DOE/CH-AI98E

Type B Accident Investigation Board Report on the March 27, 1998 Rotating Shaft Accident at Ames Laboratory Ames, Iowa

April 1998

Chicago Operations Office
U.S. Department of Energy

This report is an independent product of the Type B Accident Investigation Board appointed by John Kennedy, Acting Manager, Chicago Operations Office, U.S. Department of Energy (DOE).

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

The discussion of facts, as determined by the Board, and the views expressed in the report are not necessarily those of the DOE and do not assume and are not intended to establish the existence of any legal causation, liability, or 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.

U.S. Department of Energy
Chicago Operations Office
9800 S. Cass Avenue
Argonne, IL 60439

A. L. Taboas, Chairperson
Accident Investigation Board

On March 30, 1998, I appointed a Type B Accident Investigation Board to investigate the March 27, 1998 Rotating Shaft Accident at the Ames Laboratory, located in Ames, Iowa. The responsibilities of the Board have been satisfied with respect to the 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 report of the Board. The report is unclassified and I authorize its release for general distribution.

John Kennedy
Acting Manager
Chicago Operations Office

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EXHIBITS, FIGURES, AND TABLES

ACRONYMS AND INITIALISMS

AMCA	Air Movement and Control Association International, Inc.
Ames Group	A unit of DOE-CH with oversight of Ames Laboratory
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CFR	Code of Federal Regulations
CH	Chicago Operations Office
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DPS	(ISU) Department of Public Services
EH&S	(ISU) Environmental Health and Safety
ES&H	Environment, Safety and Health
ESH&A	Environment, Safety, Health and Assurance
FS	Facilities Services
HVAC	Heating, Ventilation and Air Conditioning
ISM	Integrated Safety Management
ISU	Iowa State University
ORPS	Occurrence Reporting and Processing System
OSHA	Occupational Safety and Health Administration
PM	Preventive Maintenance
PPE	Personal Protective Equipment
PPS	Ames Laboratory Plant Protection Services
RR	Readiness Review
SOR	Service Order Requisition
TASF	Technical and Administrative Services Facility
Twin City	Twin City Fan and Blower Company

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EXECUTIVE SUMMARY

INTRODUCTION

A personal injury accident involving the entanglement of an Electrician's jacket with a rotating shaft occurred on March 27, 1998, at the Ames Laboratory in Ames, Iowa. The Electrician and a Mechanic had gone to the basement of the administration building to evaluate a duct smoke detector that had initiated a false fire alarm earlier in the day. The detector is located on the discharge side of an air supply fan. The supply and return air fans are enclosed in separate air handling rooms as part of the building's ventilation system. The supply fan was turned off at the control panel, but the Electrician and the Mechanic entered the supply fan room before the fan had coasted to a complete stop. The Electrician was wearing an unbuttoned nylon jacket and carrying a ladder in the cramped area adjacent to the fan. The **direct cause** of the accident was the entanglement of the Electrician's jacket on the supply fan's exposed rotating shaft.

The rotating shaft is 2 diameter and projects 1 through the bearing pillow block, at about waist height. The decelerating shaft pulled the jacket, pinning the Electrician for about 10 seconds. The impact and torsion resulted in severe injuries to his arms, face, head, neck, ribs, and lungs. The Electrician received timely emergency medical care, which probably saved his life. He was then evacuated by ambulance and flown by helicopter to a local hospital.

Ames Laboratory is managed through the DOE Ames Group, which is part of the DOE Chicago Operations Office (CH). A Type B Accident Investigation Board was appointed by CH, and began its onsite investigation on March 30, 1998, by conducting interviews, evaluating physical evidence, and performing the analyses contained in this report. This report was coordinated through the DOE-HQ Office of Environment Safety and Health (EH).

Ames Laboratory provided exceptional support and cooperation with the Board. There was a clear indication of ownership of the situation, and of taking actions to prevent recurrence.

CAUSAL FACTORS

The Board concluded that there were two **root causes** of the accident:

> **Local Root Cause:** ***Failure to identify the hazard of the exposed rotating shaft***. Had line management and/or workers identified the exposed rotating fan shaft as a hazard, a guard or procedures would have been utilized to control the hazard. A physical guard offers the most effective means of safeguarding by controlling hazard at the source.
>
> **Systemic Root Cause:** ***Lack of integrated safety management***. Management failed to assure that systems were in place to identify and analyze all hazards, to conduct adequate work planning, and to establish appropriate hazard controls. This finding is supported by several of the contributing causes.

Several **contributing causes** were identified:

- Corrective actions for prior assessments failed to prevent recurrence of machine guarding deficiencies.

- The Laboratory relied upon the overall building procurement process to ensure that installed equipment was safely configured.

- The Laboratory failed to completely assess hazards in the fan rooms, as required by the Occupational Safety and Health Administration (OSHA) standards for hazardous energy control, confined space, and personal protective equipment.

- Periodic walkthrough inspections by DOE and the Laboratory failed to adequately identify exposed rotating shafts as hazards.

- Work planning was inadequate for the work the Electrician and Mechanic were engaged in at the time of the accident.

- The Electrician's jacket being unbuttoned increased the likelihood of it becoming entangled in the exposed rotating fan shaft.

CONCLUSIONS AND JUDGMENTS OF NEED

Complete descriptions of the conclusions and judgments of need for the accident are contained in Table 4-1 in page 31. The dominant findings of the Board are:

1. All motion hazards should be guarded through physical barriers. Locating HVAC equipment in an enclosed area does not prevent exposure to motion hazards within the enclosure. Even though electrical power to an air-handling unit is disconnected and locked out, inertia can sustain rotation for several minutes. In addition, differential air pressures may cause spontaneous rotation ("windmilling"). In the absence of engineered barriers, access to such areas should be restricted to personnel trained in the hazards present, using appropriate tools and safety equipment, and in accordance with established procedures.

2. Sole reliance on the requirements of Subpart O, *Machinery and Machine Guarding*, of the OSHA General Industry Standards should be avoided. OSHA permits a shaft end to project not more than one-half the diameter of the shaft unless guarded by a non-rotating cap or sleeve based on a 1953 edition of ANSI Standard B15.1. The ANSI standard was revised in 1972, eliminating the allowance of any rotating shaft projections. Information on current industry practices is in the 1996 revision of the ANSI/ASME standard, which can be found on-line at http://www.ansi.org. An advisory notice of this problem was issued on April 2, 1998. Further, DOE should request OSHA to update their exposed-shaft standards.

Type B Accident Investigation Board Report on the March 27, 1998, Rotating Shaft Accident at Ames Laboratory Ames, Iowa

1.0 INTRODUCTION

1.1 BACKGROUND

On March 27, 1998, at approximately 2:30 p.m., the Manager of the Electrical Services Shop (referred to as "the Electrician") was seriously injured as a result of his jacket becoming entangled on an exposed rotating shaft in the HVAC supply fan room of the Technical and Administrative Services Facility (TASF) at Ames Laboratory in Ames, Iowa.

An employee was seriously injured as a result of his jacket becoming entangled on an exposed rotating shaft.

On March 30, 1998, John Kennedy, Acting Manager, Chicago Operations Office (CH), U.S. Department of Energy (DOE), appointed a Type B Accident Investigation Board (referred to as "the Board") to investigate this accident in accordance with DOE Order 225.1A, *Accident Investigations* (See Appendix A).

The U.S. Department of Energy appointed an Accident Investigation Board.

1.2 FACILITY DESCRIPTION

Ames Laboratory is operated for the DOE by Iowa State University (ISU) and located on approximately ten acres on the ISU campus in Ames, Iowa. The mission of the Laboratory is to conduct fundamental research in the physical, chemical, materials, and mathematical sciences and engineering, which underlie energy generation, conversion, transmission and storage technologies, environmental improvement, and other technical areas essential to national needs.

The primary mission of Ames Laboratory is to conduct fundamental research in basic energy sciences.

Current Laboratory operations utilize both federally owned buildings at the main site and space in University-owned buildings adjacent to the main site. The TASF, which contains approximately 27,400 square feet of usable space, was completed at the end of 1994. It is situated on land

currently leased from ISU and houses the management, administrative, and technical support groups. At the end of 1997, the Laboratory had approximately 480 full and part time employees.

Contractor activities at Ames Laboratory are managed by the DOE Ames Group, which reports to, and receives support from, the Chicago Operations Office (see Figure 1-1.). The primary DOE sponsor is the Office of Basic Energy Sciences within the Office of Energy Research.

