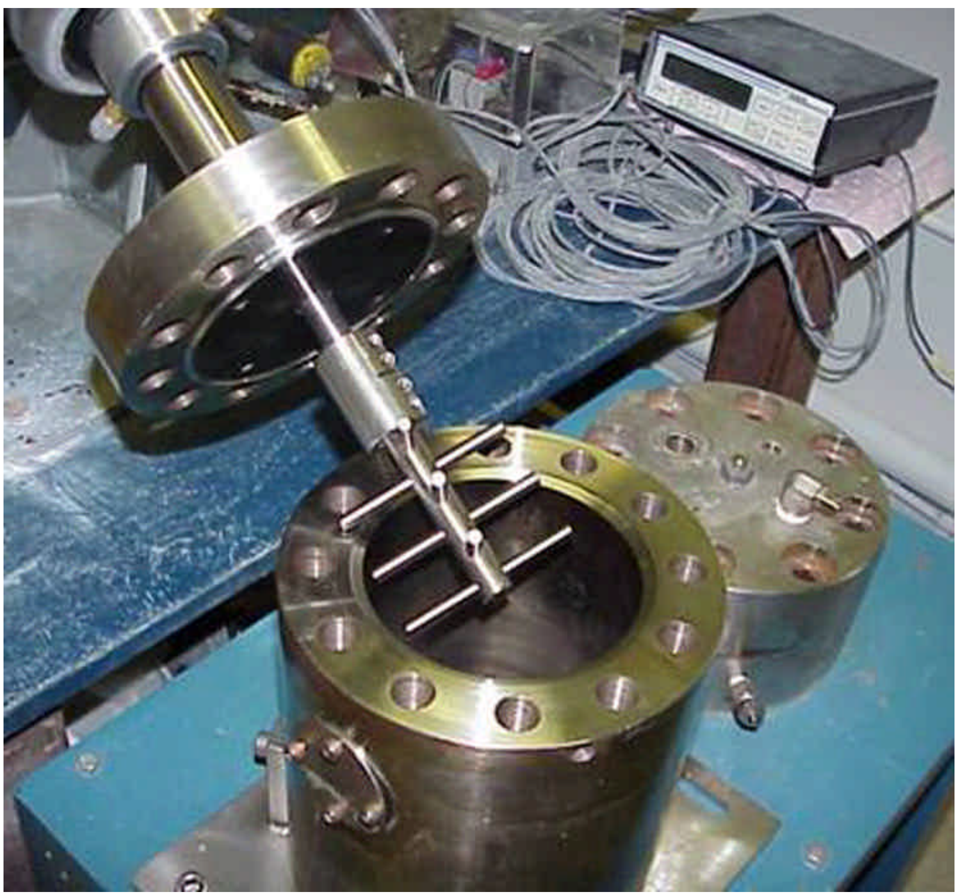
Type B Accident Investigation of the January 10, 2006, Flash Fire and Injury at the Savannah River National Laboratory



February 2006
Savannah River Operations Office
U.S. Department of Energy

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DISCLAIMER

This report is an independent product of the Type B Accident Investigation Board appointed by Jeffrey M. Allison, Manager, Savannah River Operations Office, U.S. Department of Energy.

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 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.

RELEASE AUTHORIZATION

On January 12, 2006, I appointed a Type B Accident Investigation Board (Board) to investigate the January 10, 2006, flash fire and injury event at the Savannah River National Laboratory. The Board's responsibilities have been completed with respect to this investigation. The analyses and the identification of the contributing causes, the root cause, and the Judgments of Need resulting from this investigation were performed in accordance with DOE O 225.1A, *Accident Investigations*.

I accept the report of the Accident Investigation Board and authorize its release for general distribution.

Jeffrey M. Allison
Manager
Savannah River Operations Office

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FIGURES AND TABLES

ACRONYMS AND ABBREVIATIONS

AMNMSP	Assistant Manager of Nuclear Materials Stabilization Project
Board	Accident Investigation Board
DOE	U.S. Department of Energy
EMS	Emergency Medical Services
ES&H	Environment, safety, and health
EH	Headquarters Office of Environment, Safety and Health
FLM	First-Line Manager
FR	Facility Representative
FRAP	Functions, Responsibilities, and Authorities Procedure
HAP	Hazard Analysis Package
IPA	Isopropyl alcohol
ISC	Incident Scene Coordinator
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
JCO	Justification for Continued Operation
JHA	Job Hazards Analysis
LFL	Lower flammability limit
MS&T	Materials Science and Technology
NMED	Nuclear Materials Engineering Division
NMOD	Nuclear Materials Operations Division
OESH	Savannah River Office of Environment, Safety, and Health
ORPS	Occurrence Reporting and Processing System
OSHA	Occupational Safety and Health Administration
PI	Principal Investigator
psi	Pounds per square inch
R&D	Research and Development
rpm	Revolutions per minute
S/RID	Standards/Requirements Identification Document

SIRIM..Site Item Reportability and Issue Management
SME ....Subject matter expert
SR...Savannah River Operations Office
SRNL ....Savannah River National Laboratory
SRS...Savannah River Site
SRSOC...Savannah River Site Operations Center
TRU..Transuranic
WFO ....Work for Others
WSI ....Wackenhut Services, Inc.
WSRC ....Washington Savannah River Company

EXECUTIVE SUMMARY

The Accident

On January 10, 2006, at approximately 7:47 a.m., a first-line manager (FLM) at the Savannah River National Laboratory (SRNL) received first- and second-degree burns to his head, face, neck, and left hand that required hospitalization after a flash fire occurred during equipment cleaning operations in SRNL Laboratory D-1169.

On January 12, 2006, the Manager of the Department of Energy (DOE) Savannah River Operations Office (SR) appointed a Type B Accident Investigation Board (Board) to analyze causal factors, identify root causes, and determine Judgments of Need related to the accident to preclude similar accidents in the future.

The Board began its investigation on January 17, 2006, and completed the investigation on February 14, 2006.

Background

SRNL is an applied research and development (R&D) laboratory located at the Savannah River Site (SRS). Total SRNL staff numbers approximately 870, with a research staff of approximately 670, including chemists, physicists, biologists, microbiologists, and a variety of scientists, engineers, and technicians, of whom 25 percent hold Ph.D. degrees. At the time of the accident, the work being conducted in D-1169 centered on a Work for Others (WFO) program to process metal powders in support of automotive hydrogen fuel cell research. The DOE Savannah River Operations Office is responsible for oversight of WSRC and SRNL activities. Washington Savannah River Company (WSRC) is responsible for the management and operation of the SRNL.

Results and Analysis

The SRNL *Conduct of R&D Manual* defines and implements the Laboratory's Integrated Safety Management program, and establishes SRNL management expectations and requirements for conducting research. The accident resulted from a number of deficiencies in the implementation of SRNL work control processes and informality in execution of the requirements contained in the *Conduct of R&D Manual*.

The tasks being conducted in D-1169 on January 9 and 10, 2006 were the final activities associated with a project phase that began on November 1, 2005. The project was designed to manufacture and study the hydrogen storage capability of various compounds (alanates) for the automotive industry. Actual planning for the project began in 2004. The first hazard assessment was developed by a job hazard analysis (JHA) preparer and the personnel assigned to manufacture alanate, and the initial JHA was approved for use on July 20, 2004. As part of the preparation for processing alanate, a glovebox capable of maintaining an inert environment was installed in D-1169. The inert environment was required because the materials to be manufactured would react with air and moisture.

A fire in D-1169 in February 2005 resulted in the reevaluation of work practices and controls associated with powdered-metal handling, material compatibility, and flammable material storage issues. Although the February 2005 fire was not directly related to the proposed alanate processing, the corrective actions from the fire resulted in a revision to the hazard assessment for the alanate processing task on April 26, 2005. Neither of the hazard assessments conducted for alanate processing identified the key work steps associated with using alcohol to clean equipment or components outside the inert glovebox. SRNL had documentation available that clearly indicated that alanates react with alcohols.

The Materials Science and Technology (MS&T) Directorate presented corrective actions taken in response to the February 2005 fire in D-1169 to the SRNL Laboratory Director and the Safety and Quality Council on April 26, 2005, and requested authorization to resume activities in D-1169. As a result of that presentation, the Laboratory Director and the Safety and Quality Council prohibited the use of alcohols to clean alanate process components outside the inerted glovebox in D-1169. This prohibition was verbal and was not documented in meeting minutes, management-level directives, or other instructions.

On June 27, 2005, MS&T line management issued e-mail guidance on the use of alcohol in D-1169, stating, in part, "The attached contains the SRNL-management-approval alcohol management plan for D-1169 can be cut and pasted into your Con R&D packages and Work Instructions." The instruction, addressed to personnel assigned to work in D-1169 at the time, stated that "Ethanol may be used for de-greasing and cleaning nanomaterials from processing components and process apparatus. This cleaning is not typically a passivation step, and a defined passivation process must be in place." Although these instructions were contrary to the prohibitions on alcohol use established by the Laboratory Director and the Safety and Quality Council, neither the instructions nor the prohibition against alcohol use for cleaning process components or apparatus were incorporated into the documents used to establish the safety envelope for the alanate processing task in D-1169.

