actions. This team report also identified non-compliance with requirements and inadequate management systems as major factors in the previous accidents. The University tasked the LANL Director to establish an integrated safety management program, improve safety communication, implement a consequences and reward program and simplify standards across LANL.

LANL has experienced a number of serious accidents recently.

A fatal shooting was caused by failure to comply with procedures and inadequate management systems.

A non-fatal forklift accident was caused by a lack of management control.

Another electrical accident was caused by, among other things, a failure to comply with procedures and inadequate management systems.

A University of California fact finding team emphasized the previously identified safety management weaknesses.

In response to these accidents and other external factors, LANL has been attempting to reform their management systems. The external factors driving management systems improvements include downsizing, contract reform, revisions to traditional oversight programs, Departmental standards programs, rule making, and recommendations related to safety management from the Defense Nuclear Facilities Safety Board.

Shortly after the first accident, LANL's Operations Working Group (OWG), which is composed of senior LANL line and staff managers, began to establish "operational priorities" instituting proven safety management principles on a facility-by-facility basis. These principles were derived from experience gained in earlier efforts directed toward improving safety at the Plutonium Facility, TA-55. The OWG has focused on five operational priorities: standards, authorization bases, facility management, safe work practices and awareness and accountability. The Facility Management Model was created to implement these priorities. These actions were designed to be integrated with the longer term actions to implement an Integrated Safety Management Program. The ongoing OWG-led efforts, along with other measures, were identified to the University of California as corrective actions in response to the University's tasking.

In response to this latest accident, a stop work order was issued on July 12, 1996, for energized electrical work in research and development. Recognizing the importance of individual awareness and commitment to safe work practices the LANL Director ordered the first ever site-wide stand-down of all non-essential work throughout LANL on July 16, 1996. This action included all LANL technical and administrative staff, and contractors. The objective of this stand-down was to have management and workers jointly review their work and determine if they are adequately addressing their specific hazards. A five step process is outlined in an employee safety commitment form, which upon completion of the review is to be signed jointly by all employees and their supervisors. The LANL Director informed the Board on July 15, 1996, that the signing and execution of this safety commitment will become a condition of employment at LANL. On July 17, 1996, LANL's Director held a two-hour session for all LANL

LANL management reform has been affected by a number of external influences.

LANL has established operational priorities emphasizing safety management.

In response to this accident, the LANL Director issued a Laboratory-wide stand-down to allow time for a reevaluation of safety practices and procedures.

management. Resumption of work is dependent upon the specific conditions in individual work places. Many facilities resumed work after a few days and others will take much longer to return to work. Details of the stand-down were communicated to LANL employees through a special edition of the weekly LANL newspaper. The local community was informed via the news media.

2.2.1 Policy and Procedures

Requirements for electrical safety at LANL are contained in LANL Administrative Requirements, Section 7 (AR 7-1). This document specifies the requirements for work on electrical components and circuits that are or have been energized. Several essential elements of this document were not followed at the time of this accident.

According to LANL, AR 7-1 is based upon the requirements set by the Occupational Safety and Health Administration. Efforts are underway to update the electrical safety program at LANL to be consistent with Departmental Guidelines for a Model Electrical Safety Program. Previous appraisals and DOE accident investigations at LANL have identified weaknesses in the site's electrical safety program.

AR 7-1 and its associated referenced Administrative Requirements require the use of Standard Operating Procedures or Special Work Permits for work on systems with the potential for "hazardous voltages and hazardous energized electrical equipment and systems "exceeding 50V nominal (30V root mean square, 48V dc) with potential barriers removed," thereby identifying electrical hazards such as those involved in this accident as requiring mitigation. AR 7-1 also contains more general requirements for Work Place Safety systems, including critical electrical design communication, document control, and employee training, as well as provisions for the use of protective equipment and restrictions on working alone. Responsibility for electrical safety is assigned to line management and there is a clause that allows for a graded approach depending upon the magnitude of the hazard involved.

LANL requirements for electrical safety are contained in AR 7-1.

LANL is updating its electrical safety program.

AR 7-1 requires Special Work Permits, restrictions on working alone, and other mitigation for electrical hazards.

Interviews revealed that the AOT line management and most of the staff recognized AR 7-1 as the applicable standard for electrical work conducted at facilities such as MPF-14. The Board found there were varying degrees of familiarity and differing interpretations of AR 7-1.

Line management and staff agree that AR 7-1 is the applicable standard, but interpretations vary.

2.2.2 Work Planning and Controls

AR 7-1 requires line managers to implement safeguards to ensure that the operations under their control are conducted safely. AOT management stated they expected their staff to use the Two Person Rule, Standard Operating Procedures, and Special Work Permits as principal safeguards for work on high voltage systems. Review of this accident revealed that none of these work planning and control mechanisms were employed to prevent this accident.

None of the required work planning and control mechanisms were employed to prevent this accident.

The student employee was not following the Two Person Rule at the time of the accident; however, it was in use the day before the accident. There was no control in place to enforce and/or monitor the use of the Two Person Rule.

The Two Person Rule was not followed.

Interviews with LANL personnel revealed that the intent of the LANL Two Person Rule was not clearly understood. Senior management interpreted this Rule to mean that the second person should check the work of the first person. Less experienced staff and student employees interpreted the role of the second person to be accident response and to call for assistance. These two interpretations require distinctly different levels of knowledge and vigilance by the second person.

There was also no Standard Operating Procedure or Special Work Permit for the testing being performed on the microwave oven. All MPF-14 personnel interviewed stated that a Special Work Permit was required for this work and the student employee also recognized, after the accident, that there should have been a Special Work Permit. Again, there is no evidence for a monitoring and enforcement system for this requirement.

There was no approved Special Work Permit for the testing being performed.

2.2.3 Supervision, Management and Oversight

This accident occurred during research and development work, which is the core activity at LANL. The work involved was conceived, staffed and executed by the staff and line management within the AOT Division, specifically the AOT-9 Group. LANL documents reviewed in connection with this accident clearly and repeatedly state that line management is responsible for assuring the safety of their staff.