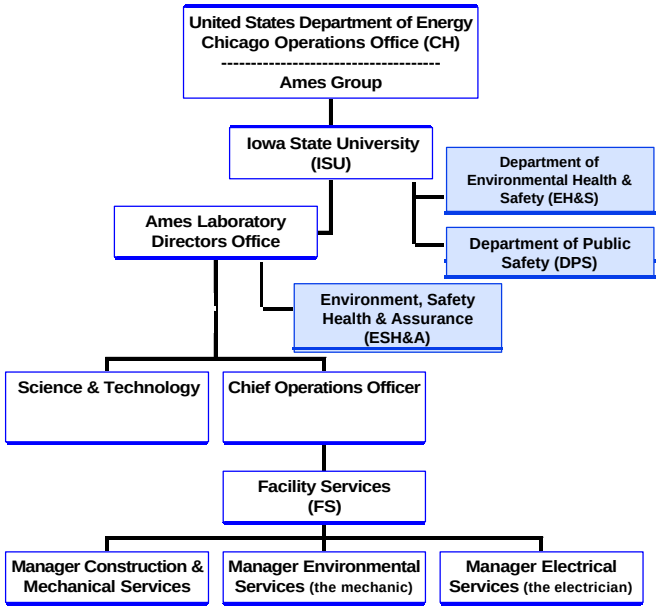

Figure 1-1. Line Management of Ames Laboratory Facilities

1.3 SCOPE, PURPOSE, AND METHODOLOGY

The Board began its investigation on March 30, 1998, completed the investigation on April 10, 1998, and submitted its final report to the CH Manager on April 15, 1998.

The **scope** of the Board's investigation was to review and analyze the circumstances of the accident to determine its cause. The Board also evaluated the adequacy of safety management systems and work control practices of DOE and Ames Laboratory, as they relate to the accident.

The purpose of the investigation is to determine the cause of the accident in order to improve safety.

The **purposes** of this investigation were to determine the cause of the accident including deficiencies, if any, in the management systems and to assist DOE in understanding

lessons learned to improve safety and reduce the potential for similar accidents.

The Board conducted its investigation using the following **methodology**:

- Facts relevant to the accident were gathered through interviews, document and evidence reviews, and examination of physical evidence.
- Facts and analyses were organized using the framework of the core functions and selected guiding principles of DOE Policy 450.4 Safety Management System Policy (see Figure 1-2).
- Barrier analysis[1] techniques, along with event and causal factors charting[2], were used to analyze facts and identify the accident's cause.
- Based on analysis of the information gathered, judgments of need for corrective actions to prevent recurrence were developed.

The Board considered Integrated Safety Management principles in its deliberations.

Figure 1-2. Integrated Safety Management Principles and Functions

[1]Barrier analysis reviews hazards, the targets (people or objects) of the hazards, and the controls or barriers that management control systems put in place to separate the hazards from the targets. Barriers may be administrative, physical, or supervisory/management.
[2]Charting depicts the logical sequence of events and conditions (causal factors) that allowed the event to occur.

2.0 ACCIDENT DESCRIPTION AND CHRONOLOGY

2.1 BACKGROUND AND ACCIDENT DESCRIPTION

On March 27, 1998 the duct smoke detector in the supply fan room of the TASF (see Figure 2-1) alarmed at 1346, automatically shutting off the supply and return fans (see Exhibit 2-1). Both the Laboratory's Manager of Facilities Services (FS) and the Industrial Safety/Fire Protection Officer (the Safety Officer) responded to the alarm by going to the supply fan room. They entered the supply fan room and determined there was no smoke and, thus, no apparent reason for the duct smoke detector to have been activated. After exiting the supply fan room, the Manager of FS informed the Ames Fire Department that there was no smoke or fire. The Ames Fire Department did not verify this. The Ames Fire Department was released and the Manager of FS turned both fans back on. The Manager of FS reentered the supply fan room with the Safety Officer to check the system. Finding no problems again, they exited the supply fan room.

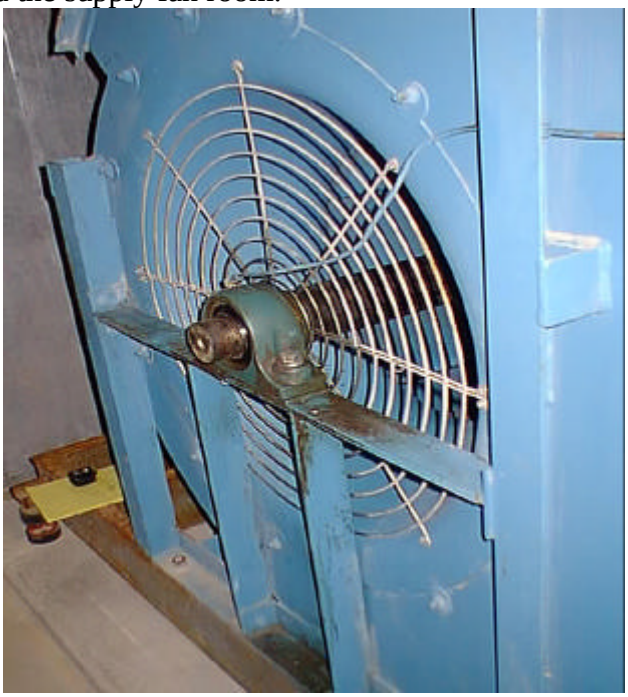

Exhibit 2-1. Supply Fan

A duct smoke detector alarm automatically shut off the air handling fans in TASF.

The Facilities Services (FS) Manager, the Safety Officer, and the Ames Fire Department responded. Finding no smoke, the Manager of FS turned both fans back on, and reentered the supply fan room with the Safety Officer. Finding no problems again, they exited.

The Manager of FS asked the Manager Environmental Services (referred to as "the Mechanic") and the Manager Electrical Services (referred to as "the Electrician") to check the duct smoke detector.

The Mechanic and Electrician entered the supply fan room to scope the job and determine what equipment would be needed.

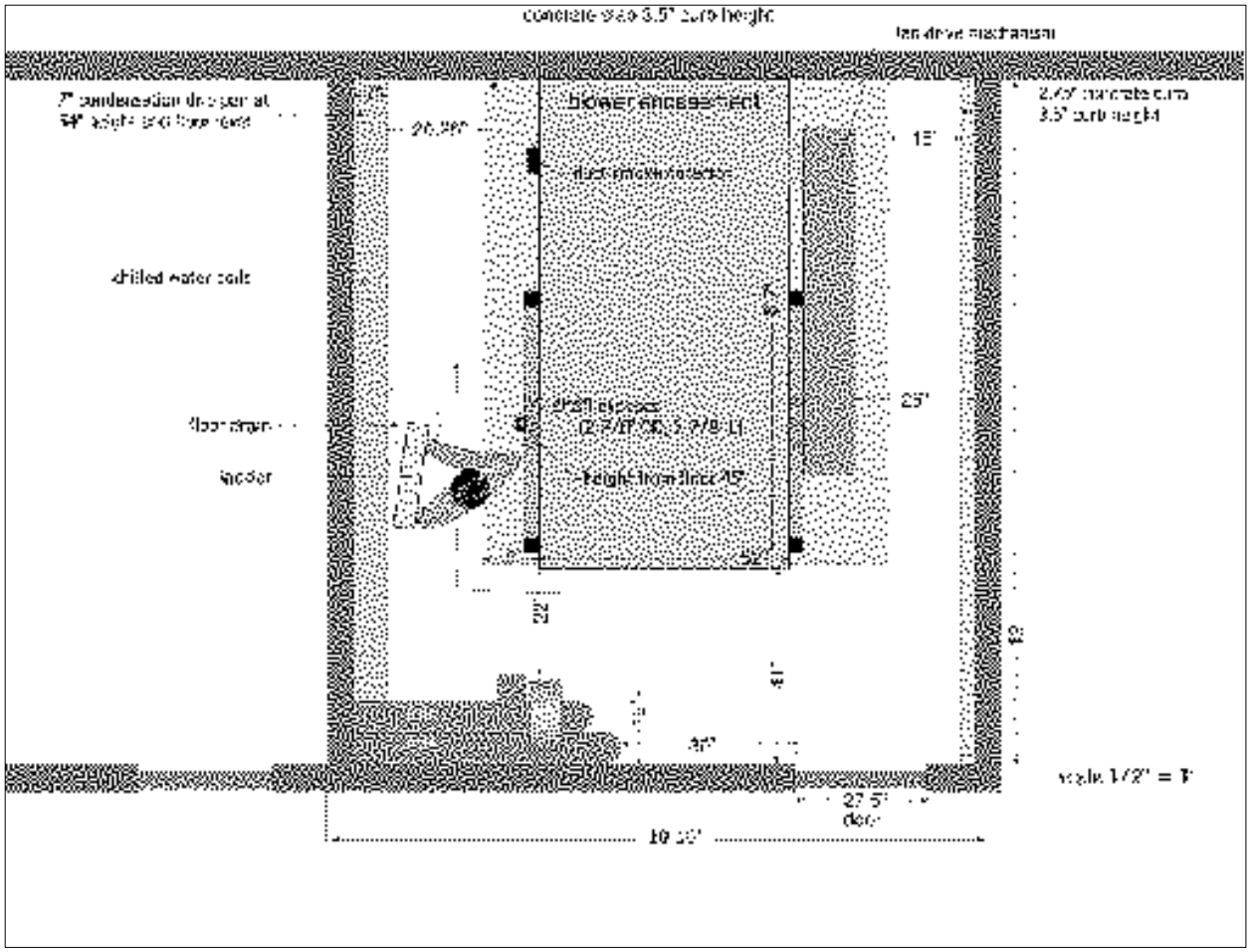

Figure 2-1. Supply Fan Room Layout

The Manager of FS decided to have a mechanic and electrician check the duct smoke detector. He discussed the need to check the duct smoke detector with the Manager Environmental Services (referred to as "the Mechanic") and requested that the Mechanic contact the Electrician for assistance.