Between November 1, 2005 and January 10, 2006, 10 batches and 3 reruns of alanate were produced. The attritor vessel used in this process was loaded in the inert glovebox, sealed, and transferred out of the glovebox to the attritor mill. Each time the assembled attritor vessel was removed from the glovebox, it was wiped with isopropyl alcohol to remove material that adhered to its surface.

SRNL line managers did not ensure that the entire scope of the work during the alanate processing task was identified and analyzed. Although similar deficiencies were identified during the safety inspection following the February 2005 fire, no process was implemented to verify that reactive materials in and on the attritor vessel had been effectively removed or passivated. When the attritor vessel was removed from the glovebox on January 10, 2006 in a disassembled state to prepare it for storage, reactive alanate materials remained in the vessel boltholes. Consequently, exposing the vessel to room air, moisture, or isopropyl alcohol caused the residual unpassivated alanate material in the boltholes to react. The reaction ignited the isopropyl alcohol vapor plume generated during the cleaning, and resulted in the flash fire that burned the FLM.

The weaknesses in executing the Integrated Safety Management program enabled the FLM and researcher to conduct cleaning operations using an expert-based approach without a defined scope of work. No task-specific hazard analysis was conducted for this aspect of the task; consequently, appropriate work controls were not implemented. The absence of formal line management awareness and authorization permitted the FLM and researcher to continue the attritor cleaning activities that ultimately resulted in the accumulation of isopropyl alcohol vapors exceeding the lower flammability limit.

Conclusion

The Board concluded that this accident was preventable. The **direct cause** of the accident was the ignition of IPA vapors by reacting with alanate during attritor vessel cleaning operations outside the inert glovebox. The burning vapors came into contact with the FLM, causing first- and second-degree burns.

The Board determined that the **root cause** was the failure to define the complete scope of work, resulting in a failure to identify and mitigate the isopropyl alcohol hazard during cleaning operations.

The Board identified weaknesses in the implementation of Integrated Safety Management System policy pertaining to attritor mill cleaning activities performed on or before the day of the accident. These weaknesses impacted the effectiveness of worker safety and health protection, including the processes for translating safety policy into implementing procedures, and the implementation of line management's Integrated Safety Management responsibilities established by the *Conduct of R&D Manual*.

Although SRNL line managers responsible for work conducted in D-1169 on the day of the accident were engaged in work monitoring and follow-up activities to ensure that work was planned, hazards were analyzed, and controls were developed and implemented, the fact that key task steps were omitted from the defined scope of work was not recognized. SRNL had established formal criteria for determining when task-specific hazard analyses should be performed and documented. However, the process was not effectively executed during the hazard assessment process for attritor cleaning activities that occurred 13 times during November and December 2005, and culminated in a worker injury during the final cleaning activity on January 10, 2006. Table ES-1 below presents the Board's conclusions and Judgments of Need.

Table ES-1. Conclusions and Judgments of Need

Conclusions	Judgments of Need
Equipment cleaning and restoration was not included in the work scope for processing alanate. Because the scope of work for alanate processing was incomplete, the Hazards Assessment failed to identify and mitigate the hazards of isopropyl alcohol use outside the glovebox. Because the scope of work was never fully defined, line management failed to ensure the development and implementation of adequate controls to protect workers during the cleaning of the attritor vessel with isopropyl alcohol outside of the inert glovebox. Based upon evidence of chemical use and the absence of industrial hygiene monitoring in the workplace, the potential existed for an unmonitored exposure of personnel to isopropyl alcohol during attritor cleaning operations in D-1169.	WSRC needs to ensure that the scope of work for R&D activities at SRNL is defined in sufficient detail such that the hazard assessment process can be effectively applied.
The corrective actions implemented as a result of the D-1169 fire on February 14, 2005 were narrowly focused and were not applied to a broader range of laboratory activities.	WSRC needs to determine why the corrective actions taken in response to the February 2005 fire were not effective in preventing this accident.
The formality of operations required by the SRNL *Conduct of R&D Manual* was not effectively implemented for the alanate processing activity.	WSRC needs to ensure that SRNL R&D activities are conducted with the level of rigor and formality required by the *Conduct of R&D Manual*. WSRC needs to ensure that SRNL includes the controls identified in the hazards assessment process in the procedure or instructions used to conduct the work.

Conclusions	Judgments of Need
Process steps were performed during alanate processing activities that were not addressed by procedure, Work Instruction, JHA, or Notebook controls.	WSRC needs to ensure that skill-of-the-craft activities are identified during the work planning phase of SRNL R&D projects so that the hazard assessment process can identify appropriate controls.
Although their actions were commendable, Operations first responders placed themselves at risk by entering an unknown and uncharacterized environment without knowledge of the hazards that could be present.	WSRC needs to develop, implement, and institutionalize mechanisms to ensure that SRNL Operations first responders are provided with accurate and sufficient information to make informed decisions regarding their prospective actions in responding to an incident.
The Board concluded that low-hazard, non-nuclear work activities are not being assessed.	DOE-SR needs to re-evaluate assessment priorities related to low-hazard, non-nuclear work activities when developing their annual assessment plans to ensure that the appropriate level of oversight is provided.
The Board concluded that AMNMSP does not have a safety and health SME that could assist the FRs and lead safety and health assessments in AMNMSP facilities.	DOE-SR needs to ensure that oversight and assistance responsibilities contained in the FRAP are adequately staffed to ensure that safety and health work activities are assessed.
The procedures used for accident scene management required by DOE Order 225.1A were adequate, timely, and effective.	
The emergency response was timely and well coordinated.	
The MS&T Director was actively involved with personnel through the self-assessment program and other avenues.	
The MS&T Directorate had developed, implemented, and maintained an active self-assessment process.	

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1 INTRODUCTION

1.1 Work Activity Background

In addition to its applied science missions for the Office of Environmental Management and the National Nuclear Security Administration, the Savannah River National Laboratory (SRNL) conducts a variety of research on alternative energy systems, including research in support of the "hydrogen economy." SRNL has experience in developing and handling powdered metals and metal hydrides (alanates) that have been proposed for use in hydrogen storage applications. The SRNL Materials Science and Technology (MS&T) (formerly the Materials Technology Section) and the Hydrogen Technology Directorates were cooperatively participating in a research project to investigate the feasibility of using a hydrogen storage cell in a vehicle fuel system. The cell consisted of a storage container filled with an absorbent material onto which hydrogen would be absorbed and desorbed.

Alanate: A class of materials being studied for potential use as an absorbent in hydrogen storage applications. Alanates are hydrides of aluminum with an alkali metal such as sodium or lithium and possibly other metals such as titanium.

The absorbent material was a blend of very fine alanate powder, which is pyrophoric (reactive with water, alcohols, and acids). The objective of this research project was to study the performance and physical characteristics of the cell during absorption-desorption cycles. The project scope included several tasks, including preparing a designated quantity of alanate powder for testing; loading the powder into a fuel-storage test cell designed and supplied by the corporate sponsor; conducting absorption-desorption tests on the assembled test vessel; and analyzing the test data.

In order to produce the required amount of alanate powder, SRNL personnel produced 10 batches of material, each about 400 grams in weight, for a total production of approximately 4 kilograms. The personnel prepared each batch of alanate powder by mixing and grinding commercially available sodium aluminum hydride, aluminum powder, and a catalyst in an attritor mill (Figure 1-1) under a high-pressure hydrogen atmosphere. Details of this work are provided in Section 3.2.