Operations conducted by the AOT Division are overseen by a number of organizations. These include the LANL Facility Management Group and Audits and Assessments Group. DOE oversight includes observation of daily activities by LAAO Facility Representatives and surveillance by DOE Headquarters (HQ) Environment, Safety, and Health Site Residents. Under the Department's Pilot Oversight Program, oversight by AL has been modified, on-site oversight by HQ line management offices has been significantly reduced, and greater reliance is being placed on contractor self-assessment. In addition, the HQ Office of Oversight will be conducting its first safety management evaluation at LANL during August-September 1996.

The AOT Division includes eight technical program groups and a Facility Management Group. Group Leaders and the Facility Manager report to the Division Director. There is a Deputy Division Director and in some groups, including AOT-9, there are Deputy Group Leaders. Within Groups, there may be additional responsibilities assigned, such as team or project leaders. In this case, a technical staff member was assigned the responsibility of mentoring the student employee.

The Group Leader develops proposals, secures funding, and prepares reports to preserve research activities at AOT-9. He stated he is responsible for diverse activities in several areas within TA-53 and elsewhere at LANL. While the Group Leader has little day-to-day involvement in the activities of individual staff members and does not have detailed knowledge of worker training status in his group, he does accept ultimate responsibility for the safety of his staff.

Responsibility of line management for assuring staff safety is well documented.

A number of LANL and DOE organizations oversee activities in the LANL AOT Division.

In addition to line management supervision, the student employee was assigned a technical mentor.

The Deputy Group Leader for AOT-9 has technical and administrative duties, including acting for the Group Leader in his absence. He oversees two student employee-led projects and could not define the mentor's role, but acknowledged the mentor had some supervisory responsibility. The Deputy Group Leader acknowledges that he and the Group Leader have responsibility for the technical supervision of the staff in AOT-9.

The Deputy Group Leader oversees two student employee-led projects, but was somewhat unclear on the role of technical mentor.

A lack of clarity existed between the technical mentor and Deputy Group Leader involved as to the level of supervisory responsibility each had over the student employee involved in this accident. The mentor, a technical staff member, had worked with the student employee for approximately one year and considered himself a mentor and supervisor to the student employee, but not in an official capacity. The student employee would receive suggestions and direction from either the mentor or Deputy Group Leader when they met together or separately. In this case, roles and responsibilities for supervision of the student employee were not clear and the specific level of line management responsible for implementing policies and standards was not clear.

There was a lack of clarity in the relative supervisory roles of the Deputy Group Leader and the technical mentor.

Further, senior management within AOT does not do safety reviews or walkthroughs of AOT-9 on a routine basis, and management information systems within AOT do not provide sufficient information to the Division Director. Specifically, the system does not provide management-level reports directly to the Division Office concerning the training status of AOT staff or safety-related audit findings by the Facility Management Group.

Senior AOT managers are not provided sufficient information to effectively exercise their responsibility for staff safety.

2.2.4 Training and Qualification

AR 7-1 requires line managers to assess the hazards in the workplace and, if electrical hazards are found, assure that workers receive the appropriate electrical safety training. OJT and classroom training are allowed, but all training must be documented and should be based on identified workplace hazards. In addition to AR 7-1, AOT has a documented training program described in the TA-53 *Training Program Manual*, 53FMM-113-01.01, dated February 1, 1995. This is a detailed program designed to meet the training and qualification requirements of DOE

Line management responsibilities for safety training are not sufficiently specified.

5480.25, Safety of Accelerator Facilities, but it is applicable to all operations at TA-53. The manual establishes that it is line management's responsibility to develop individual training plans tailored to the individual worker's needs, however it does not specify which member of line management is responsible.

The electrical safety training program at AOT-9 consists of classroom training and on-the-job training (OJT). The classroom portion is well documented, but comprises a relatively small portion of the necessary training. OJT represents the majority of the needed training and is informal and undocumented. OJT is not integrated into an overall training plan nor is completed OJT documented in the employee training record. New employees are normally shown the facility by a senior staff person and hazards and warning devices are discussed. The workers are then teamed with a technical mentor who continues the OJT. At some undefined point in time, the mentor, line manager, project leader and senior staff informally agree, based upon their observation and perception of the individual, that he or she is qualified to do certain tasks. At that point, the new person is allowed to perform work without supervision. Consultation and interactions with senior people continues throughout the individual's assignment to AOT-9.

The majority of the staff in AOT-9 have advanced degrees and some practical experience in high voltage electrical systems. The only formal electrical safety course offered to satisfy the requirements of AR 7-1 by LANL is Electrical Safety Awareness Training. Interviews revealed that this training is universally considered by the AOT-9 staff to be inadequate for their knowledge level and work assignments.

Each staff member and student employee in AOT-9 has a formal training plan and a record of institutionally-required classroom training in electrical safety and other required site training. Records are centrally maintained on the Employee Development System. However, the training records of the AOT-9 staff show many incomplete or expired training certifications. For example, the student employee's electrical safety refresher training was overdue at the time of the accident.

AOT-9 electrical safety training is largely informal and is poorly documented.

AOT-9 staff consider the formal training they receive to be inadequate.

AOT-9 training records are incomplete and indicate many expired training certifications.

The Facility Manager has formally been assigned responsibility for maintaining AOT training records, but stated that staff training is the responsibility of the other group leaders. The Facility Manager provides notification that training updates are required to the individual and to his or her supervisor. The Board determined by record review that the only training kept up-to-date by AOT-9 is that required by external groups such as security and radiation protection, and CPR training that the staff generally thinks is important in the performance of their duties. Many members of the staff, particularly student employees, state that electrical safety training for a research and development environment would be beneficial and well received.

Deficiencies cited in AOT-9 are not found in all groups within the AOT Division. Records for AOT-2, 5, 6 and 7 were reviewed by the Board. These were found to be current and to comply with LANL requirements.

2.3 ACCIDENT ANALYSIS

At the time of the accident, the student employee was conducting tests to characterize the power requirements of a commercial microwave oven magnetron. The tests had commenced one or two days prior to the date of the accident, and were being conducted with different high voltage probe configurations. The accident occurred when the student employee contacted an electrical component, energized due to an improper grounding connection, resulting in a shock from the 4000 volt power supply of the microwave oven.