The Mechanic and Electrician entered the supply fan room to scope the job and determine what equipment would be needed – the fan and chiller (see Figure 2-1 and Exhibit 2-1) were on while they were inside the supply fan room at this time. The Electrician left the area to get the necessary tools and, having felt cold in the supply fan room, returned with a nylon jacket on. The jacket was not buttoned.

After turning the fan off, but before the fan had stopped rotating, the Electrician and the Mechanic reentered the supply fan room. The Electrician grabbed a five-foot

The Electrician left the area to get the necessary tools and, having felt cold in the supply fan room, returned with a nylon jacket on. The jacket was not buttoned.

After turning the fan off, but before the fan had stopped rotating, they reentered the supply fan room. The Electrician grabbed a ladder and proceeded to the duct smoke detector.

The Mechanic did not witness the accident.

ladder that was in the supply fan room and proceeded to the duct smoke detector. Since the Mechanic remained on the other side of the fan, he did not witness the actual accident. The Board was unable to interview the Electrician because of his medical condition and, thus, had no eyewitness account of the accident. However, in the Board's opinion the following sequence of events probably occurred within ten seconds:

- The Electrician proceeded to the duct smoke detector side of the fan, carrying the stepladder near the exposed rotating shaft (see Exhibit 2-2).
- The Electrician's unbuttoned jacket (see Exhibit 2-4) was entangled and wound on the exposed rotating shaft, tightening the jacket around his arms and neck.
- The Mechanic heard a "thump" and went around the side of the fan to investigate.
- The Mechanic saw the Electrician slumped over the exposed shaft and attempted to lift him off the shaft (see Exhibit 2-3).
- The Mechanic was unable to remove the Electrician from the shaft until it stopped rotating, after approximately five seconds.

The Mechanic then gently laid the injured Electrician on the floor and used his radio to call for assistance.

The Electrician's unbuttoned jacket was entangled and wound on the rotating shaft.

The Mechanic heard a "thump" and went around to investigate.

Exposed fan shaft (not energized)

Space in the supply fan room is cramped.

Exhibit 2-2. Re-enactment of Electrician Carrying Ladder in Supply Fan Room

Exhibit 2-3. Re-enactment of Mechanic Assisting Injured Electrician

Exhibit 2-4. Electrician's Jacket

The Mechanic saw the Electrician slumped, lifted him off the shaft, then gently laid him on the floor. He then called for assistance.

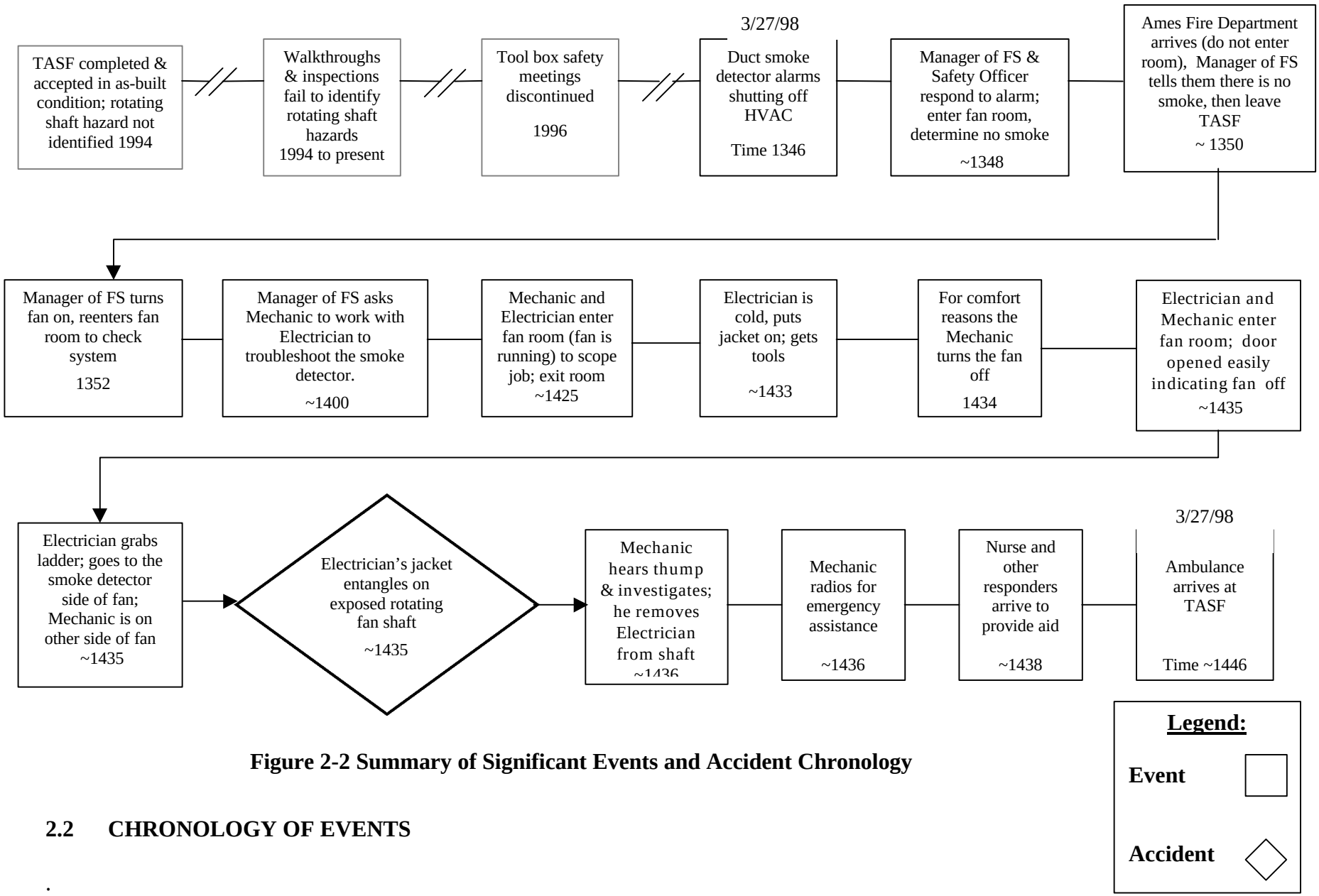

Figure 2-2 Summary of Significant Events and Accident Chronology

2.2 CHRONOLOGY OF EVENTS

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2.3 EMERGENCY RESPONSE

The Electrician was unresponsive by the time the Mechanic removed him from the exposed shaft. The Mechanic radioed the Ames laboratory Plant Protection Services (PPS) that he had an emergency in the sub-basement of the TASF. This call was logged in by PPS at 1436[3]. The Mechanic radioed PPS a second time, stating that he required emergency assistance for a severely injured employee. PPS followed established procedures by contacting the ISU Department of Public Services (DPS) to request an ambulance be sent to the TASF. DPS contacted Mary Greeley Medical Center (the "Medical Center") to request an ambulance be dispatched to the accident scene. Following the emergency call, the Ames Laboratory Occupational Nurse (the "Nurse"), personnel from the Ames Laboratory Environment, Safety, Health, and Assurance Department (ESH&A), and a second mechanic responded to the accident scene. The Nurse performed an initial examination of the Electrician, noting an obstructed airway and subsequently clearing it. Had the Nurse not arrived when she did, the Electrician's airway may not have been cleared, possibly resulting in a fatality. The Incident Report from the Medical Center indicated that the ambulance was dispatched from the Medical Center at 1438.

The Mechanic found the Electrician unresponsive.

Following the emergency call, the Ames Laboratory Occupational Nurse (the "Nurse"), ESH&A personnel, and a second mechanic responded to the accident scene.

Had the Nurse not arrived when she did, the Electrician's airway may not have been cleared, possibly resulting in a fatality.

At 1439 DPS logged a second call from Ames Laboratory with additional information relating to the accident. At 1440 DPS dispatched an Officer to the scene (DPS Officers are state-certified to serve as first responders for emergencies), who then radioed back to DPS at 1442 that the accident was indeed a real emergency and to rush the ambulance. At 1443 DPS logged a call from Ames Laboratory requesting Life Flight medical helicopter services be placed on alert. At 1444 DPS received a second request affirming the need for Life Flight services. The ambulance dispatched from the Medical Center arrived at approximately 1446 and the paramedics began immediate treatment of the Electrician.

DPS Officers are state-certified to serve as first responders for emergencies.

[3] The times used in this section from Ames PPS, DPS, and the Medical Center were all synchronized with DPS to establish a more exact emergency response timeline.

At 1450 DPS evaluated a nearby ISU practice golf driving range to be used as the landing area for the helicopter. At 1501 Mercy Hospital's Air Life[4] was contacted because

A medical helicopter was placed on alert.

Life Flight could not fly due to weather conditions. At 1508 the Electrician was secured in the ambulance to be transported to the helicopter for airlift to Mercy Hospital in Des Moines. DPS contacted the ambulance at approximately the same time and re-routed the ambulance to meet Air Life at the Ames Airport. Several factors were considered in making the decision to send the helicopter to Ames Airport instead of the Laboratory: poor weather conditions, unstable soil (due to heavy rains), the lack of appropriate clearances at the designated landing area, and the fact that little, if any, time would be saved. The pilot also felt the airport would be a safer location to meet the ambulance.