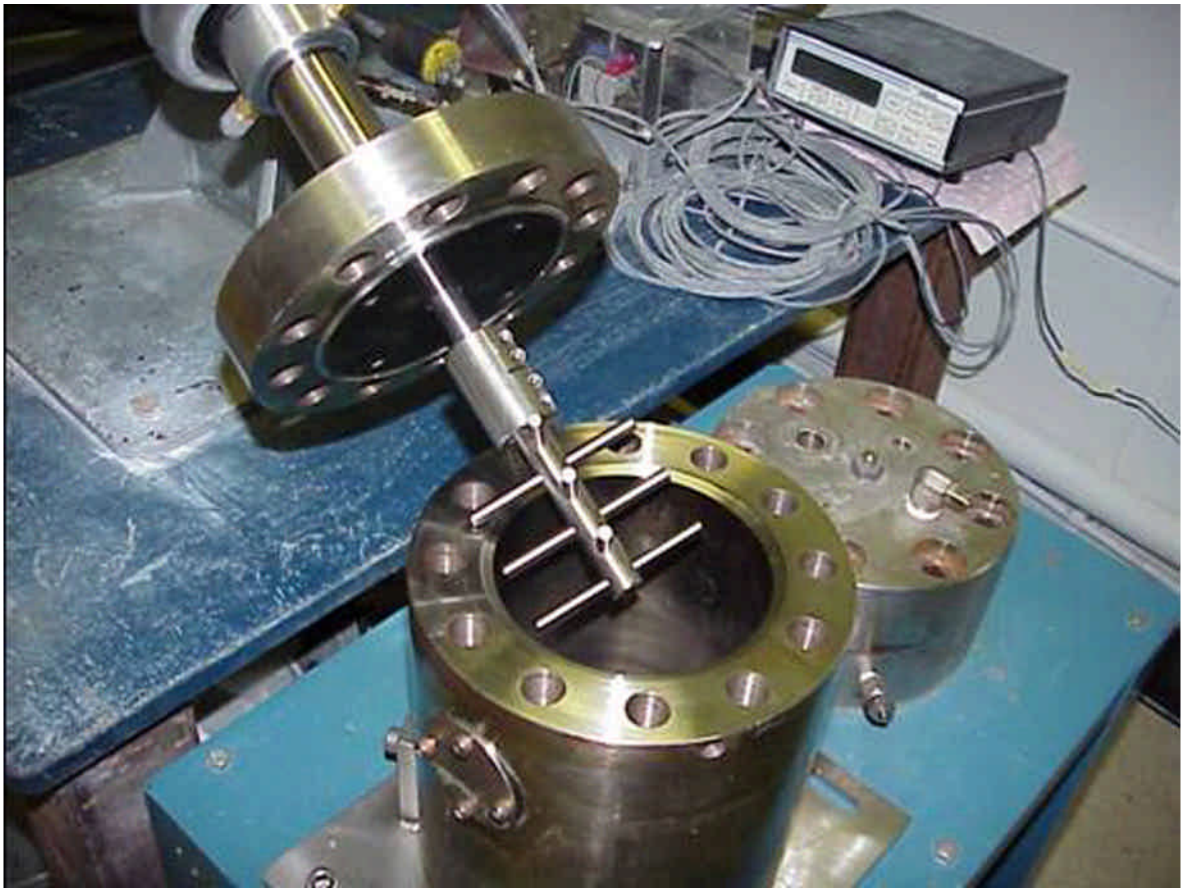

Figure 1-1. Disassembled attritor mill

The researchers had completed the first task, producing the alanate blend for testing. They were preparing for the second task by cleaning the equipment used to produce the powder and cleaning out the inert-atmosphere glovebox when the accident occurred.

1.2 Facility Description

SRNL is an applied-research and development (R&D) laboratory located at the Department of Energy (DOE) Savannah River Site (SRS) near Aiken, South Carolina. Established in 1951 as the Savannah River Laboratory to provide technology R&D support for the Savannah River Plant, researchers developed technological solutions for building and operating five nuclear production reactors and related facilities at the site. Over the intervening years, the Laboratory developed expertise in hydrogen technology, materials science, environmental research, robotics engineering, analytical chemistry, hazardous materials stabilization, and technologies for nonproliferation and national security.

In 2004, in recognition of the Laboratory's service to the nation, SRNL was designated as the country's twelfth national laboratory. Total SRNL staff numbers approximately 870, with a research staff of approximately 670 that includes chemists, physicists, biologists, microbiologists, and a variety of scientists, engineers, and technicians, of whom 25 percent hold Ph.D. degrees. The DOE Savannah River Operations Office (DOE-SR) is responsible for oversight of the Washington Savannah River Company (WSRC) and SRNL activities. WSRC is responsible for the management and operation of SRNL.

At the time of the accident, the work being conducted in the Advanced Particulate and Nanomaterials Processing Laboratory (D-1169) centered on a Work for Others (WFO) program to process alanate powders. The layout of D-1169 is shown in Figure 1-2.

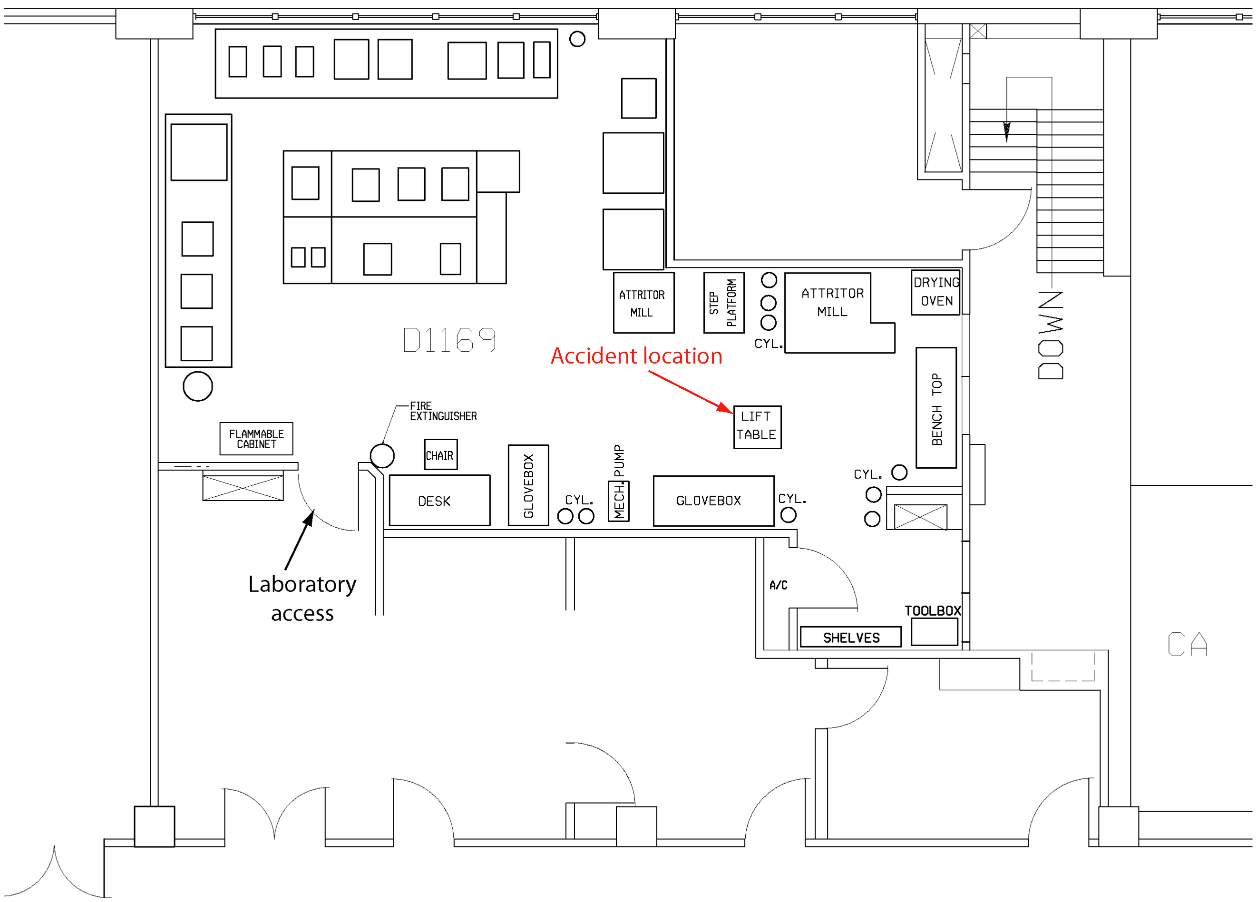

Figure 1-2. D-1169 layout

1.3 Scope, Purpose, and Methodology

The Board began its investigation on January 17, 2006, completed the investigation on February 14, 2006, and submitted its final report to the DOE-SR Manager on February 22, 2006. The scope of the Board's investigation was to review and analyze the circumstances surrounding the accident. The purpose of the investigation was to determine the causes of the accident, including deficiencies, if any, in safety management systems, and to assist DOE in understanding lessons learned to reduce the potential for similar accidents. To accomplish its mission, the Board also focused on the role of DOE and contractor organizations, the Integrated Safety Management (ISM) systems associated with the accident, and the application of lessons learned from similar accidents within DOE, including a previous fire that occurred in the same laboratory on February 14, 2005, which is discussed in Section 3.6. A partial SRNL organization chart is shown in Figure 1-3.