On the day of the accident, the student employee was attempting to obtain a differential voltage measurement across the filament of the magnetron, using two high voltage probes connected to the filament of the magnetron and one of the two available oscilloscopes. Each high voltage probe consists of a probe body containing a voltage divider circuit with a coaxial cable connected to a compensator box, and a grounding wire. The compensator box contains low voltage circuitry to tune the waveform and provides the connection to the oscilloscope through a BNC connector. Normally the tip of the probe is connected to the voltage source to be measured and the grounding wire is clipped to a suitable chassis ground. The compensator box

The Facility Manager maintains AOT training records, but does not have responsibility for assuring that staff training needs are identified or met.

Other groups in AOT have more complete training records.

The student employee was injured while conducting tests to characterize the power requirements of a microwave oven.

On the day of the accident, two high voltage probes were being used to obtain a differential voltage measurement across the filament of the microwave oven magnetron.

is then connected to an oscilloscope. Voltage measurements are obtained by calibrating the oscilloscope to a known value for volts/division on the display and measuring the height of the waveform.

The two probes differ in the color of the insulator knobs on their BNC connectors - one is black and one is gray. For the remainder of this section, the probes and compensator boxes will be referred to by the color of these insulators, for example, the gray compensator box is connected to the gray probe.

Extensive equipment testing was performed by the Board, with the assistance of LANL staff, to determine the operability of all equipment involved in the accident. All equipment, including the microwave oven, the high voltage probes, and the oscilloscopes were found to be fully operable. Calibrated test equipment was used for all ground path and high voltage measurements.

Examination of the accident scene revealed that the gray high voltage probe was incorrectly connected to the microwave. The probe tip was connected to one side of the magnetron filament and the grounding wire was clipped to the other side of the filament. A statement from the student employee indicated that he might have been distracted due to being emotionally upset from a personal situation the day before. This distraction may have caused the student employee to improperly connect the gray high voltage probe on the day of the accident. The improper connection resulted in the grounding wire, the compensator box case, and the BNC connector shell and center pin being at approximately 4000 volts. The black probe tip was connected to the gray probe tip and the black grounding wire was properly connected to a microwave oven ground. Figure 2-2 shows a simplified representation of the test configuration at the time of the accident. Figure 2-3 is a photograph of the high voltage probe connections to the microwave oven.

Fifteen burn marks were present on the outer case of the black compensator box, including the front face. (See Figure 2-5) Five small burn or scratch marks were present near one corner of the gray compensator box. (See Figure 2-6) Three small burn marks can be seen on the right side

Testing conducted by the Board after the accident confirmed that all equipment was fully operable.

Examination of the accident scene revealed an improper grounding connection.

Burn marks were found on the oscilloscope face and on the compensator boxes.