The Electrician was secured in the ambulance and transferred to the helicopter, and flown to Mercy Hospital in Des Moines.

The ambulance arrived at the Ames Airport at approximately 1522. At 1524 the ambulance had Mercy Hospital's Air Life in sight. The Electrician was transferred to the helicopter and flown to Mercy Hospital in Des Moines, arriving at 1553.

The Board concluded that the Electrician received timely medical attention, and found no significant issues with the Laboratory's emergency response for this accident. However, there are other issues that merit evaluation. Currently, the Laboratory instructs employees to dial 4-5511 for emergencies, which is received by PPS. If warranted, PPS communicates with DPS via the 911 system. The Board was concerned that emergency response might be delayed because of the need to place two separate emergency calls. The Laboratory is currently evaluating the need for both systems, and is exploring the possibility of instructing employees to dial 911 directly.

The Board concluded that the Electrician received timely medical attention.

Based on a review of the recorded DPS phone/radio transmissions, the Board noted that the Medical Center might have been confused of TASF's exact location. DPS spoke with the ambulance driver directly and instructed him on the exact location of TASF. The Board concluded that the Laboratory should evaluate the need to familiarize all potential ambulance responders with the location of their facilities.

[4] Life Flight and Mercy Hospital's Air Life are two distinct medical transport services based in Des Moines, IA.

The Mechanic found the Electrician unresponsive.

2.4 MEDICAL REPORT

The Electrician is a 56-year-old, white male of 5'8" height, weighing 130 pounds. He sustained severe trauma to the head, torso and upper extremities when the shaft of a large, decelerating fan caught his clothing. The Electrician was unresponsive when removed from the shaft and was laid down on the floor. The initial evaluation by the Nurse recognized eye findings, suggesting brain injury that was later confirmed by a head scan that revealed intraventricular fluid. The Nurse noticed upper respiratory obstruction so she secured an open airway by the insertion of an oral airway. The paramedics subsequently did an oral intubation during evacuation. A gaping wound at the right shoulder was associated with an incomplete amputation of the right arm, which was noted to have no radial pulse at the scene. The left shoulder was described as boggy at the time of the initial assessment with diminished peripheral pulses at the left wrist.

Further evaluation of the injury in the Mercy Hospital Emergency Room, noted the Electrician's unresponsive state, the nearly completely avulsed right arm, a pulseless left arm, at least three facial/head lacerations (including a severe wound of the right ear), and spontaneous movements of the lower extremities. A chest x-ray noted probable blood in the apex of the right chest in an extra-pleural area. No other fractures were detected at this time. The decision was made to support the patient and attempt prompt revascularization of the upper extremities.

2.5 INVESTIGATIVE READINESS AND FOLLOW-UP ACTIONS

Immediately following the accident, the Laboratory:

- Restricted access to the accident scene
- Photographed the accident scene
- Recorded statements from the Mechanic and the first Laboratory staff to arrive at the scene of the accident
- Cleaned up the scene in accordance with 29 CFR 1910.1030, *Bloodborne Pathogens*
- Restarted the HVAC to provide ventilation for the TASF.

The Board found no significant issues with investigative readiness.

The Board found no significant issues with the

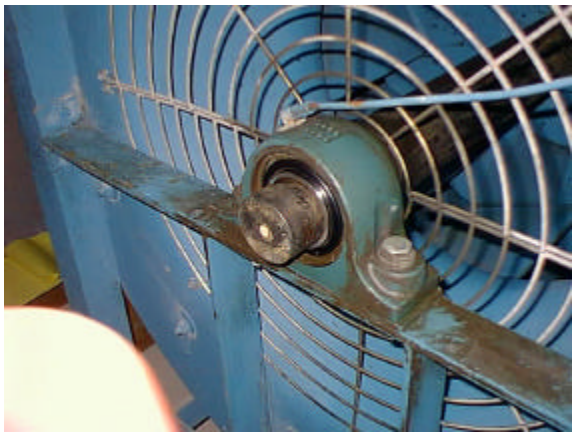
investigative readiness at Ames Laboratory.
Based on preliminary accident investigation information, the Ames Group Manager directed Ames Laboratory to take immediate action to make the operation safer. Specifically, the Laboratory was directed to place protective guards over the ends of the fan shafts in the TASF air-handling unit and to inspect other fan units at the Laboratory for similar conditions. The Laboratory also developed a new policy utilizing administrative controls, treating the fan enclosures as spaces requiring a permit to enter, until all fans could be inspected and the fan shafts adequately guarded. Only the Manager of FS or Facility Engineers can approve future access to the fan rooms.

Ames Laboratory placed protective guards over the ends of the fan shafts in TASF.

The Laboratory contacted the fan vendor (Products, Inc.) to order an off-the-shelf guard for the exposed end of the fan shaft. Twin City Fan and Blower Company (Twin City) manufactured the fan. Since Products, Inc. no longer carries the fans or parts manufactured by Twin City, they suggested that Twin City be contacted directly. Twin City stated that they do not offer an off-the-shelf guard for the exposed end of the shaft.

DOE issued a Lessons Learned Notice on the protection of personnel working in close proximity to mechanical power transmission apparatus.

Ames Laboratory personnel fabricated and installed a protective box that adequately covers the exposed shaft (see Exhibit 2-5).



Exposed Shaft

Guarded Shaft

Exhibit 2-5. Ames Laboratory Fabricated Guard

On April 2, 1998, CH issued a DOE-wide Lessons Learned Notice (Red/Urgent) providing preliminary information on the protection of personnel working in close proximity to mechanical power transmission apparatus (see Appendix B).

3.0 ACCIDENT FACTS AND ANALYSIS

3.1 INDUSTRIAL AND WORKER SAFETY

3.1.1 Machine Guarding

The hazard of rotating objects has clearly been recognized in industry and OSHA standards for many years as evidenced by:

- The U.S. Department of Labor/Bureau of Labor Standards published a bulletin in 1959, entitled, *The Principles and Techniques of Mechanical Guarding*, that states,

  > "Any rotating object is dangerous. Even smooth, slowly rotating shafts can grip clothing or hair, and through mere skin contact force an arm or hand into a dangerous position. Accidents due to contact with rotating objects are not frequent, but the severity of injury is always high."

- The hazard of rotating parts was again reiterated in the *Accident Prevention Manual* published by the National Safety Council in 1974.

- The list of Work Smart Standards identifies consensus standards to be followed by Ames Laboratory and specifically references "ANSI Standards, as relevant." The relevant standard for this accident is ANSI/ASME Standard B15.1-1996, *Safety Standard for Mechanical Power Transmission Apparatus*, that states,

  > "All motion hazards associated with the operation of mechanical power transmission apparatus shall be eliminated by design of the equipment or protection by a guard, device, safe distance or safe location."

- According to a report that identified all standards cited by OSHA during 1997, mechanical power transmission apparatus (29 CFR 1910.219) ranked 6th out of all citations issued.

The hazard of rotating objects has clearly been recognized for many years.

Accidents due to contact with rotating objects are not frequent, but the severity of injury is always high.

- Recognizing the hazards of dangerous moving parts, OSHA published a document entitled, *Concepts and Techniques of Machine Safeguarding*, to help employers, employees, machine manufacturers, machine guard designers and fabricators, and all others with an interest in protecting workers against the hazards of moving machine parts. It states,

  "OSHA encourages employers to abide by the more current industry consensus standards since those standards are more likely to be abreast of the state of the art than an applicable OSHA standard may be."

- As stated in 29 CFR 1910.219 (c)(4)(i),

  "Projecting shaft ends shall present a smooth edge and end shall not project more than one-half the diameter of the shaft unless guarded by nonrotating caps or safety sleeves."

- General requirements for all machines are found in 29 CFR 1910.212(a)(1) which states,

  "One or more methods of machine guarding shall be provided to protect the operator and other employees in the machine area from hazards such as . . . rotating parts. . ."

- The exposed shaft was not protected by a non-rotating cap or safety sleeve. The diameter of the exposed shaft measures 2 inches and projects 1 inches beyond the pillow block for the bearing. According to the referenced standard, the exposed shaft is only allowed to extend 1 $^{7}/_{16}$ inches.

The exposed shaft was not protected by a non-rotating cap or safety sleeve.

The Board determined that the Laboratory did not use any of the following methods for safeguarding the exposed shaft:

- The exposed rotating shaft was not guarded to prevent possible contact.
- There was no motion hazard safeguarding device that would prevent or stop normal motion of the shaft if someone were to enter the hazardous area.
- Maintaining a safe distance from possible contact did not guard the exposed shaft. The top of the shaft was located only 45 inches from the floor.

– The exposed shaft was not guarded by location, since this would have required access to the supply fan room to be restricted to trained personnel who are aware of both the hazards and the control measures to be taken. Personnel who had access to the supply fan room were not aware of this potential hazard. Furthermore, it was standard practice to enter this supply fan room while the fan was operating.

The Board concluded that the exposed shaft was not safeguarded in accordance with current OSHA standards or ANSI/ASME B15-1

The Board concluded that the exposed shaft was not safeguarded in accordance with current OSHA standards or ANSI/ASME B15.1-1996.