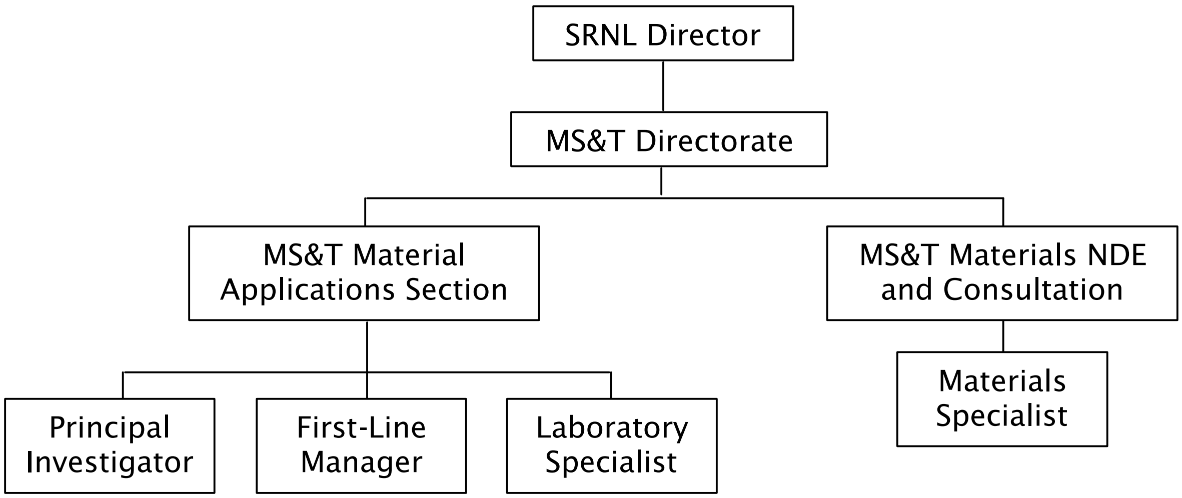

Figure 1-3. SRNL line organization chart

The Board conducted its investigation using the following methodology:

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

ACCIDENT INVESTIGATION TERMINOLOGY

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

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

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

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

2 THE ACCIDENT

2.1 Accident Overview

On January 10, 2006, at approximately 7:47 a.m., a first-line manager (FLM) at SRNL received first- and second-degree burns to his neck, head, face, and left hand that required hospitalization after a flash fire occurred during equipment cleaning operations. Local smoke detectors automatically activated, and the SRS Fire Department, Emergency Medical Services (EMS), and Security personnel responded to the alarm. There are no installed automatic fire-suppression systems in D-1169. Before EMS personnel arrived, SRNL first aid-trained employees responded to the accident scene and administered preliminary assistance to the FLM. At the FLM's request, he was initially transported to the SRS on-site medical facility by EMS personnel, where he was evaluated by site medical staff and subsequently transferred to the Burn Unit at Doctor's Hospital in Augusta, Georgia. The FLM returned to work on January 18, 2006.

On January 12, 2006, the DOE-SR Manager appointed a Type B Accident Investigation Board to investigate the accident in accordance with DOE Order 225.1A, *Accident Investigations*. A copy of the appointment memorandum appears in Appendix A.

2.2 Accident Description

On January 9, 2006, the FLM and a principal investigator (PI) passivated the top half of the attritor mill inside a glovebox inerted with argon gas in D-1169. That same day, the FLM and PI removed the top half of the attritor mill from the glovebox, wiped it down with isopropyl alcohol (IPA), and placed it on a bench in the laboratory. The PI then passivated the bottom half of the attritor mill (vessel). On the morning of January 10, the FLM and PI removed the vessel from the glovebox onto a lifting table and then moved the lifting table to a nearby open area for cleaning. They placed disposable wipes in a metal pan and soaked them with IPA using a plastic squeeze bottle. Interview statements indicated that normal practice for cleaning the assembled mill outside the glovebox was to saturate the wipes in the pan and then wipe the mill; alcohol was not squirted directly onto the mill.

> ***Passivation:*** As applied to the alanate materials processing work at SRNL, passivation is understood to mean oxidation of the metal hydride using a liquid such as alcohol or water so that the material will not react in air.

About 20 minutes into the wiping evolution, the FLM observed smoke rising from two of the boltholes. The PI wiped that area, but the smoke continued. The FLM had turned to retrieve a fire blanket when the flash fire occurred. The FLM, seeing flames on his sweater, dropped to the floor and rolled to put out the fire. Interview statements indicated that the PI smothered the flames on the vessel, wipes, and floor with MET-L-X® (an extinguishing agent for metal fires). He then threw the fire blanket over the vessel and later put the vessel back into the glovebox antechamber. Figure 2-1 illustrates the glovebox and antechamber.

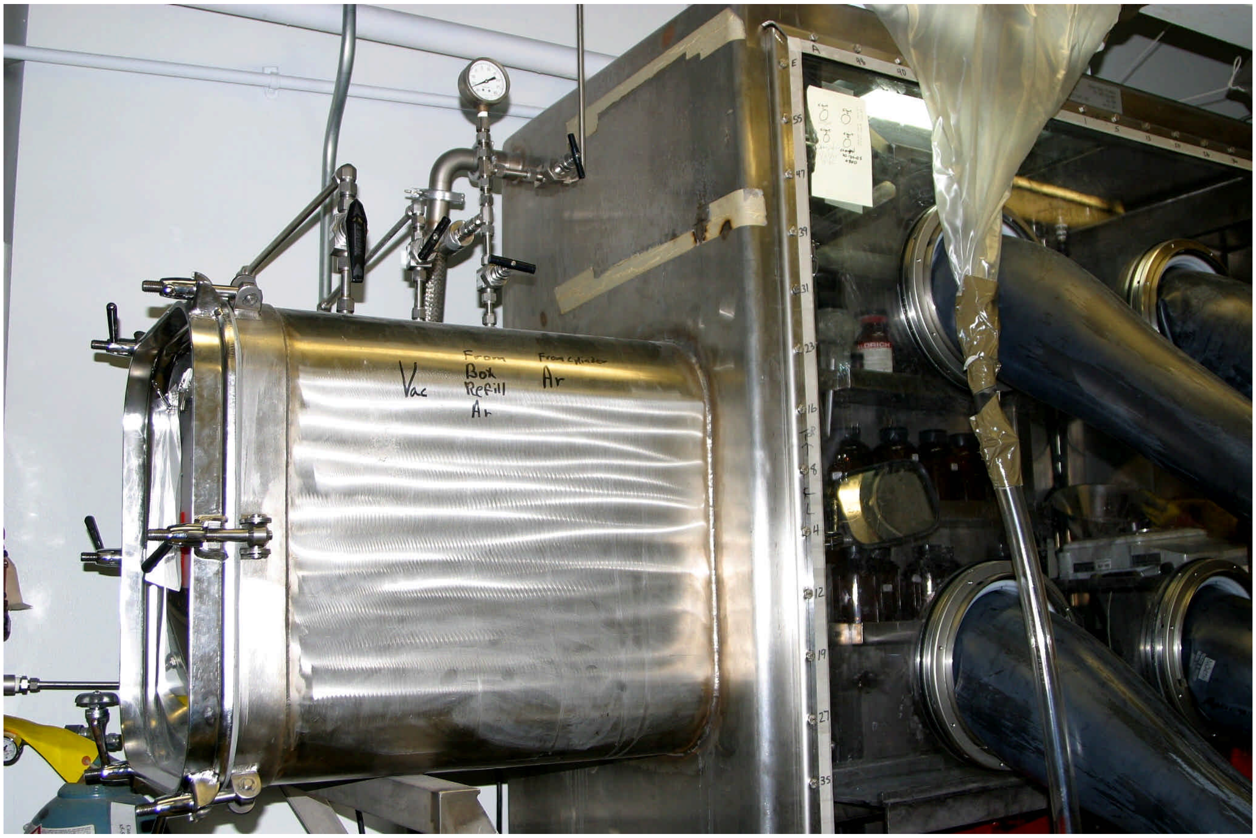

Figure 2-1. Glovebox and antechamber

Two other employees were working in the laboratory at the time of the accident. The FLM directed one of these employees to notify the control room. Both employees exited to the rally point when the Operations first responders arrived.

2.3 Engineering Evaluation of Ventilation Flows in D-1169

At the Board's request, SRNL personnel conducted, and a Board Member witnessed, airflow pattern tests in D-1169 on February 1, 2006. The tests were conducted to determine the extent to which IPA vapor could accumulate in the work area occupied by the two SRNL employees involved in the flash fire, as well as to evaluate the potential for a flashback ignition of the alcohol vapor by an ignition source remote from the immediate work area. Three tests were conducted: (1) supply airflows and pressure differentials were measured using standard instruments, (2) visible airflow patterns were observed using Borazin® (zinc stearate) powder, and (3) visible airflow patterns were observed using a glycol test aerosol.

The airflow measurements show that D-1169 is slightly pressurized with respect to the FLM's office and an adjoining contamination area. The testing documented minimal airflow at the working level where the cleaning operations were being conducted by the PI and FLM, but presented clear indications of stronger airflow at the floor level. When testers used a one-gallon paint can filled with aerosol to simulate the vessel and perform a more controlled smoke release, the aerosol, being heavier than air, settled into the can and was not disturbed by ambient air currents. Testers had to reach in and stir the aerosol by hand to clear the can.