Figure 2-5

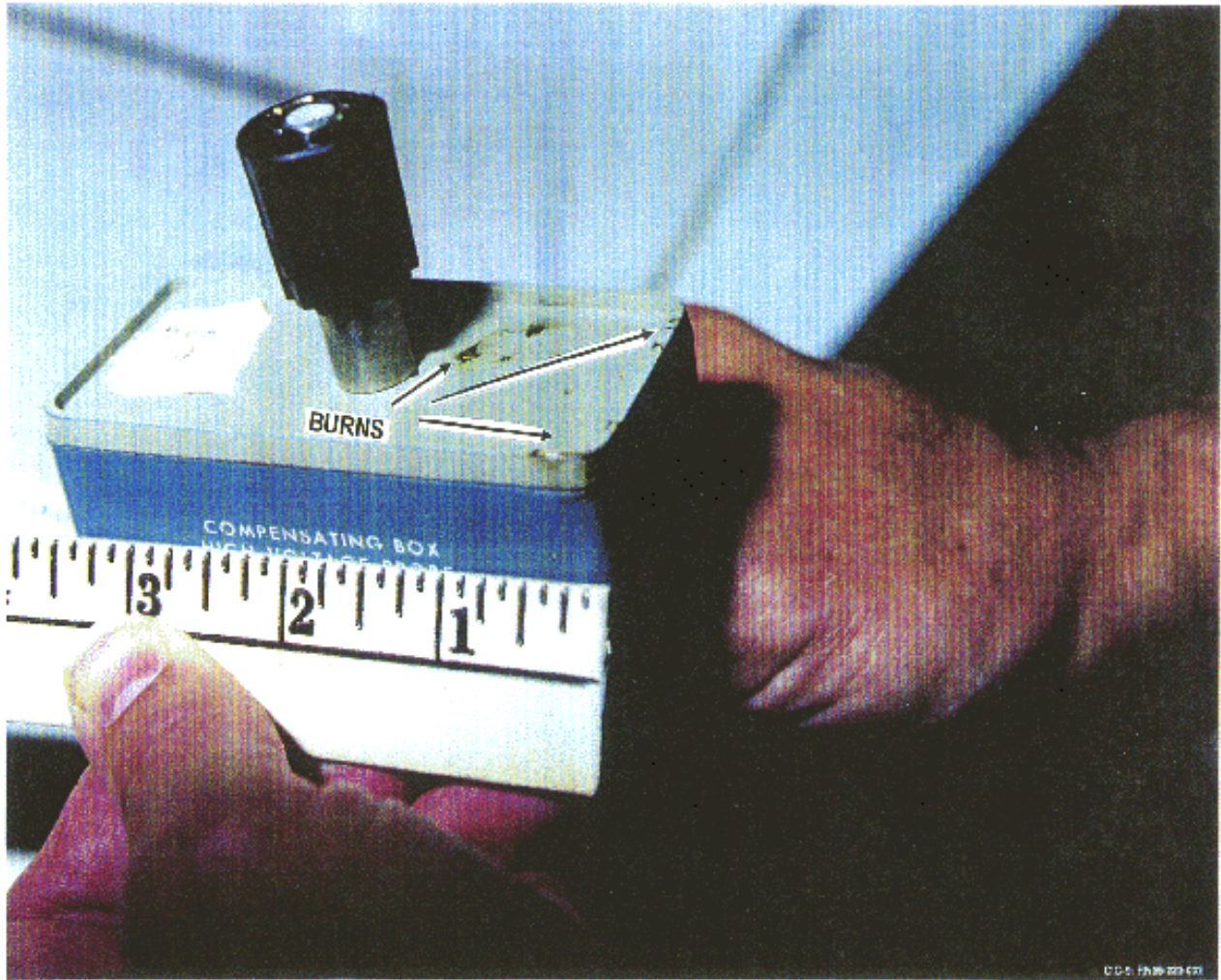


Figure 2-5: Black Compensator Box Showing Burn Marks

Figure 2-6

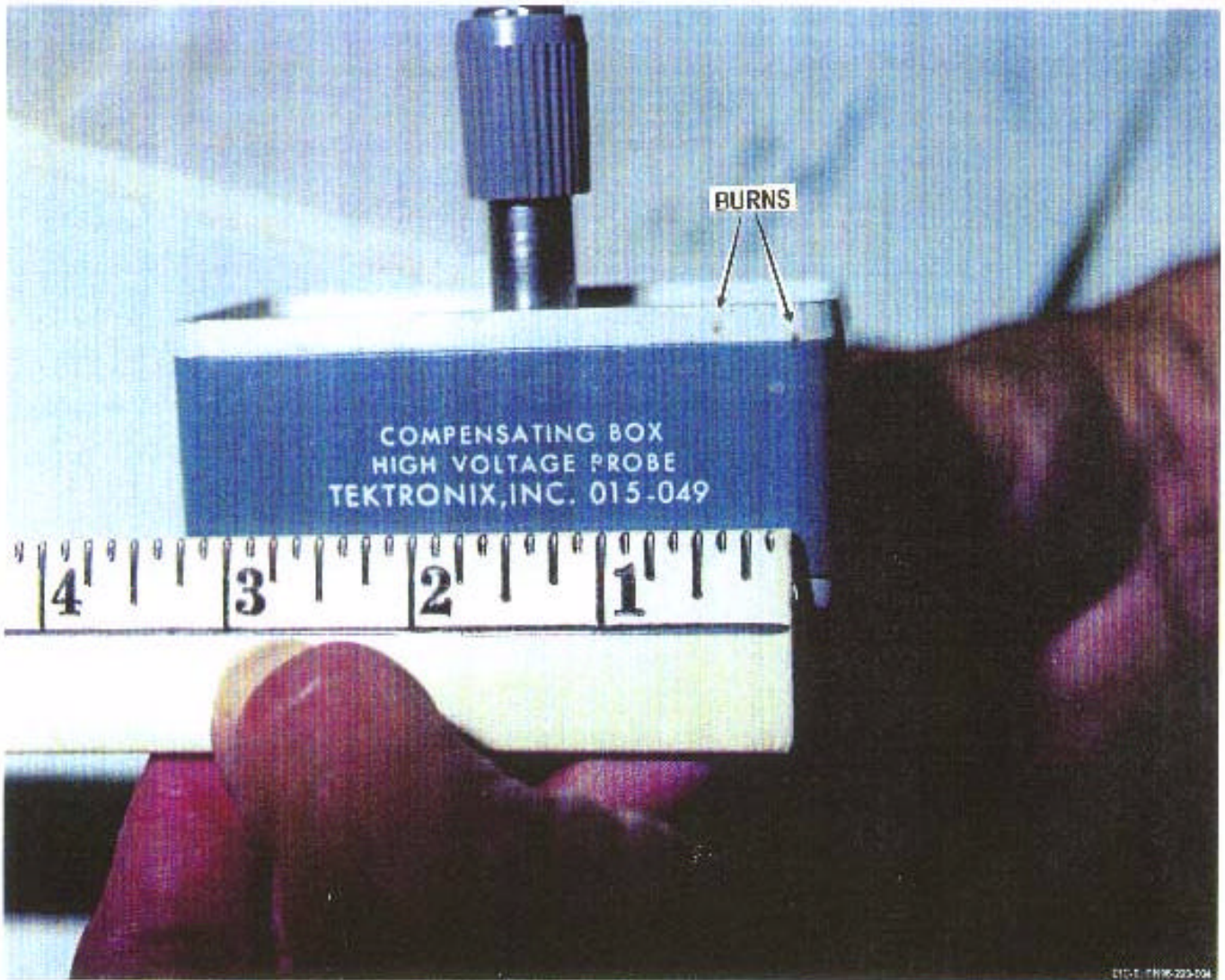


Figure 2-6: Gray Compensator Box Showing Burn Marks

of the screen bezel of the Hewlett Packard 54111D oscilloscope and one small burn mark may be seen near the “Clear Display” button. (See Figure 2-7)

No direct account of the accident is available, since there were no eye witnesses to the accident. The Board has reconstructed the most probable sequence of events, based on the measurement being conducted, the physical evidence, and on statements from the student employee and his coworkers. In the scenario constructed, the high voltage probes and their respective compensator boxes are key components.

The accident scenario considered most likely by the Board can be summarized by the six steps below.

- The gray high voltage probe was connected improperly to the magnetron of the microwave oven.
- Both compensator boxes were attached to the inputs of the Hewlett Packard 54111D Oscilloscope.
- The student employee energized the microwave oven and noted an improper waveform on the oscilloscope.
- The student employee attempted to correct the waveform by disconnecting and reconnecting the compensator boxes.
- He grasped the gray compensator box in his left hand and disconnected it from the oscilloscope.
- He then grasped the black compensator box and the shock occurred.

The discussion below presents the evidential and logical path followed to develop the most probable scenario.

Based on the equipment configuration observed at the scene of the accident, the status of the compensator box to oscilloscope connection is the key element in the scenario. The possible connections are presented in Table 2-1 and the potential for the student employee receiving an electrical shock is presented for each of the two possible grounding

The Board has reconstructed the most probable sequence of events, since no direct account of the accident is available.

The most likely scenario involves the student employee contacting an unexpectedly energized component while checking oscilloscope conditions.

Figure 2-7



Figure 2-7: Hewlett Packard 54111D Oscilloscope Showing Burn Marks

conditions. The four possibilities in the right column are eliminated if there was a continuous path to ground. During equipment testing, the quality of the grounding connections was checked at all plugs and BNC connectors, including the connection between the compensator boxes and the oscilloscope inputs. Both compensator boxes were checked with all oscilloscope inputs. No evidence of an intermittent or high resistance grounding path was found at any point. The maximum grounding path resistance between any two points measured was 1.3 ohms. This, then, eliminates all possibilities in the right column of Table 2-1.