3.1.2 User Responsibility

- The explanatory information for the Application/General Requirements of ANSI/ASME B15.1-1996 states,

  "It is understood that in the application of this Standard, there are responsibilities incumbent upon the owner, the manufacturer, the installer, the operator, and the user of the power transmission apparatus. Some safeguarding features are incorporated into the design of the equipment. Some protection depends upon the installation of safeguarding features after assembly of all the associated components in the field: other safeguarding features are a part of a building or structure and are not an integral part of the components themselves. Some protection depends upon the operator and maintenance by the user, and some protection depends upon training and supervision."

Some safeguarding features are incorporated into the design of the equipment. However, the user has ultimate responsibility for the safe operation of equipment.

- The responsibility of the user is reiterated in a recommended safety practice that is published by the Air Movement and Control Association International, Inc. (AMCA) which is a trade association of manufacturers of fans, air movers, etc. The AMCA Publication 410-96 states,

  "The safe installation and operation of fans is the responsibility of the system designer, installer, maintainer, and user."

- A warning on the manufacturer's label on the supply fan states,

  "This equipment must not be operated without proper guarding of all moving parts…"

- The Contract Documents-Bid Issue from the architects for the TASF, dated June 1, 1992, does not address the hazard of exposed shafts. The procurement document, however, has specifications for centrifugal fans. Two potential hazards and control measures were identified: one requires an inlet screen that complies with OSHA regulations, the other requires a belt guard.

Both the ANSI standard and the AMCA publication place a shared responsibility for the safe operation of the equipment upon the user, i.e., Ames Laboratory. Manufacturers should not be relied upon to have completely analyzed and installed controls for equipment.

The Board concluded that Ames Laboratory relied upon the overall procurement process to ensure safe equipment configuration. The Board could find no evidence that Ames Laboratory personnel had ever recognized this exposed shaft to be a safety hazard.

3.2 WORK PLANNING

- Work by FS is normally planned through one of three processes: (1) Service Order Requisitions (SOR), (2) Preventive Maintenance (PM), and (3) Repair and Service Requests. Each of these processes is documented in an FS instruction or manual, and provides for scheduling and tracking the work through completion.

- The work that the Electrician and the Mechanic were engaged in at the time of the accident was not tasked through any of the three "regular" processes. The need to troubleshoot the duct smoke detector was verbally tasked to the Mechanic by the Manager of FS, after the detector improperly alarmed. It is accepted practice at Ames Laboratory for FS personnel to enter fan rooms while the fan is running to perform equipment checks, lubricate bearings, and troubleshoot duct smoke detectors. FS shop managers are responsible for

scoping and assigning work to their staff, including any special safety precautions for unusual situations. The Laboratory relies upon familiarity with the ES&H Program Manual, combined with the experience and awareness of the FS craftsmen and shop managers, so that each individual takes the necessary precautions to work safely.

The principles of integrated safety management require worker involvement in work planning.

- The FS Safety Plan contains sections on electrical and environmental procedures that identify troubleshooting as a task that can be performed while working alone.

The work that the Electrician and the Mechanic were performing at the time of the accident had not undergone any formal work planning, using any of FS's three work processes. Although the Board understands that minor unplanned work tasks such as these are inevitable for a service/maintenance/repair organization, the Laboratory should ensure that relevant safety precautions are addressed.

The Board concluded that work planning, particularly those aspects that address the need to fully understand the work environment, was inadequate for the work that the Electrician and the Mechanic were engaged in at the time of the accident.

Work planning was inadequate for the work the employees were engaged in at the time of the accident.

The Laboratory allows working alone while troubleshooting. Although the work-alone provisions were not a factor in this accident, the Board felt that had the Electrician been working alone at the time of the accident, emergency response would have been significantly delayed. To avoid the potential for such an occurrence in the future, the Laboratory should examine their work-alone provisions.

3.3 HAZARDS ANALYSIS

- The SOR process provides for evaluation of the work against Ames Laboratory's *Activity ES&H Hazard Identification Checklist* and for review of the SORs by Ames Laboratory's ESH&A Department.

- The primary means by which Ames Laboratory identifies and controls hazards associated with new and modified scientific activities is through their Readiness Review (RR) process. This requirement is incorporated into new research requests. RR can be an effective process for identification, mitigation, and control of hazards. Through the use of the *Activity ES&H Hazard Identification Checklist* and *Hazard Management Statements*, hazard controls are identified. The approvals and reviews ensure that controls are properly evaluated and implemented. The classification of activities into ES&H Hazard Level I, II, or III ensures that a graded approach is applied.

- Until the issuance of the *Activity Status Review Procedure* on January 1, 1998, the RR was confined to new and modified scientific activities. Existing research and nonscientific activities were not subjected to formal hazard identification such as that provided through the RR process. The *Activity Status Review Procedure* requires the application of the RR process to all existing activities at Ames Laboratory, including experimental, fabrication, and maintenance activities. Implementation of this procedure will establish safety envelopes for all work at Ames Laboratory. Safety envelope is defined as " The range of conditions covered by the safety documentation of a process or facility under which safe operation is adequately controlled" (reference DOE M 411.1-1 Functions, Responsibilities and Authorities Manual). The decision to subject all activities at the Ames Laboratory to the RR process was a result of the joint Ames Laboratory/CH Integrated Safety Management (ISM) Self-Assessment performed in June 1997.

- A memo from the ESH&A Manager to all Program Directors, Department Managers, and Group/Section Leaders directs the application, during 1998, of the *Activity Status Review Procedure* to all activities involving lasers, analytical X-ray systems, radiological materials, or hot work. This direction initiates the phased implementation of the *Activity Status Review Procedure* and also requires all Laboratory activities that have not been subjected to the RR process to undergo RR within the next three years.

The Laboratory did not conduct an adequate hazard evaluation.

- The Laboratory did not conduct an adequate evaluation as required by 29 CFR 1910.146 (c)(1),

  "The employer shall evaluate the workplace to determine if any spaces are permit-required confined spaces."

  The supply fan room clearly meets the definition of confined space, as defined in 29 CFR 1910.146 (b) and the ES&H Program Manual, Section 2.5. The unguarded rotating shaft is clearly a recognizable safety hazard, in accordance with the definition for a permit-required, confined space in 29 CFR 1910.146(b).

- The AMCA Publication 410-96 has recognized confined spaces in requirements for special purpose fans. It states that,

  "Fan inlet boxes, housings, ductwork, and other system components which are large enough to permit entry should be considered confined spaces. System areas may also serve as low points where heavy gases, liquids, or other substances may accumulate and present explosive, fire, health, or suffocation hazards. Appropriate protective measures and safety practices should be observed when entering or working within these areas."

- Section 2.5 of the ES&H Program Manual defines a confined space as an enclosed space which is large enough, and so configured, that an employee can bodily enter and perform assigned work, has limited or restricted means for entry or exit, and is not designed for continuous employee occupancy. The Confined Space Entry Permit form recognizes moving machinery as a potential hazard.

- A hazard assessment is required by 29 CFR 1910.132(d)(1) involving the use of personal protective equipment (PPE). It specifically requires that the employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of PPE. This assessment was not conducted.

- No hazard analysis of the work that the Electrician and the Mechanic were performing at the time of the accident was conducted before commencing the work.

- The Electrician's jacket was unbuttoned at the time of the accident.

Although the absence of any particular PPE was not directly involved in this accident, had the required hazard assessment been completed, the rotating shaft should have been recognized as a hazard. During the walkthrough survey, various sources of motion should be observed: i.e., machinery or processes where any movement of tools, or machine elements exists.

The hazard associated with clothing that may get caught in rotating equipment has been recognized in 29 CFR 1910.219 (p)(7). ANSI B15.1-1996 also states that, "Employees shall not wear such clothing, jewelry, or unrestrained hair styles as will be hazardous to their personal safety." The Board concluded that, since the supply fan room meets the definition of a confined space, it should have been evaluated to determine whether or not it was a permit-required, confined space. The presence of the exposed shaft, in the relatively cramped space in which the duct smoke detector is mounted, was not recognized as a hazard that required shutting off the fan as a safety precaution. If the Laboratory had conducted a confined space or a PPE assessment, it would have provided another opportunity to identify the hazards found in the supply fan room and the need to prohibit any loose clothing.

The Board recommends that the Laboratory give high priority to establishing safety envelopes for the work performed by Facility Service.

The Board concluded that the overall environment (i.e., the cramped space in the supply fan room and the presence of the exposed shaft) in which the work was being performed at the time of the accident, was not adequately evaluated with respect to hazards identification and analysis. The Board recommends that the Laboratory give high priority to establishing safety envelopes for the work performed by FS.

3.4 DEVELOP AND IMPLEMENT CONTROLS

The ES&H Program Manual requires all machines to be provided with guards to protect the operator and other

employees in the machine area from hazards such as those created by rotating parts. It also requires all employees to wear reasonably snug fitting clothing, with no loose flaps or strings, around rotating or reciprocating machinery.

- The Laboratory's *Safety Rules*, signed by the Laboratory Director and attached to the FS Safety Plan, requires rotating parts, such as shafts, to be guarded against personal contact.