The Board determined that any IPA vapor plume that could be present at floor level during attritor cleaning activities in D-1169 would sweep toward the contamination area. The Board also determined that, based on D-1169 airflow test results, flammable concentrations of IPA vapor generated during the cleaning operation accumulated in the attritor vessel.

2.4 Flash Fire Analysis

A fire requires the presence of four elements: oxygen, fuel, heat, and a chain reaction (the Fire Tetrahedron). For the January 10, 2006 event, the room air provided the oxygen source. The principal fuel was IPA vapor. Witness statements indicated that electronic grade IPA, (91 percent alcohol by volume), was applied to soak disposable wipes that were then used to wipe down the attritor vessel. Some of the alcohol evaporated during cleaning operations. IPA vapor is flammable in air at concentrations between 2 and 12 percent by volume. The airflow test conducted in D-1169 (see section 2.3) revealed minimal airflow in the area occupied by workers involved in the cleaning operation. A stagnant zone existed within the vessel cavity where the flammable vapor concentration accumulated. The uninhibited chain reaction produced sufficient exothermic reaction energy to support ignition.

If present, residual alanate would also provide a fuel source for the initial ignition. Alanate reacts with water to produce hydrogen and heat along with metal hydroxides. Similar hydrogen-producing reactions occur with other oxidizers such as air and alcohol. As long as sufficient quantities of the alanate and the oxidizer are present, the chain reaction will continue.

The Board considered three possible ignition sources for the flash fire: (1) reaction of residual alanate contamination on the vessel with air, moisture, or IPA; (2) flashback from a remote ignition source along a floor-level IPA vapor plume; and (3) a discharge of static electricity.

The first ignition source considered by the Board was the reaction of alanate residue with air, moisture, or IPA. The Board considered the following evidence in conducting this analysis:

- Alanate powder was unloaded from the vessel in the inert glovebox with a scoop. A small brush was used to sweep alanate powder that had spilled onto the vessel rim back into the vessel cavity. The Board determined that material spillage during the vessel unloading process resulted in alanate material accumulating in the boltholes.

- The boltholes were not thoroughly cleaned during the passivation process.
- The FLM stated that he saw "smoke" near two of the boltholes just before the flash occurred. The Board determined that the smoke was the visible reaction product of the alanate with IPA, moisture, or air.
- Photographs and visual inspections of the attritor vessel on January 27, 2006 showed discoloration in two of the twelve boltholes (Figure 2-2), the rim, and the interior surfaces of the vessel. These surfaces had not been exposed to air during the previous attritor vessel cleanings because the attritor mill was assembled and disassembled inside the inerted glovebox.

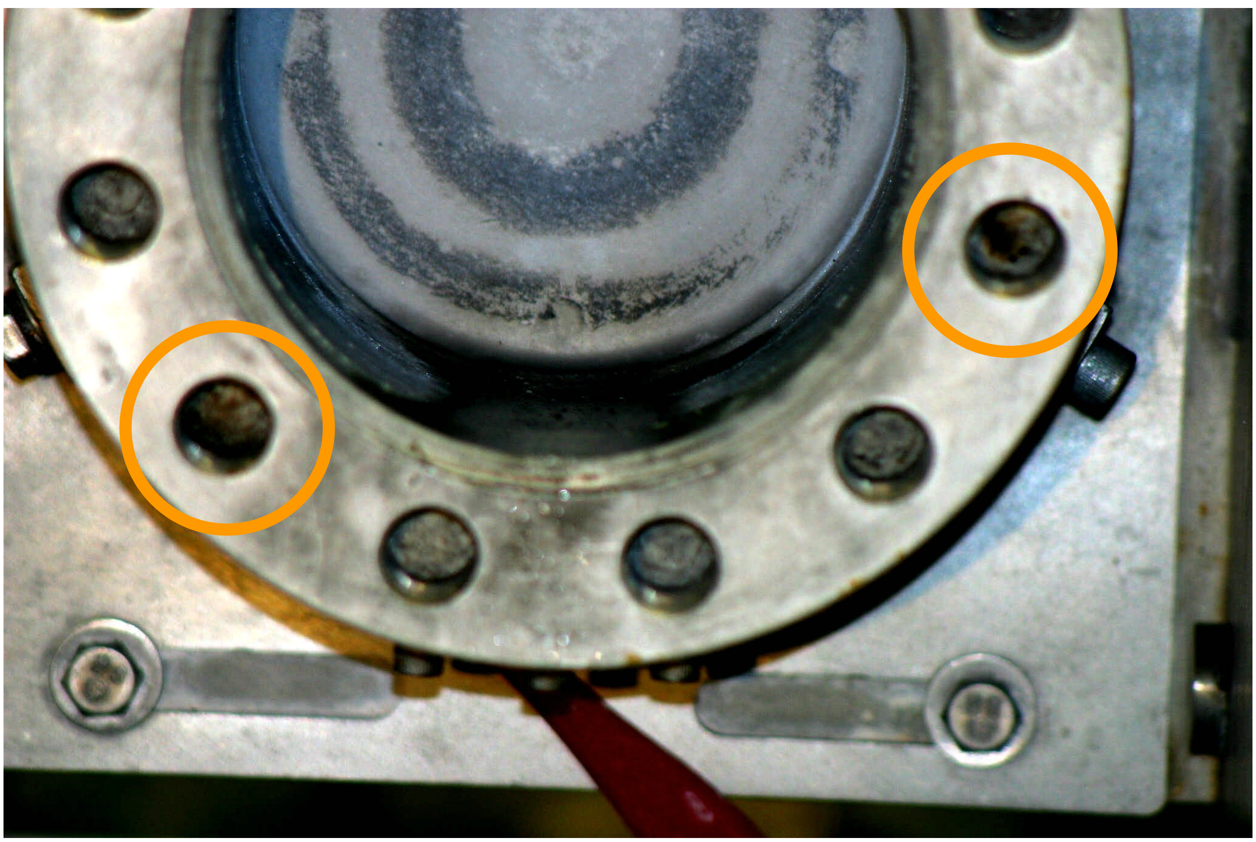

Figure 2-2. Discoloration in the boltholes

A second ignition source considered by the Board was flashback along the IPA vapor plume generated during the cleaning operation. The Material Safety Data Sheet (MSDS) for IPA states that the vapors, which are heavier than air, may sink and travel considerable distance to a remote ignition source. The Board observed that there are several electrical outlets and one motor within 10 feet of the work location, none of which was intrinsically safe. Evidence collected during the airflow test performed in the laboratory on February 1, 2006, documented minimal airflow at the working level for the cleaning operation but a stronger airflow at floor level, with directional flow away from the potential ignition sources. Based upon these airflow test results, the Board eliminated flashback along a floor-level IPA vapor plume as a potential source of ignition.

The Board also analyzed a third possible ignition source, static electricity discharge ignition of IPA vapors present in the work area. Static electricity is associated with dry air and synthetic fabrics. Evidence obtained by the Board indicates that, based on reported weather conditions on the morning of the accident and the supply air heating setpoint, the relative humidity in the laboratory was approximately 60 percent (i.e., not dry air). Evidence indicates that both the PI and FLM were wearing natural-fiber clothing on the day of the accident. The Board determined that ambient humidity, as well as the composition of the clothing worn, would not be conducive to static electricity generation. Based on this evidence, the Board eliminated a discharge of static electricity as a potential ignition source.

Based upon its evaluation of the evidence, the Board determined that the reaction of air, moisture, or IPA with residual alanate in the vessel boltholes was the most likely ignition source for the alcohol vapor flash fire.

2.5 Emergency Response and Medical Treatment

Emergency response to the accident consisted of (1) the initial response to the scene by Operations first responders, (2) EMS and Fire Department personnel response to the accident scene; (3) the transport of the injured FLM to the onsite medical facility, and (4) the transfer of the injured FLM to the hospital.

After the flash fire occurred, the FLM stated that he dropped and rolled on the laboratory floor in an attempt to extinguish flames on his sweater. When the fire was extinguished, the FLM directed a technician in the laboratory to contact the control room to report the fire. Less than a minute after the fire, a first-aid-trained Operator arrived at the scene. Additional Operations personnel arrived and called the control room to request medical assistance for the injured FLM. The first Operator to arrive stated that she saw considerable smoke and haze in the room, peeked around the door, and saw personnel moving about in the laboratory. The Operator further stated that the PI opened a side door to the adjoining contamination area, which immediately allowed the smoke to vent from the room.

Savannah River Site Operations Center (SRSOC) records obtained by the Board indicate that the fire call was received at 7:47 a.m. and that emergency units were dispatched at 7:49 a.m. Fire Department and EMS units arrived at D-1169 at about 7:52 a.m. A Fire Department Captain evaluated the incident scene and informed his EMS personnel that turnout gear was not required for entry into the laboratory. Because the SRSOC had dispatched all available units to SRNL following the fire call, he also terminated the response by the other Fire Department and EMS units from across the site.