TABLE 2-1: Conditions Presenting the Possibility of Electrical Shocks

Compensator Box Connection to Oscilloscope	Possibility of Electrical Shock	
	Grounding Path Good	Grounding Path Bad
Black Box On Gray Box On	Not Possible	Possible
Black Box Off Gray Box On	Not Possible	Possible
Black Box On Gray Box Off	Possible	Possible
Black Box Off Gray Box Off	Possible	Possible

The shock probably occurred when the student removed the gray compensator box from the oscilloscope and then touched a grounded object.

Next, consider the situation if the gray compensator box is attached to the oscilloscope and a continuous path to ground is present. If a continuous path to ground existed and the gray compensator box was connected to the oscilloscope, then the 4000 volts would be grounded through the oscilloscope chassis ground. Discussions with a Hewlett Packard Accident Investigator indicated the oscilloscopes in use at the time of the accident were designed and factory-tested to tolerate a 30 ampere current through the chassis ground for a minimum of two minutes. The design philosophy is that a fault current of this magnitude should trip the supply breaker before a failure of the grounding path occurs. This design protects the user if high voltage is applied to the ground of the oscilloscope input. Testing of the equipment, including the microwave,

oscilloscopes, and probes, and the building wiring demonstrated that a continuous, high-quality grounding path did, in fact, exist at the time of the accident. The existence of a grounding path indicates that the gray compensator box was either not connected to the oscilloscope when the oven was energized or was disconnected by the student employee, thereby initiating the accident.

Therefore, the two conditions that are most consistent with the known facts are those highlighted in the lower left of the table. Given the grounding conditions that prevailed at the time of the accident, the position of the black compensator box is immaterial, but the gray compensator box must have been disconnected. It is important to note that Table 2-1 reflects the status of the oscilloscope connection **at the time the electrical shock was received** and may not reflect the condition which immediately preceded the accident.

The student employee stated that it was his normal practice to make all connections involved in a test prior to energizing the microwave. This is consistent with statements made by a coworker who had assisted with the testing the day before the accident. The student employee also stated that it was not uncommon to either wiggle the compensator box or disconnect and reconnect it if the displayed waveform did not appear to be correct.

Since the gray probe was incorrectly connected, the oscilloscope would not have displayed the correct waveform. This would probably have caused the student employee to either wiggle or remove the gray compensator box, disconnecting it from the oscilloscope and initiating the electrical shock.

The small burns on the gray compensator box are consistent with the rectangular pattern of the small burns on the student employee's left hand, indicating that the student employee disconnected the gray compensator box with his left hand. No shock would occur at this time unless he were grounded at some other point. If he had been grounded at the time he removed the gray compensator box, an arc would be expected between the compensator box and oscilloscope BNC connectors, resulting in burn marks on the connectors. No such marks were observed on any of

The burned marks on the test equipment and the burns on the student employee are consistent with the scenario.

the BNC connectors. At this point, it is believed that the student employee attempted to remove the black compensator box with his right hand. From the position of the burn marks on the front face of the black compensator box, it appears that he may have inserted the first two fingers of his right hand between the box and the oscilloscope face to pull the box off. The burn marks on the black compensator box are consistent with the burns to his right hand that would probably have been inflicted if he performed this action.

Since the case of the black compensator box was grounded through the oscilloscope, this action would have completed an electrical path from the gray compensator box, up his left arm, across his upper body, and down his right arm. This current path would typically cause contraction of the muscles in the arms, back and chest, possibly dislocating both shoulders. This is consistent with the information provided by the LANL Medical Director. It is speculated that the burn marks on the face of the oscilloscope may have been caused by contact with either the student employee or one of the compensator boxes prior to him falling to the floor. The student employee fell to the floor, possibly landing on his left side, creating additional damage to the left shoulder. This would account for the fact that the left shoulder dislocation required surgical reduction while the right shoulder dislocation was manually reduced. The burn marks on his back and left arm may have occurred after he fell to the floor, since the electrical shock would not have terminated until the timer automatically shut off the microwave oven.

An alternate scenario, also consistent with the physical evidence, is that both compensator boxes were lying on the workbench prior to the accident. The student employee may have energized the microwave oven, walked around to the front of the oscilloscope cart, noted the compensator boxes were not connected, and then picked them up in a manner similar to that described above. From the point that he picks up both compensator boxes, the scenario continues as described above. This scenario accounts for the student employee's injuries and the compensator box damage, but does not explain the burn marks on the oscilloscope as well as the above scenario. It is also not as consistent with the normal sequence of events as described by the student

The medical evidence is consistent with the Board's reconstruction.

An alternate scenario assumes that the compensator boxes were both disconnected initially, and the student employee picked them up.

employee and the coworker who had assisted in the testing on the day before the accident.

2.4 BARRIER ANALYSIS

The safety barriers between the accident victim and the high voltage hazard of the microwave oven included physical barriers, management barriers, and administrative barriers. The barriers are presented in summary form in Figure 2-8 and are discussed in more detail below.

2.4.1 Physical Barriers

The only physical barrier between the user and the energy source in normal operation is the microwave cover. This barrier was removed intentionally in order to perform the test being conducted at the time of this accident. Removal of the cover allowed the student employee and anyone else in the immediate area direct access to high voltage when the microwave oven was operating. The oven timer continued to control power to the system and limited high voltage exposure at the readily accessible circuitry to the duration of test runs. Although not a barrier, the timer played an important role by limiting the duration of the shock to the student employee. **It is the finding of the Board that the removal of the microwave cover did not directly contribute to this accident because it had been intentionally removed in order to perform tests on the system.**

No physical barriers were in use.

2.4.2 Management Barriers

Direct Supervision

Close supervision of the activities of the injured student employee could have prevented this accident. Supervision is an important factor in this accident because the person doing the test was a student employee with limited experience in working on high voltage systems. Supervisory controls were shared between the project leader and a mentor, without a clear understanding of who was responsible for observing the work of the student employee. A very informal reporting relationship existed between the student employee and his two potential supervisors. It is the finding of the Board that the AOT-9 Group Leader failed to clearly define who was responsible

The Group Leader failed to clearly define responsibility for supervision of the student employee.