- At the time of the accident, the exposed shaft was not identified as a hazard that required guarding.

- The size of the supply fan room, the size of the fan unit, and the position at which the duct smoke detector was mounted requires a worker to be in a cramped space in close proximity to the exposed shaft when working on the duct smoke detector.

- As required by 29 CFR 1910.147 (c)(4)(i),
  "Procedures shall be developed, documented and utilized for the control of potentially hazardous energy when employee are engaged in the activities covered by this section."

  And 29 CFR 1910.147 (c)(6)(i),
  "The employer shall conduct a periodic inspection of the energy control procedure at least annually to ensure that the procedure and the requirements of this standard are being followed."

- The ES&H Program Manual addresses lockout/tagout.

- Ames Laboratory does not have procedures for trouble-shooting duct smoke detectors or for personnel entry into the supply fan room.

- There were no documented procedures requiring proper lockout for performing servicing and/or maintenance on the supply fan. The fan is driven by electrical energy but will also rotate as it decelerates after the power is turned off or as a result of windmilling. Windmilling and stroboscopic effects (i.e., a rotating shaft appearing to be stopped) are described in the

At the time of the accident, the exposed shaft was not identified as a hazard that required guarding.

AMCA Publication 410-96. To guard against this hazard, the impeller should be secured to physically restrict rotational movement and irregular marks should be placed on the moving parts.

- This HVAC system is unique in that variable frequency drives for the supply and return fans can be controlled from two other remote locations at the Laboratory. Therefore, using the touch pad to turn off the fans at the variable frequency drives is not a sure means of controlling power to the supply and return fans. The only way to positively isolate the power to the fans is to turn the power off at the disconnect located in each fan room and then lockout the disconnect. The Board discovered that after locking out the return fan, verification on the touch pad re-energized the supply fan. These conditions mandate the need for specific energy control procedures.

- There were no warning signs on the equipment to alert employees of the potential hazard with the shaft as required by ANSI/ASME B15.1-1996.

There were no danger signs warning of specific hazards in the supply fan room.

The Board concluded that had proper energy control procedures been developed identifying all types and magnitudes of the energy sources including the stroboscopic effect, the hazard of the exposed shaft could have been identified. Also, had a periodic inspection been conducted, it would have provided an opportunity to identify the hazard.

The Board concluded that had proper energy control procedures been developed the hazard could have been identified.

Accident prevention signs are among the most widely used safety measures in industry. The Board concluded that there were no danger signs warning of specific hazards in the supply fan room, nor caution signs warning against potential hazards or cautioning against unsafe practices.

The Board determined that a combination of the following factors led to inadequate hazard controls being instituted for the work that was being performed at the time of the accident:

- Twin City does not offer an off-the-shelf guard for the exposed shaft.
- Potential hazards in the supply fan room were neither identified, nor analyzed.

– Standard practice was for Laboratory workers to enter the supply fan room, while the fan was operating, for lubrication and other purposes.

The Board concluded that the need for hazard mitigation/prevention controls for working in close proximity to an exposed rotating shaft was not recognized and, therefore, controls were not provided. Had administrative control required the fan to be stopped or a guard to be installed, the accident may have been prevented. Furthermore, had the hazard of the exposed shaft been identified, the ES&H Program Manual would have led to the guarding of the exposed shaft.

3.5 PERFORM WORK WITHIN CONTROLS

Since the hazards present in the environment in which the work was being performed at the time of the accident were not recognized, appropriate engineered and administrative controls were not provided. This prevented the employees from working within appropriate controls.

3.6 FEEDBACK AND IMPROVEMENT

- There is no indication that the Ames Group surveillance representative received notification of the accident as required by the Ames Group Standard Operating Procedures. The Ames Group does not have a designated alternate ORPS Facility Representative.

- Two types of self-assessment activities are implemented by Ames Laboratory, Program/Department Walkthroughs and Independent Walkthroughs. These walkthroughs provide an external assessment of the individual programs/departments, focused assessments of ES&H topics, and space allocations and equipment utilization. Previously, Independent Walkthroughs were scheduled so that all areas of the Laboratory would be covered in a three-year cycle. As a result of the ISM Self-Assessment, the Independent Walkthroughs are scheduled so that all areas of the Laboratory are covered annually.

- The ISM Self-Assessment cited the following weaknesses in the implementation of the walkthrough programs:

Since the hazards present in the environment in which the work was being performed at the time of the accident were not recognized, appropriate engineered and administrative controls were not provided. This prevented the employees from working within appropriate controls.

Self-Assessment activities are implemented by Ames Laboratory.

- Program Director/Department Manager involvement is sporadic or lacking
- Safety Coordinators receive no formal training for conducting assessments and/or walkthroughs
- Formal systems for documenting, tracking, and trending ES&H issues are lacking.

Ames Laboratory has instituted corrective action plans to address these ISM Self-Assessment concerns.

- A joint CH and Ames FS team on March 19 and 20, 1998 conducted the most recent walkthrough in the vicinity of the accident. Neither the Program/Department Walkthroughs by FS, nor the Independent Walkthroughs that covered the TASF sub-basement, checked inside the supply and return fan rooms, as they were considered to be the overall fan enclosure.

- FS discontinued the practice of toolbox safety meetings in 1996.

Safety walkthroughs did not check inside the fan rooms.

- The Ames Laboratory Tiger Team Assessment of March 1992, identified the following problems:

  - "Ames Laboratory does not comply with all requirements of 29 CRF 1910, Subpart 0, Machinery and Machine Guarding" (Concern WS. 4-1)
  - "Management has not developed comprehensive and technically correct operating procedures that provide direction and guidance for the recognition, evaluations, and control of occupational safety and health hazards at Ames Laboratory." (Concern PP.2-1)
  - "Laboratory management and staff are not sufficiently knowledgeable of ES&H requirements to develop and implement a comprehensive and integrated ES&H program". (Section 5.4, root causes).

  DOE approved corrective actions for these concerns were implemented by the laboratory.

Issues similar to the contributing causes of the accident were identified during the 1992 Tiger Team Assessment.

The Board concluded that CH, Ames Group and the Laboratory should re-examine their ES&H oversight

efforts to ensure adequate ES&H oversight is provided. The Laboratory should examine its corrective action mechanisms since contributing causes of this accident were previously identified by the 1992 Tiger Team assessment. The Laboratory immediately conducted an assessment for exposed shafts throughout their facilities.

3.7 LINE MANAGEMENT RESPONSIBILITY FOR SAFETY

Work at Ames Laboratory is conducted under the general operating contract (W-7405-ENG-82 Modification NO. M255). ES&H guidance is set forth in Appendix I, *Laws, Regulations and DOE Directives*, and Appendix K, *Work Smart Standards and Sets of Requirements*. Guidance is also delineated in the Ames *ES&H Program Manual.* An ISM Self-Assessment outlining areas to be developed and improved to facilitate the full implementation of ISM was performed. The laboratory developed a corrective action plan to address the concerns identified by the ISM Self-Assessment.

- The Board was not provided with any documented evidence that a substantive final inspection and acceptance had been conducted by Ames Laboratory for the TASF building. A completed project report was submitted to DOE.

. . . no documented evidence that a substantive final building inspection and acceptance was ever conducted.

Line management has the responsibility to conduct a final inspection and acceptance of a project. This is to ensure that all work has been properly performed, that all work meets specifications, that all required deliverables have been provided (such as, but not limited to, as-built drawings), and that all necessary inspections have been conducted to ensure full compliance with regulations, specifications, drawings and change orders.

It is the Board's opinion that in a final inspection and acceptance, all responsible organizations within the Laboratory should be integrated into the process. ESH&A should be responsible for ensuring that all applicable ES&H requirements are completed. The Chief Operations Officer should be responsible for ensuring that the facility is ready for operation and maintenance. The Project Manager should be responsible for ensuring that all design drawings and specifications have been met, that there is a

copy of appropriate drawings, and that the original requesting division is satisfied with the completion of the work. Once the Laboratory completes its inspection and acceptance, the Laboratory is fully responsible for the facility, as is.

The Board concluded that had a fully integrated final inspection and acceptance occurred, the exposed shaft hazard should have been identified.

The Board concluded that had a fully integrated final inspection and acceptance occurred, the exposed shaft hazard should have been identified.

The Board concludes that issues related to this accident were previously identified in the 1992 Tiger Team Assessment has implications on line management talking responsibility for safety (refer to Section 3.6).

3.8 CLEAR ROLES AND RESPONSIBILITIES

ES&H roles and responsibilities are documented through the Laboratory's ES&H Program Manual, Standard Operations Document, job description documents, and activity policies and procedures. Although concerns related to roles and responsibilities were identified in the ISM Self-Assessment, the Board did not believe they had an impact on this accident. The Laboratory has developed corrective action plans for these concerns. They are contained in the ISM Preliminary Implementation Plan, which has been submitted to the CH-Ames Group for approval.

3.9 COMPETENCE COMMENSURATE WITH RESPONSIBILITIES

- Information provided to the Board during an interview with the Laboratory's Acting Chief Operations Officer, demonstrated his unfamiliarity with TASF utility and HVAC systems, ES&H Program Manual, and ISM. There has been significant turnover in this position during the past five years.