Because the FLM initially refused medical treatment, EMS personnel discussed the need for treatment with him. At the FLM's request, he was initially transported to the onsite medical facility, where he was evaluated by site medical staff and, by 8:45 a.m., was en route to the Burn Unit at Doctor's Hospital in Augusta, Georgia. The FLM sustained first- and second-degree burns to the right side of his head, face, and neck, and on his left hand. This burn pattern was consistent with the FLM's statements that he had turned to the left to retrieve a fire blanket when the flash fire occurred, thereby exposing his right side to the flame. The burns on his left hand were also consistent with his statements regarding his attempt to extinguish the fire on the right side of the sweater he was wearing at the time of the accident. The FLM returned to work on January 18, 2006, and was interviewed by the Board the same day.

The Board concluded that the emergency response was timely and well coordinated.

The Board evaluated the training provided to Operators assigned to provide first response to emergencies at SRNL. SRNL procedure EPIP-LSD-300, *SRNL Fire Response Procedure, SRNL Technical Area*, Revision 5, dated May 23, 2005, provides instructions to SRNL personnel on responding to fire alarms or discoveries of fire or smoke. Attachment 1, *Shift Manager/Facility Emergency Coordinator Fire Response Instructions,* states that "Personnel will not enter potentially unsafe areas or facilities without the approval of the Facility Emergency Coordinator/Emergency Duty Officer."

The procedure in Attachment 1 provides position-specific response actions for fire response that depend on how the fire alarm is received. In all cases, Operations personnel are directed to the location of the fire to assess the situation and report back to the Control Room. Attachment 1 authorizes the Operations Shift Manager to dispatch an individual trained in first-aid or cardiopulmonary resuscitation to the requested location as necessary. Attachment 3, *ISC* [Incident Scene Coordinator] *Response Instructions*, Response Action 1 requires the ISC to consider the potential for exposure to radioactive or toxic materials or explosions. However, in the next action, the ISC is instructed to "Proceed immediately to the fire alarm zone and determine location, type, and extent of fire then report the situation to the Facility Emergency Coordinator or Control Area Operator."

The Board noted that the SRNL procedure for Operations first responders assumed that responding personnel had some level of knowledge of the potential hazards to which they could be exposed. Statements indicate that emergency response personnel across the SRNL rely on postings for information regarding the hazardous materials that could be present in a given room or laboratory. The Board noted that the Laboratory Hazard Summary for D-1169 was placed on the door to the laboratory, but was not visible to responding personnel because the door was open. The Board also observed that the Laboratory Hazard Summary indicated that there were no flammable materials present in the room, and that it had not been updated to reflect the current hazardous materials inventory of the room since August 15, 2005. The Board observed, during a tour on January 17, 2006, that flammable materials were stored in D-1169.

While their desire to provide aid to an injured employee was commendable, Operations personnel responding to the flash fire in D-1169 stated that they observed smoke and haze in the room atmosphere, but were not cognizant of the source or composition of the smoke or whether it could present an inhalation health hazard. Instead of evacuating the remaining personnel in D-1169 to a known safe location and turning the response over to the SRS Fire Department, Operations first responders opted to enter the unknown room atmosphere and provide first-aid treatment inside D-1169. SRNL management stated that first responders decide whether to enter an unknown or potentially harmful area to rescue or assist personnel. However, the Board noted that accurate and sufficient information should be provided to first responders so they can make informed decisions regarding their prospective actions in responding to an incident, particularly given the varied nature of materials, processes, and hazards found at SRNL.

The Board concluded that although their actions were commendable, Operations first responders placed themselves at risk by entering an unknown and uncharacterized environment without knowledge of the hazards that could be present.

2.6 Investigative Readiness and Accident Scene Preservation

DOE O 225.1A, *Accident Investigations*, Attachment 1, "Contractor Requirements Document," paragraph 2, requires that contractors develop provisions for supporting Type A and B accident investigations and that contractor staff establish and maintain a site readiness capability to preserve an accident scene. SRNL implements the requirements of DOE O 225.1A through a variety of requirements documents, including:

- WSRC Manual 9B, *Site Item Reportability and Issue Management (SIRIM),* Procedure 1-0, Revision 2, "Occurrence Reporting," dated October 15, 2004. This procedure requires actions to be taken to preserve and document accident scene conditions for continued investigation through photography and other means, when appropriate.

- WSRC Manual 2S, *Conduct of Operations*, Procedure 5.2, Revision 6, "Investigation of Abnormal Events," dated June 30, 2005. This procedure outlines the incident critique process for the site.

- WSRC Manual 8Q, *Employee Safety*, Procedure 8Q-18, Revision 9, *Reporting, Responding, Investigation, and Recording of Occupational Injury/Illness or Near Miss*, dated June 24, 2003, Attachment B, "General Investigating Guidance for Injuries/Illnesses." This Attachment contains guidance on accident scene preservation, as well as the actions to be taken by contractor representatives immediately following an accident.

- WSRC Manual SCD-7, Revision 3, dated March 8, 2004, Section 9, *Recovery and Reentry*, contains requirements for control of the incident scene such that it will be preserved until cognizant investigative authority concurs that recovery or normal operations may be resumed.

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

- Evidence provided to the Board consisted of photographs of the accident scene that were taken by an SRNL employee and initial witness statements collected by the readiness team. Evidence was accumulated by the DOE readiness team and transferred directly to the Board.

- Effective and timely access controls were instituted to preserve the accident scene and to ensure that the area was properly secured to prevent alteration or removal of evidence.

The Board concluded that the procedures used for accident scene management required by DOE Order 225.1A were adequate, timely, and effective.

3 ACCIDENT FACTS AND ANALYSIS

3.1 SRS and SRNL ISM Processes

This section addresses the facts related to the accident, along with the results of the Board's analysis. The Board presents this information in terms of the ISM Core Functions, which comprise the fundamental DOE safety and health policies that should be incorporated into all work planning and execution.

The DOE Integrated Safety Management System (ISMS) is described in DOE P 450.4, *Safety Management System Policy*. SRS's ISMS implementation is described in WSRC-RP-94-1268, *Integrated Safety Management System Description,* which is part of the Standards/Requirements Identification Document (S/RID) that is included in DOE Contract DE-AC09-96SR18500. WSRC-RP-94-1268 states, "The *Conduct of Research and Development Manual,* WSRC-IM-97-00024, aligns R&D work to the five ISMS Functions and provides guidance to researchers on the use of ISMS mechanisms for R&D work." The purpose of this document is to provide a comprehensive process by which the hazards inherent in R&D activities may be identified and mitigated.

The correlation between the SRS ISM process and the SRNL Conduct of R&D process is illustrated in Figure 1 of the *Conduct of R&D Manual*. The two parts of this figure are reproduced in Figures 3-1a and 3-1b for the purposes of illustration.