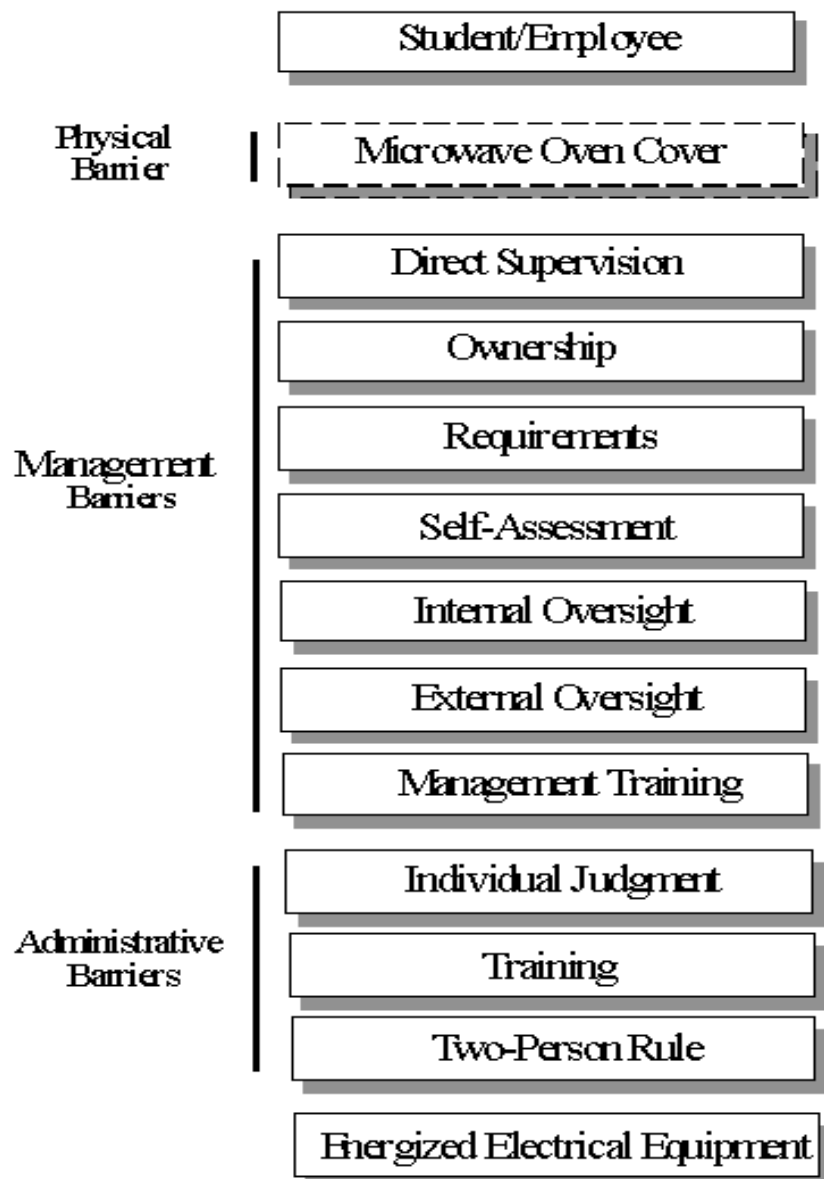


Figure 2-8 Barrier Analysis Summary

for the supervision of the student employee and that this contributed to the accident.

Ownership

At each appropriate level within every organizational unit, line management must assume ownership and clearly communicate responsibility for the protection of workers, the public, and the environment. LANL has consistently stated this in their policy and procedures.

The TA-53 Facility Management Manual differentiates facility management responsibilities from line management. In areas related to Accelerator Safety, clear assignments of responsibility for individual positions in line management are made, however roles are not well defined and communicated for the type of work involved in this accident. The TA-53 Training Program Manual is also deficient. It assigns responsibility for training plans, qualifications, course development to “TA-53 group leaders and other line managers,” but within the AOT-9 group there are at least three people who would fit this description and none had executed the requirements of the TA-53 Training Program Manual. **It is the finding of the Board that the AOT Division has not sufficiently defined line management safety responsibilities for the type of work being conducted in AOT-9.**

Requirements

Organizations create safety requirements to ensure adequate and consistent implementation of safety policies. Line management must reliably implement these requirements in order to protect workers. Administrative Requirement 7-1 is the LANL electrical safety standard. There was much discussion with AOT and ESH staff relative to the adequacy of this standard. However, it is the finding of the Board that, if implemented, AR 7-1 is adequate to provide an acceptable level of protection to workers. Specifically, AR 7-1 requires an assessment of hazards, hazards mitigation, formal training, and the use of the Two Person Rule. It also references other standards and technical bulletins that provide substantial information on electrical safety. All members of AOT-9 have been trained on the applicability and content of AR 7-1 through Electrical Safety Awareness

AOT Division has not sufficiently defined line management safety responsibilities.

Failure of AOT-9 management to implement AR 7-1 contributed significantly to this accident.

training (required by LANL for all personnel who work on electrical components or circuits). **It is the finding of the Board that the failure of AOT-9 management to implement the LANL Electrical Safety standard AR 7-1 contributed significantly to the occurrence of this accident.**

Self Assessment

All members of line management share some degree of responsibility for assuring that individuals within their purview are adequately protected from hazards in the workplace. Within AOT Division, there was no information management system in place to allow senior management to monitor operations within AOT-9. There is no program for managers to walk through facilities to observe the safety of operations and there are no management reports summarizing such key information as the status of worker safety training or the use of required work procedures. The Facility Management Group within AOT performs safety walkthroughs of facilities for the Division Director, but the Division Director does not receive a copy of these reports for AOT-9 and there is no system to track deficiencies. **It is the finding of the Board that senior AOT management s failure to monitor safety aspects of operations within AOT-9 contributed to this accident.**

Internal Oversight

The LANL Office of Audits and Assessments monitors safety performance for the Laboratory Director. The size and complexity of LANL prohibits direct observation by the Office of the activities of all individuals within LANL. This Office should monitor programs within the 27 Divisions at LANL and provide the Laboratory Director summary data on performance in each Division. Since the deficiencies in training and implementation of procedures are well documented in previous accident investigations and persist in the AOT Division, the effectiveness of the Office of Audits and Assessments (AA) is questionable. Additional review of the activities of the Office of Audits and Assessments is warranted to assure they are assessing interpretation of LANL policies and implementation of standards within the Divisions.