Information provided demonstrated unfamiliarity with TASF utility and HVAC systems.

- All Ames Laboratory employees receive General Employee Training and are required to read the ES&H Program Manual. Job performance requirements are identified and documented in various questionnaires, training profiles, hazards inventory/job task analyses, position information questionnaires, and position description questionnaires. Together these documents

identify job tasks, typical hazards associated with the job position, and required training.

- The ISM Self-Assessment identified that several employees had not submitted a completed training need questionnaire. The Laboratory's ISM Preliminary Implementation Plan mandates the completion of all employee questionnaires by May 1, 1998. Currently, not all line managers have submitted a completed questionnaire.

- An employee's supervisor is responsible for assuring the employee completes required training. Each employee's supervisor may identify additional ES&H training they deem appropriate for an individual's job. The Group/Section provides "on-the-job" training to assure individuals are properly trained prior to the start of work.

An employee's supervisor is responsible for assuring the employee is trained.

- ES&H training is provided and coordinated through ESH&A. The ESH&A subject matter experts determine the need for training courses in their area(s) of expertise.

- The Electrician and the Mechanic each have over 30 years of relevant experience at Ames Laboratory. Training records indicate they both have complied with Ames Laboratory training requirements.

The Electrician and the Mechanic have significant experience, have complied with training requirements.

- A training course that specifically addresses the safety aspects of working on, or near, heavy machinery with moving/rotating parts is not offered by either the "corporate" Ames Laboratory training group or by FS. The training records of both the Electrician and the Mechanic did not indicate that they had received such training from other sources.

The Laboratory should assure extensive operations experience at the senior management level.

The Board recommends that the Laboratory evaluate whether training specifically focused on the safety aspects of working on, or near, machinery with moving/rotating parts should be provided to its employees.

The safety barriers included physical, administrative, and management barriers. All barriers failed.

The Board concluded that the Laboratory's operations organization at the executive level, does not have the appropriate combination of training and experience

necessary to lead the safe operation of facilities. The Chief Operations officer is a key position in establishing safety culture, defining operating philosophy, and exemplifying management's commitment to safety. There has been considerable turnover of personnel assigned this responsibility during the past five years. The Board recommends that the Laboratory assure extensive operations experience at the senior line management level.

3.10 BARRIER ANALYSIS

A barrier is defined as anything that is used to control, prevent, or impede process or physical energy flows and that is intended to protect a person or object from hazards. The safety barriers that should have protected the Electrician from the exposed rotating shaft included physical barriers, administrative barriers, and management barriers. A description of why these barriers were missing or failed is contained in Table 3.1.

The Local Root Cause is the failure to identify the hazard of the exposed rotating shaft.

3.11 CAUSAL FACTORS

The **direct cause** of the accident was the entanglement of the Electrician's jacket on the supply fan's exposed rotating shaft. However, there are also a root causes and contributing causes. **Root causes** are the fundamental causes, that if corrected, would prevent recurrence of this and similar accidents. The Board derived two root causes of the accident: A **Local Root Cause** and a **Systemic Root Cause**.

The Systemic Root Cause is a lack of integrated safety management. This is supported by several contributing causes.

The Laboratory operated without a comprehensive safety management system.

Contributing causes are other causes that would not, by themselves, have prevented the accident but are important enough to be recognized as needing corrective action. An Events and Causal Factors Analysis was used to evaluate the causal factors of this accident. A summary of this analysis is contained in Table 3-2.

The exposed shaft was not safeguarded in accordance with OSHA and ANSI/ASME standards.

Table 3-1 Missing or Failed Barriers between the Person and Hazard

PERSON	ELECTRICIAN
Physical Barrier	**Shaft Guard** Recognizing that an exposed rotating shaft was present, the physical barrier between the Electrician and the exposed rotating fan shaft should have been a guard covering the shaft. The failure to identify the rotating shaft as a hazard caused this barrier to be missing.
Administrative Barriers	**Hazard Identification** Industry and OSHA standards require work area assessments (e.g. Confined Space, Hazardous Energy Control, Personal Protective Equipment, Machine Guarding) to be conducted to identify hazards. Hazard identification for the supply fan room was inadequate, undocumented, and was not sufficiently comprehensive for appropriate controls associated with the machinery. Had an energy control procedure using effective lockout/tagout been implemented, this barrier would not have failed.
	Work Planning Effective work planning should have resulted in the identification of hazards and the use of specific procedures for entry to the fan room, was not conducted. There was no focused training related to working on or near, motion hazards, including rotating shafts.
Management Barriers	**Line Management** Management failed to identify the need to conduct work planning, to conduct hazard identification, and to establish controls for all troubleshooting and maintenance jobs. The Laboratory relied on the building procurement process to provide an adequately safe facility, in lieu of performing its own complete hazard assessment. Training and experience at the executive level of facility operations is not adequate to identify and maintain an appropriate, integrated, operating safety envelope. The Laboratory relied too much on maintenance employees to establish safe work envelopes during troubleshooting and small maintenance jobs.
HAZARD	EXPOSED ROTATING FAN SHAFT

Table 3-2 Causal Factors Analysis

Root Causes	Discussion
Local Root Cause: Failure to identify the hazard of the exposed rotating shaft.	Had line management and/or workers identified the exposed rotating fan shaft as a hazard, a guard or procedures would have been utilized to control the hazard. A physical guard controls the hazard at the source.
Systemic Root Cause: Lack of integrated safety management. Management failed to assure that systems were in place to identify and analyze all hazards, to conduct adequate work planning, and to establish appropriate hazard controls.	The Laboratory is operating without an integrated safety management system. This root cause is supported by several of the contributing causes.
Contributing Causes	**Discussion**
Corrective actions for prior assessments failed to prevent recurrence of deficiencies.	In 1992 the Tiger team identified issues relevant to this accident.
The Laboratory relied upon the overall building procurement process to ensure that installed equipment was safely configured.	Neither the Laboratory nor the Ames Group conducted an effective final inspection and acceptance upon completion and turnover of TASF in 1994.
The Laboratory failed to completely assess hazards in the fan rooms, as required by OSHA standards for hazardous energy control, confined space, and personal protective equipment.	Had the Laboratory conducted the required hazard assessments of the fan rooms, the hazard could have been identified and appropriate control measures installed.
Periodic walkthrough inspections by CH, Ames Group, and the Laboratory failed to adequately identify exposed rotating shafts as hazards.	Walkthrough inspections failed to assess all Laboratory spaces. Failure to identify the exposed rotating shaft in the fan room prevented the establishment of appropriate hazard controls.
Work planning was inadequate for the work the Electrician and Mechanic were engaged in at the time of the accident.	The Laboratory relied primarily on skill-of-the-craft (i.e., worker expertise) to perform the work in a safe manner.
The Electrician's jacket being unbuttoned increased the likelihood of it becoming entangled in the exposed rotating fan shaft.	Failure by the Laboratory to identify the exposed rotating fan shaft as a hazard resulted in a lack of special entry procedures or warning signs prohibiting loose clothing inside the fan room. The hazard associated with an unbuttoned jacket being worn near moving equipment is identified by OSHA and ANSI standards, as well as the Laboratory's ES&H Program manual.

4.0 CONCLUSIONS AND JUDGMENTS OF NEED

Conclusions are a synopsis of those facts and analytical results that the Board considers especially significant. **Judgments of need** are managerial controls and safety measures believed necessary to prevent or minimize the probability or severity of a recurrence. They flow from the conclusions and are directed at guiding managers in developing corrective actions. Table 4-1 summarizes the Board's conclusions and judgments of need.

Table 4-1 Conclusions and Judgments of Need

Conclusions	Judgments of Need
The Laboratory is operating without an integrated safety management system.	There is a need for the Laboratory to develop its integrated safety management system in accordance with the Department's Acquisition Regulations (DEAR), 48 CFR 970.5204-2 and DOE P 450.4 *Safety Management System Policy*. There is a need for the CH-Ames Group to verify the adequacy and effective implementation of the Laboratory's integrated safety management system, once established. There is a need for CH to examine the Ames Group's organizational ability to provide oversight of, and support to, the Laboratory.
The Laboratory's operations organization, at the executive level, does not yet have the appropriate combination of training and experience necessary to ensure safe operation of Laboratory facilities	There is a need for the Laboratory to ensure that the competence of its senior line managers is commensurate with their responsibilities for safety. There is a need for the CH-Ames Group to evaluate the competence of the Laboratory's senior line managers to ensure that facilities are designed, operated, and maintained safely.
Corrective actions for previous assessment findings failed to prevent recurrence of machine guarding deficiencies.	There is a need for the Laboratory to improve its process implementation for developing corrective actions that prevent recurrence of deficiencies. There is a need for the CH-Ames Group to monitor the implementation of these corrective actions.
The Laboratory relied upon the overall building procurement process to ensure that installed equipment was safely configured.	There is a need for the Laboratory to develop and implement an integrated final inspection and acceptance program upon completion and turnover of new facilities. ESH&A must be involved in the acquisition of major systems. There is a need for the CH-Ames Group to oversee the implementation of the Laboratory's integrated final inspection and acceptance program.