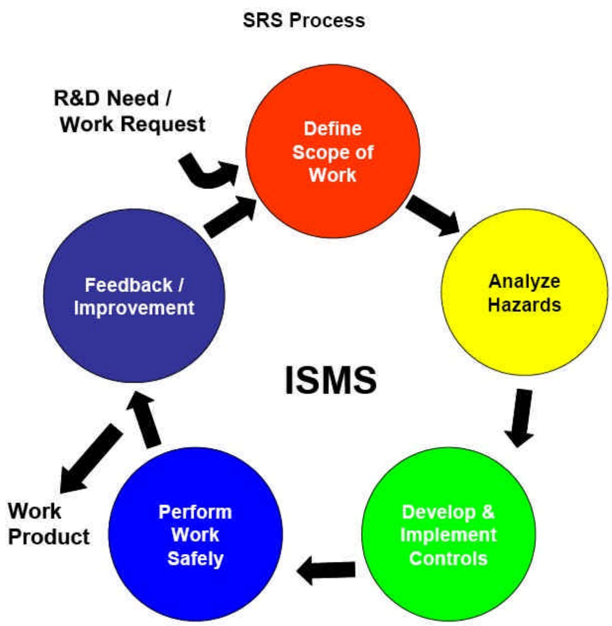

Figure 3-1a. SRS ISM Process

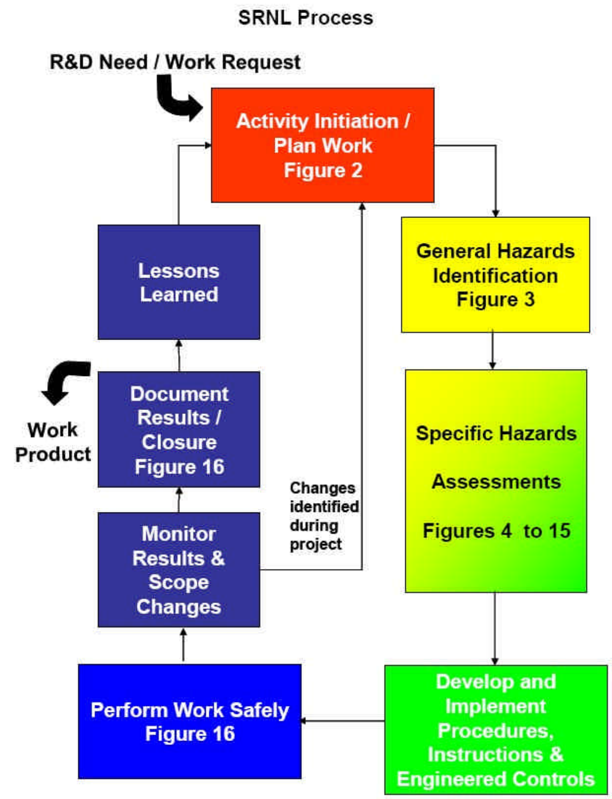

Figure 3-1b. SRNL ISM Process

3.2 Define the Scope of Work

Effective work execution begins with the preparation of a well-defined scope of work that translates mission and requirements into terms that those who are to accomplish the work can clearly understand. The definition of work scope must provide sufficient detail to support hazard analysis and subsequent development and implementation of controls at the task level. To fulfill its responsibilities, line management must determine the work to be performed and be accountable for understanding it as completely as possible through every phase of the work cycle. This process, discussed in the *Conduct of R&D Manual*, applies to the alanate processing task being conducted in D-1169. The *Conduct of R&D Manual,* Section 2, "R&D Responsibilities," in the "Roles and Responsibilities" subsection requires Researchers to:

> "Review the entire scope of work, including peripheral activities using the hazard assessment process," and to "Perform Job Hazard Analyses (JHAs), as appropriate, for new or changing conditions. Include setup and restoration phases, not just experimental tasks."

Similar instructions are provided for Laboratory Custodians to:

> "Review the entire scope of work, including peripheral activities using the hazard assessment process," and to "Perform JHAs, as appropriate, for new or changing conditions. Include setup and restoration phases, not just experimental tasks." In addition, Laboratory Custodians are required to "Review and approve work plans (including hazard assessment documents) for work performed by other personnel in the lab/workspace."

The *Conduct of R&D Manual*, Section 2, in the subsection entitled "Activity Initiation," states, in part, that

> "The success of any R&D activity is largely dependent on the effort applied early in the stages of work initiation…but in all cases developing a clearly understood agreement on the scope of the work and associated risks is essential to success."

The scope of work for the alanate R&D is contained in WFO Agreement WFO-04-006 and included seven tasks:

1. Preparation and inspection of the storage system;

2. Baseline characterization of the prototype storage system with uncatalyzed sodium alanate;

3. System disassembly, inspection, and preparation for further testing;

4. Analysis of data to formulate an improved methodology for tank loading and sealing, characterize the thermal and mechanical response of the system during thermal cycling, and identify anomalies in system performance;

5. System testing with catalyzed sodium alanate. This included generating and characterizing catalyzed sodium alanate, loading it into the storage system, and conducting cycle testing;

6. System disassembly and inspection to provide descriptions of the alanate material and any anomalies observed; and

7. Preparation of the final report.

Before work began, SRNL and the customer mutually agreed that SRNL would not conduct testing using uncatalyzed sodium alanate (tasks 2 through 4). Both parties agreed that this scope change would minimize possible damage to the customer's vessel from repeated sealing and unsealing, and revising the scope would save project time. Although requested, the documentation eliminating these tasks was not available for the Board's review. The *Conduct of R&D Manual* states,

> "...the very nature of R&D often results in scope changes. To effectively accommodate such changes, it is important that work plans and/or scoping documents be uniquely identified, documented, and assigned revision numbers to control changes. Changes in the scope of work need to be clearly communicated and authorized."

The WFO Task 5 included processing catalyzed alanate powder in a high-pressure attritor mill. MS&T personnel developed the following steps to accomplish this task, which are summarized below:

- loading the attritor mill vessel with the designated powders and chemicals inside a glovebox inerted with argon,
- placing the lid on the vessel to isolate the powders and chemicals from atmosphere,
- removing the vessel from the glovebox,
- pressurizing the vessel with hydrogen,
- connecting the vessel to the mill, and
- grinding the material by rotating it at a specified speed under hydrogen pressure.

When the grinding was complete, the vessel was returned to the inert glovebox, the lid was removed, and the material was scooped out of the vessel and placed into a temporary storage container.

These steps were developed during a tabletop session conducted in D-1169 with the initial PI, the laboratory specialist, and the JHA preparer. This led to the development of the "Attritor Instructions" included in WSRC-NB-2005-00151, *Controlled Laboratory Notebook for Alanate Processing* (Notebook) and the JHA.

The *Conduct of R&D Manual* requires Researchers and Laboratory Custodians to "[p]erform JHAs, as appropriate, for new or changing conditions. Include setup and restoration phases, not just experimental tasks." However, none of the work scope documents or process steps described wiping down the attritor vessel with IPA outside the inerted glovebox before placing it on the mill stand, or equipment dismantlement and recovery operations outside the inerted glovebox when the task was complete. Had wiping down the attritor vessel outside the glovebox been identified, controls such as the use of an alternate glovebox or laboratory hood could have been employed to conduct the evolution.

The Board concluded that equipment cleaning and restoration was not included in the work scope for processing alanate.

3.3 Hazards Analysis

The objective of the hazards analysis process is to develop an understanding of task-specific hazards that may affect the worker, the public, and the environment. Each level of hazard analysis forms the foundation for a more detailed analysis; that is, a hazard analysis for facility operation, maintenance, or modification is, in turn, used as the basis for an activity-level or task-specific hazard analysis. Hazard identification and analysis must occur at any phase of the work cycle to which it applies, and is dependent upon the adequate and full definition of the activity or task to be performed. If the activity or task is not fully identified or defined, it follows that an adequate task-specific hazard analysis cannot be performed.

Section 2, "R&D Responsibilities," of the *Conduct of R&D Manual* delineates the responsibilities of personnel in conducting R&D activities. Among the responsibilities of the Manager are to:

- Provide safe facilities and work environments;
- Identify a custodian for each lab/workspace and convey responsibilities and expectations;
- Ensure qualified personnel are performing and reviewing the work; and
- Review testing and research procedures.

Among the responsibilities of the Researcher are to:

- Establish procedures and provide instruction for conducting research activities safely;
- Assess work in progress for safety and technical issues;
- Ensure that all aspects of personnel, facility, and environmental safety have been considered before beginning an R&D activity;
- Incorporate solutions for identified safety issues into the plans, procedures, or equipment of the R&D activity prior to beginning work;
- Discuss new or changing experimental tasks and peripheral activities with the laboratory (or workspace) custodian to ensure conformance with the safety envelope and environmental requirements;
- Conduct work according to the plan and appropriate procedures or work instructions;

- Develop necessary procedures for specialized instrumentation/equipment;

- Know the lab/workspace safety envelope (i.e., safety basis, services, radiological requirements, equipment limitations, environmental restrictions, etc.); and

- Perform JHAs, as appropriate, for new or changing conditions. Include setup and restoration phases, not just experimental tasks.

Among the responsibilities of the SRNL Laboratory Custodians are:

- Know the lab/workspace safety envelope (i.e., safety basis, services, radiological requirements, equipment limitations, environmental restrictions, etc.);

- Review the entire scope of work, including peripheral activities, using the hazard assessment process;

- Review and approve work plans (including hazard assessment documents) for work performed by other personnel in the lab/workspace;

- Perform JHAs, as appropriate, for new or changing conditions. Include setup and restoration phases, not just experimental tasks; and

- Stop work.

Hazards associated with R&D work are analyzed in accordance with Section 3, "Hazards Assessment and Abatement," of the *Conduct of R&D Manual*. The decision matrix contained in the *Conduct of R&D Manual* leads Hazard Assessment Package (HAP) preparers through a series of checklists or flowcharts to aid them in identifying hazards associated with conducting tasks. The process is initiated by completing an R&D hazards screening checklist (Figure 3 of the *Conduct of R&D Manual*), which lists the characteristics of an experiment that could present hazards above normal risks to SRNL.

Each "yes" answer generated within the checklist directs the preparer to a secondary hazard review that directs the completion of specific actions needed to manage and mitigate the identified hazard. Figure 15 of the *Conduct of R&D Manual* requires a JHA to be conducted in accordance with L1, *SRNL Procedures Manual*, Procedure 7.17, "SRNL Job Hazards Analysis Program."

SRNL staff conducted a hazards assessment and prepared a JHA in this manner for the alanate processing task. However, the scope of work discussed during the task planning activity failed to identify that the assembled attritor mill would be cleaned with IPA outside the inert glovebox, and did not include steps associated with equipment dismantlement and cleaning outside the glovebox prior to storage.