Senior AOT management s failure to monitor safety contributed to this accident.

The effectiveness of the LANL internal safety audit process is questionable.

External Oversight

Independent external oversight of policies, programs, and procedures can be effective in assisting line management in protecting workers from hazards in the workplace. Oversight alone, however, cannot effectively protect workers. There are several levels of DOE oversight at LANL. These groups have previously identified systemic deficiencies in the electrical safety program, procedural compliance, and training at LANL. These persistent deficiencies contributed to the occurrence of this accident. There have also been several recent Type A Accident Investigation Board reports and a review by the University of California that drew similar conclusions. Oversight cannot correct deficiencies - it can only identify them and attempt to indicate how they might be addressed. The ultimate responsibility remains with line management. It is, therefore, the finding of the Board that DOE and University of California oversight has adequately identified the systemic deficiencies that contributed to this accident. **It is the finding of the Board that LANL management needs to effectively review the programs of individual Divisions against these findings and to require and verify corrective actions derived from the occurrence of this accident and three previous serious accidents with similar causal factors.**

Management Training

The ability of management to define work, assess and mitigate hazards and determine the skills, knowledge and abilities of workers is an essential barrier to the performance of unsafe acts. Specifically, there is a weak understanding of the LANL Electrical Safety Program requirement for the development of training plans and the documentation of OJT. The Board found no evidence of any “Fitness for Duty” training in the AOT-9 training records. It is evident from testimony that the student employee injured in this accident was emotionally upset the day before and the morning of this accident. It is also clear that his immediate supervisor was aware of his condition and allowed him to work on high voltage tests without additional controls or supervision. **It is the finding of the Board that AOT-9 management has received inadequate training to fulfill the**

External oversight had identified safety issues, but LANL has not effectively implemented corrective actions.

AOT-9 management has not received adequate supervisory electrical safety training or fitness-for-duty training.

broad spectrum of responsibilities inherent to the supervision of work in their group.

2.4.3 Administrative Barriers

Individual Judgment

Individuals are responsible for their own safety and the safety of others resulting from their actions. The student employee injured in this accident was trained to know that an SWP was required for this work and that the Two Person Rule should have been in place the morning of the accident. Furthermore, even though the student was aware of his inability to concentrate, he continued to work on a hazardous system. **It is the finding of the Board that the student employee did not perform his duties in accordance with his training and that he used poor judgment in doing hazardous work in light of his own assessment of his fitness for duty.**

The student employee did not take effective individual action to protect himself.

Training

Training of workers to identify and protect themselves and others from hazards in the workplace is an effective safety barrier. Electrical safety training in AOT-9 is primarily OJT. It is informal and not documented. There is no way to objectively determine what training has actually been received or the qualification of workers to do specific tasks or use specific equipment. Workers in AOT-9 received Electrical Safety Awareness training that introduced them to the LANL Electrical Safety standard, AR 7-1. This training is required every three years. Nevertheless, the general knowledge of the requirements for electrical work was not consistent and, in fact, some obvious difference in interpretations of the requirements existed. **It is the finding of the Board that the LANL electrical safety training program is inadequate, in that it is essential to worker safety and yet is only required every three years. In addition, it is found that the informality of the OJT in AOT-9 is inconsistent with LANL requirements.**

Informality of OJT in AOT-9 is inconsistent with LANL requirements.

Two Person Rule

In doing work that requires specialized knowledge, skills and ability, and hazardous systems, the use of a two-person rule can afford additional protection to a worker. The Two Person Rule is derived from LANL requirements for working alone. As applied to the electrical work involved in this test, the rule would require the second person to be a consulting observer who is clear of the hazard and be certified in CPR. It was found that there are varying interpretations of what is meant by “consulting observer.” More senior LANL employees stated that the consulting observer should be a person knowledgeable in the work being performed. This knowledgeable person would be a second set of eyes to assure that particularly hazardous work was being done correctly. Less experienced staff viewed the second person as someone who called for help and administered first aid. It is the finding of the Board, that the intent of the Two Person Rule was not adequately communicated within the AOT-9. **In addition, it is the finding of the Board that the Two Person Rule, even as understood by the student employee, was not implemented during the activity leading to the accident.**

The Two Person Rule was not implemented at the time of the accident and the misunderstanding that prevailed concerning its requirements might have rendered it ineffective in any case.

2.5 CHANGE ANALYSIS

A change analysis was conducted to determine changes or differences that may have had an effect on the accident. Based on these differences, an analysis was made to determine if the change may have been a cause of the accident. The results of this analysis are in Table 2-2.

TABLE 2-2: Change Analysis

Change or Difference		Analysis	
Planned/Normal	Present	Difference	Analysis
Microwave oven cover is in place.	Microwave oven cover is removed.	Energized electrical parts are exposed.	Testing energized parts requires Special Work Permit and Two Person Rule implementation.
Special Work Permit was required.	Special Work Permit not issued.	Special Work Permit assists in identifying potential hazards of work.	Proper controls of the hazard would have been in place.

Change or Difference		Analysis	
Planned/Normal	Present	Difference	Analysis
Emotional condition of the student was stable.	Student employee under emotional duress.	Student employee's attention to conduct task diminished.	Student employee's potential for work errors increased.
One probe used day before accident.	Two probes used day of accident.	Testing arrangement more complex when using two probes.	More complex arrangement creates greater chance of incorrect electrical connections, especially when student employee under emotional duress.
Two Person Rule was in effect.	Two Person Rule was not implemented.	Student employee works alone.	No second person present to correct work errors or summon assistance.
Group generally works with projects in megavolt range.	Projects associated with voltages in kilovolt range.	Higher voltage work requires detailed, formal plans and procedures.	Safety controls should be consistent for all hazardous voltage.
Majority of AOT projects are core funded.	AOT-9 funding involved "work for others."	Emphasis is placed on obtaining funding for projects.	AOT-9 Group Leader focuses on generating business and staff employment.