Conclusions – Continued	**Judgments of Need - Continued**
The Laboratory failed to assess hazards in the fan rooms, as required by OSHA standards for hazardous energy control, confined space, and personal protective equipment.	There is a need for the Laboratory to complete the assessments of all work spaces as required by OSHA standards for confined space, hazardous energy control, and personal protective equipment.
The exposed shaft was not safeguarded in accordance with OSHA and ANSI/ASME standards.	There is a need for the Laboratory to inspect all machinery and equipment to ensure proper control measures are in place. There is a need for DOE HQ Office of Environment, Safety and Health (EH) to develop and issue appropriate guidance and/or requirements for guarding exposed rotating shafts. Compliance with OSHA 1910.219(c)(4)(i) may not adequately control a hazard. DOE-EH should recommend to OSHA that this standard be updated to reflect the requirements found in the 1996 ANSI/ASME B15.1 standard.
The Laboratory has not established safety envelopes for the types of work done by Facilities Services.	There is a need for the Laboratory to establish safety envelopes, as defined by DOE M 411.1, for Facilities Services work as soon as possible.
Periodic walkthrough inspections by CH, Ames Group, and the Laboratory failed to identify the hazard.	There is a need for CH to re-examine the adequacy of its oversight. There is a need for CH-Ames Group to re-examine their efforts to ensure that adequate ES&H oversight is provided. There is a need for the Laboratory to re-examine their walkthrough inspection programs.
Work planning was inadequate for the work the Electrician and Mechanic were engaged in at the time of the accident.	There is a need for the Laboratory to establish a procedure for reviewing routine Facilities Services tasks for ES&H requirements (including working alone considerations) prior to the start of work.
No specific training was provided for working on, or near, rotating parts.	There is a need for the Laboratory to provide training specifically focused on the safety aspects of working on, or near, machinery with rotating parts. If warranted, the Laboratory should provide the necessary training.
Although the Electrician received timely medical attention, the Board believes that the emergency response process can be improved.	There is a need for the Laboratory to: • re-evaluate the emergency call system • assure that all potential ambulance responders are familiar with the location of Laboratory facilities • clarify the roles and responsibilities of laboratory personnel responding to fire alarms.

5.0 Board Signatures

Signatures indicate participation in the **DOE Accident Investigation Board** for the Rotating Shaft Accident at the Ames Laboratory of March 27, 1998, and agreement with the contents of this report.

John Adachi, Member
Integrated Safety Management
QA Engineer
Safety & Technical Services
Chicago Operations Office

Michael Saar, Member *
Industrial Safety & Fire Protection
Engineer
Safety & Technical Services
Chicago Operations Office

Craig Schumann, Member *
Safety/Occupational Health Specialist
Argonne Group
Chicago Operations Office

John Scott, Member *
Emergency Response,
Safety & Fire Protection Specialist
Safety & Technical Services
Chicago Operations Office

Michael Teresinski, Member *
Safety Engineer
Office of Laboratory Operations, and
Environment Safety & Health
Office of Energy Research

*/ Denotes trained in DOE Accident Investigation procedures

Anibal L.Taboas, Board Chairperson *
Manager, Environmental Programs Group
Chicago Operations Office
April 11,1998

6.0 BOARD MEMBERS, ADVISORS, AND STAFF

Chairperson	Anibal Taboas, DOE-CH, EPG
Member	John Adachi, DOE-CH, TAS
Member	Michael Saar, DOE-CH, TAS
Member	Craig Schumann, DOE-CH, ARG
Member	John Scott, DOE-CH, TAS
Member	Michael Teresinski, DOE-HQ, ER
Support	
Advisor/Laboratory Interface	Thomas E. Wessels, Ames Laboratory
Analytical	Will Brocker, Argonne National Laboratory
Technical Writer	Michael A. Duffy, Battelle Columbus
Medical Consultant	Francis Strehl, MD, Argonne National Laboratory
Administrative Support	Daria Passo, DOE-CH, EPG
	Gloria Flores, Information Support Services

APPENDIX A

APPOINTMENT MEMORANDUM FOR TYPE B ACCIDENT INVESTIGATION

Department of Energy
Chicago Operations Office
9800 South Cass Avenue
Argonne, Illinois 60439

MAR 3 0 1998

James A. Buchar
Ames Group Manager

SUBJECT: APPOINTMENT OF AN ACCIDENT INVESTIGATION BOARD FOR THE MARCH 27, 1998, INJURY TO AN AMES LABORATORY EMPLOYEE

I hereby establish a Type B Accident Investigation Board to investigate the accident which injured an Ames Laboratory employee in the mechanical room in the basement of the Technical and Administrative Services Facility. I have determined that the accident meets the requirements for a Type B Accident Investigation as required by Department of Energy (DOE) Order 225.1A, "Accident Investigations."

I appoint Anibal L. Taboas, Manager of the Environmental Programs Group, as the Accident Investigation Board Chairperson. The Board Members will be Michael F. Teresinski, Office of Energy Research, Craig Schumann, Chicago Operations Office (CH)-Argonne Group, John Scott, CH-Safety and Technical Services (STS), Michael O Saar, CH STS, and John K. Adachi, CH STS. The Board will be assisted by advisors and other support personnel as determined by the Chairperson.

The scope of the Board's investigation will include, but is not limited to, identifying all relevant facts, analyzing the facts to determine the direct, contributing, and root cause of the accident, developing conclusions, and determining judgments of need that, when implemented, should prevent the recurrence of the accident. The investigation will be conducted in accordance with DOE O 225.1A and will specifically address the role of DOE and contractor organizations and management systems as they may have contributed to the accident. The scope will also include an analysis of the application of lessons learned from similar accidents within the Department.

The Board will provide my office with periodic reports on the status of the investigation, but will not include any conclusions until an analysis of all the causal factors has been completed. Draft copies of the factual portion of the investigation report will be submitted to me, CH-Ames Group and Ames Laboratory, for factual accuracy review prior to the report finalization.

The report should be provided to me by April 29, 1998. Any delay to this date shall be justified and forwarded to this office. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report.

By copy of this memorandum, I am advising the supervisors of each of the Board Members that this assignment is full-time until the investigation and report are completed.

John P. Kennedy
Acting Manager

APPENDIX B
LESSONS LEARNED NOTICE

Title:	Personal Injury in Air Handling Unit
Identifiers:	1998-CH-AMES-0001
Date:	April 2, 1998
Lesson Learned:	The following Lesson Learned is issued to provide preliminary information on the protection of workers performing work in close proximity to mechanical power transmission apparatus. The safeguarding of HVAC equipment by use of an enclosed location does not necessarily prevent exposure to the unguarded motion hazards found within that enclosed location. Access into these areas should be restricted to trained personnel who are aware of the hazards present, that are provided with appropriate tools and safety equipment, and who perform tasks in accordance with established entry procedures. Alternatively, ensure that all motion hazards are fully safeguarded. See American Society of Mechanical Engineers (ASME) B15.1, "Safety Standard for Mechanical Power Transmission Apparatus" for additional information. 29 CFR 1910.219(c)(4)(i) permits a shaft end to project not more than one-half the diameter of the shaft unless guarded by a non-rotating cap or sleeve. However, 29 CFR 1910.219 is based on the 1953 edition of ASME B15.1. The most current (1996) edition of ASME B15.1 no longer makes reference to this practice. This practice has not existed in ASME B15.1 since 1972. Sole reliance on the requirements of Subpart O, "Machinery and Machine Guarding," of the OSHA General Industry Standards should be avoided. The American National Standards Institute (ANSI) B11 machine tool safety standard series, and ASME B15.1, provide supplemental information that represents current industry practices for protecting employees from mechanical equipment hazards. The referenced ANSI and ASME standards can be ordered through http://www.ansi.org.

Discussion of Activities:	Two employees went to the basement of an administration building to evaluate a duct smoke detector that had initiated a fire alarm earlier in the day. The detector was located inside the supply fan room of the air handling unit. The fan was turned off by the employees at the control panel located outside the supply fan room, but both entered before the fan had come to a complete stop. One of the employee's came in contact with the exposed end of the still-rotating 3 inch diameter shaft. The exposed shaft end projects 1-⅞ inches. The force of the rotating fan entangled the employee clothes. Severe injuries resulted to both of the employee's arms due to constriction of the clothing, and to the head and neck due to contact with stationary equipment. The injured employee was airlifted by helicopter to a regional hospital where he is listed in critical condition.
Analysis:	A Type B Accident Investigation Board was appointed on March 30, 1998 by the Chicago Operations Office Manager in accordance with DOE O 225.1A, "Accident Investigations." The Board has been on-site conducting the investigation since March 30, 1998. Final determinations on the accident are pending completion of the investigation. A preliminary finding identified during the investigation is that even though electrical power is disconnected (and locked out) to the motor for an air handling unit, pressure differences within the HVAC system can cause the fan to rotate at significant speed.
Recommended Actions:	The contracting officer directed the installation of appropriate safeguards to the motion hazards found in the supply fan room where the accident occurred. In addition, the contracting officer requested that all remaining mechanical power transmission apparatus be evaluated to identify other existing motion hazards.
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Priority Descriptor:	RED/URGENT
Functional Category:	Worker Process
Keywords:	Machine Guarding, Injury
References:	Occurrence Report, CH-AMES-AMES-1998-0002