Some of the changes identified in the analysis of Table 2-2 were also identified in the barrier analysis as barriers which failed or were not present. These included the failure to request a SWP, work alone and training barriers. Other changes noted in the analysis concern the types and funding of the projects. Senior management and oversight attention is directed at the main accelerator facility and little attention is given to AOT-9 operations. The hazards to workers within AOT-9 are more serious than in the main accelerator facilities because many of the employees are students and the experiments and tests have no formal standard operating procedures. There are also budget considerations within AOT-9 that has directed the attention of the Group Leader away from safety.

2.6 CAUSAL FACTORS

The **direct cause** of the accident was the student employee contacting electrically energized parts. However, there were also contributing causes (causes that, would not, by themselves, have prevented the accident but are important enough to be recognized as needing corrective action) and root causes (the fundamental causes that, if corrected, would prevent recurrence of this and similar accidents). An Events and Causal Factors Chart used to analyze the causal factors is presented as Figure 2-9. A tabular summary of the analysis is in Table 2-3.

Root causes of the accident were:

- Management did not exercise responsibility.
- Electrical safety requirements were not implemented.
- Individual responsibility was not exercised.

Contributing causes of the accident were:

- The training was inadequate.
- Procedures were not followed.
- Supervision was inadequate.
- The Two Person Rule was not used.
- The Two Person Rule was not understood.

TABLE 2-3: Causal Factors Analysis

Root Causes	Discussion
Management did not exercise responsibility.	Management failed to adequately manage all projects, regardless of size, to ensure that the workers are properly qualified, trained and able to perform the tasks. Management also failed to ensure that appropriate roles and responsibilities for safety were established and communicated.
Electrical safety requirements were not implemented.	Management failed to implement the requirements of LANL's electrical safety uniformly throughout the division. As a result, worker's were exposed to energized electrical circuits without adequately conducting a hazard evaluation. With an hazard evaluation of the project, barriers could have been establish to prevent the accident.
Individual responsibility was not exercised.	Although other root causes were identified by the Board, it is the worker's responsibility to work in a safe manner to protect himself and the safety of his fellow worker.
Contributing Causes	Discussion
Training was inadequate.	The only documented training taken by the student employee was the Electrical Safety Awareness Training provided in 5/93. This training was required on a three-year frequency. Training was not provided to all employees or supervisors concerning Fitness for Duty.
Procedures were not followed.	At the time of the accident, the requirements established by AR 7-1, <i>Electrical Safety</i> (issuance of a SWP, documentation of OJT Training, use of a second person) were not followed.
Supervision was inadequate.	There is confusion as to the who was the direct supervisor of the student employee, the Deputy Group Leader who was also the Project Leader or the technical mentor. Although supervision was aware of the student employee's emotional state, no effort was taken to remove him from potentially hazardous tasks.
Two Person Rule was not used.	Student employee failed to implement the Two Person Rule on the day of the accident.
Two Person Rule was not understood.	The workers believed that the Two Person Rule only required an additional worker to be with in shouting distance of the work and be able to summon help. Line managers believed that the second person acts as a consulting observer.

3.0 CONCLUSIONS AND JUDGMENTS OF NEED

This section of the report identifies the conclusions and judgments of need determined by the Board as a result of using the accident analysis methods of Section 2.0. Conclusions of the Board are those considered significant and are based upon facts and pertinent analytical results. Judgments of need are managerial controls and safety measures believed by the Board to be necessary to prevent or mitigate the probability or severity of a recurrence of this type of accident. They flow from the conclusions and causal factors and are directed at guiding managers in developing follow-up actions. Table 3-1 lists the conclusions and the corresponding judgments of need identified by the Board.

TABLE 3-1: Conclusions and Judgments of Need

Conclusions	Judgments of Need
Circumstances surrounding the accident indicate that LANL managers are not held accountable for safety.	LANL needs to assure that strong and publicized consequences for poor safety performance are applied to all managers and workers.
Application of lessons learned from previous Type A accidents related to this accident is not evident at LANL.	<p>LANL needs to promptly implement corrective actions to address the lessons learned from this and other accidents.</p> <p>LANL needs to assure that lessons learned are applied across all elements of the Laboratory.</p>
LANL oversight of the AOT Division was inadequate to identify programmatic issues identified in this accident.	Consistent with the conditions of the Pilot Oversight Program, AL and LANL need to conduct a for-cause review of electrical safety programs at LANL.
LANL does not have a comprehensive program in place to identify fitness for duty issues identified in this accident.	LANL needs to develop and implement a comprehensive fitness for duty program for personnel involved in hazardous operations and their supervisors.
AOT management failed to ensure that electrical safety and training programs were implemented in compliance with defined LANL requirements.	AOT management needs to develop a system to routinely monitor the implementation of safety and other programs in accordance with LANL requirements.

Conclusions	Judgments of Need
A clear division of safety responsibilities within the AOT Division has not been established and communicated.	The AOT Division needs to establish, communicate, and implement safety roles and responsibilities.
AOT-9 electrical safety training was inadequate and inconsistent with LANL requirements.	The AOT Division needs to correct deficiencies in the AOT-9 group electrical safety training program and needs to review the status of training in other groups within the Division.
An AOT-9 student employee did not assume individual responsibility for safety. Specifically, he did not use the Two Person Rule or prepare a Special Work Permit.	AOT-9 needs to determine why procedures were not followed and implement necessary controls to prevent a recurrence.

4.0 BOARD SIGNATURES

Date _____
David A. Gurule, P.E.
Accident Investigation Board Chairperson
U.S. Department of Energy
Kansas City Area Office

Date _____
Ralph A. Fevig, P.E., C.S.P
Board Member
DOE Accident Investigator
U.S. Department of Energy
Albuquerque Operations Office

Date _____
Dennis Miotla, Board Member
U.S. Department of Energy
Office of Defense Programs

Date _____
John W. Teske, P.E., C.S.P., C.I.H.
Board Member
DOE Accident Investigator
U.S. Department of Energy
Office of Environment, Safety and Health

Date _____
William M. Bell, Board Member
DOE Accident Investigator
U.S. Department of Energy
Los Alamos Area Office

5.0 BOARD MEMBERS, ADVISORS AND STAFF

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Member	Ralph A. Fevig, DOE Albuquerque Operations Office
Member	Dennis Miotla, DOE DP-13
Member	John W. Teske, DOE EH-24
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Advisor	Dennis L. Vernon, DOE EH-21
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APPENDIX A