The Board reviewed SRNL-MS&T-2004-30004, *Hazard Assessment for the High Pressure Attritor Mill and Inert Glove Box for Metal and Ceramic Powder Processing (D-1169*), which summarizes the implementation of the HAP for attritor mill activities. The Board noted that the HAP was prepared by three personnel, approved by six managers, and independently reviewed and approved by five subject matter experts (SMEs). The Board determined that the appropriate managers and SMEs were tasked with review and approval of the hazard assessment. However, the independent reviews and approvals failed to identify the omission of key job steps in the scope definition or activities delineated in the HAP.

The failure to identify all planned work steps precluded identification that: (1) the vessel might not be totally passivated, (2) the use of IPA for cleaning outside the glovebox would generate flammable vapors, and that (3) the potential for personnel exposure to IPA vapors may exist. Failure to identify these hazards precluded implementing controls to properly protect the workers.

The Board concluded that, because the scope of work for alanate processing was incomplete, the HAP failed to identify and mitigate the hazards of IPA use outside the glovebox.

3.4 Develop and Implement Hazard Controls

The objective of developing and implementing controls is to identify and provide the full range of controls (i.e., engineering, administrative, and personal protective equipment (PPE)) consistent with the level and nature of the hazards expected to be encountered during task performance. The development and implementation of work controls assumes that the hazards associated with the defined scope of work have been completely identified.

As part of the early hazards analysis, SRNL personnel determined that an inert atmosphere would be required to handle and process alanates. Laboratory D-1169 was modified to install an argon-inerted glovebox with a gas purification system to limit oxygen and moisture inside the glovebox. This glovebox was used during the alanate processing task.

WSRC L1, *SRNL Procedures Manual,* Procedure 1.01, "SRNL Procedure Administration," contains the requirements for procedures at SRNL. Section 3, paragraph DD, defines a Work Instruction as a:

> Written directive provided to personnel for the performance of activities that do not require a procedure as determined by Procedure Need Decision Tree (Attachment 1). Work Instructions are used to describe routine activities or provide generalized instructional material (not including technician assignments). Work Instructions are not required to be in hand when performing the activity, but must be readily available upon request. One-time laboratory activities are not required to be documented as Work Instructions, but may be documented in accordance with WSRC L1, procedure 7.16, *Laboratory Notebooks and Logbooks.*

MS&T management stated that the preparation of alanate was a one-time laboratory activity that could be accomplished with the use of instructions included in the Laboratory Notebook. The Board determined that, unlike procedures and Work Instructions, the instructions included in Laboratory Notebooks are not required to receive formal review or approval by managers responsible for the activity. This is the lowest form of written direction allowed by WSRC L1. MS&T line management stated that these specific instructions were accepted to control the operation of the attritor for this work.

All of the controls identified in the JHA were not implemented in the Attritor Instructions. For example, the passivation process for alanate powders included in the JHA was not incorporated into the Attritor Instructions. Interviews with personnel indicated that both the instructions and the JHA were used to conduct the work. This is inconsistent with the method used at other areas of the SRS, where the controls identified in the JHA are included in the procedure that is ultimately used to conduct the work. The Board extracted key work steps and controls from the Laboratory Notebook, as shown in Table 3-1, which illustrates this point.

Table 3-1. Notebook safety instructions for alanate processing

Sample Work Step	Control	Where is Control Specified?			
		Attritor Instructions	JHA Rev. 0	JHA Rev. 1	Not Specified
Use of transport jack	Use leather gloves	x	x	x	
Antechamber purge	Close and secure antechamber doors	x			
	Restriction on moisture and oxygen concentration		x	x	
	Limits on antechamber pressurization		x	x	
Load vessel charge	Check moisture level before opening jars of alanate powder	x			
	Seal vessel after loading charge	x			
	Ensure valves are closed	x			
Remove vessel from glovebox	Passivate vessel exterior with IPA before removing from the glovebox				x
	Purge/depressurize glovebox		x		
Use of transfer jack	Use leather gloves, as needed		x	x	
Cleaning of vessel exterior outside of glovebox with IPA	None				x
Connect attritor vessel to the mill	Purge hydrogen lines	x	x		
	SRNL cylinder training required for operators		x	x	
Remove attritor vessel from mill	Purge vessel with argon; leave pressurized to ~15 psi	x		x	
Roll vessel into glovebox	Use rubberized tools		x	x	
	Release argon gas pressure slowly. [Do not exceed glovebox pressure limit]			x	
Wipe down glovebox	Passivate alanate powder on wipes with IPA			x	
	Ensure any waste with grease or oil is separated from passivated waste before disposing as “Green is Clean”			x	

Sample Work Step	Control	Where is Control Specified?			
		Attritor Instructions	JHA Rev. 0	JHA Rev. 1	Not Specified
	Review all waste for compliance with site disposal criteria			x	
Wipedown of equipment with IPA during restoration	None				x

The passivation process discussed in the JHA focuses solely on how to handle and dispose of the wipes and IPA (i.e., trash) used during the passivation process. However, the JHA does not include specifics on how to ensure that any alanate residue remaining on equipment such as the attritor mill has been properly removed or passivated before removing the equipment from the inert glovebox. It is of particular note that workers involved in the alanate processing task had to follow the instructions contained in a Work Instruction and in two JHA revisions to accomplish the work, even though none of these included all of the necessary steps to ensure worker safety.

As part of the corrective actions from the February 2005 fire, SRNL senior management reviewed the alcohol use policy in D-1169. The SRNL Safety and Quality Council, in May 2005, determined that the use of IPA during alanate processing should be restricted to inside the inert glovebox only. This restriction was not incorporated into the Work Instructions or JHA for alanate processing, nor was it effectively communicated to the personnel conducting the alanate processing task.

The Board concluded that because the scope of work was never fully defined, line management failed to ensure the development and implementation of adequate controls to protect workers during the cleaning of the attritor vessel with IPA outside of the inert glovebox.

3.5 Perform Work within Controls

The five ISM Core Functions serve to ensure that safety is effectively considered and implemented during all aspects of work activities. The failure of any one of the Core Functions will result in the failure to fully accomplish the subsequent Core Function. For example, if the scope of the work to be accomplished is not fully and effectively identified, or if work scope changes are not recognized, it is impossible to develop a clear understanding of the task-specific hazards that could be present in the work area. Similarly, less than adequate performance in task-specific hazards analysis would preclude the effective development and implementation of work controls to address those hazards. Safety controls must be identified and implemented before starting work.

One cycle for processing catalyzed sodium alanate is described in the Attritor Instructions located in the Notebook. The cycle was completed 13 times (including 3 reruns) under a variety of operating conditions to generate the required amount of material. The Board noted that some of the operating conditions did not comply with the requirements of the Work Instruction. For example, the Attritor Instructions specify pressurizing the vessel to

2,000 pounds per square inch (psi) before milling. The Board reviewed the results of the alanate processing runs and determined that personnel operating the equipment varied the pressure between 1,000 and 2,000 psi. Additionally, the Attritor Instructions specified setting the mill revolutions per minute (rpm) at 400. Recorded data indicate that personnel operating the equipment varied the mill speed between 400 and 1,200 rpm.

The Board acknowledges the unique nature of conducting R&D work and the difficulty in writing detailed, step-by-step instructions for conducting R&D work. However, the Board noted that, in its collective experience, it is possible to identify and analyze a range of acceptable parameters for inclusion in procedures or work instructions that would establish a safety envelope for the evolution. Operating outside the analyzed parameters would trigger an update to the hazard assessment process.

The Board determined through interviews that each time the assembled vessel was removed from the inert glovebox, it was wiped down with IPA to remove passivation residue for equipment cleaning, even though this practice was not included in the Work Instructions. Personnel did not stop the evolution when they were outside the controls established by JHA or Work Instruction. MS&T line managers stated that the cleaning steps outside the glovebox were skill-of-the-craft. The Board noted that implementation of skill-of-the-craft activities does not relieve line management of the responsibility to fully analyze the hazards associated with conducting work.

The Board reviewed the SRNL management-approved alcohol management plan distributed by e-mail on June 27, 2005, which contained instructions describing the use of IPA in D-1169 for passivation of residual nanomaterials from the alanate processing task. The e-mail stated, in part, that the alcohol management plan "can be cut and pasted into your Con R&D packages and Work Instructions."

These instructions state that

> "This cleaning is not typically a passivation step, and a defined passivation process must be in place. The following laboratory practices will be used for general cleaning of the components and process apparatus.
>
> 1. Store alcohol intended for future use in flammable materials cabinet.
>
> 2. Use the minimum quantity of alcohol that is required to complete the cleaning process and still maintain waste minimization standards.
>
> 3. If any alcohol from the cleaning process is remaining, put the alcohol in a container, label the container, and store in a flammable materials cabinet for future lab pack disposal."

The SRNL Safety and Quality Council, in May 2005, determined that the use of IPA during alanate processing should be restricted to inside the inert glovebox only. The Board determined that, contrary to the restrictions imposed by the SRNL Safety and Quality Council, the plan authorized the general use of alcohol in D-1169 for cleaning nanomaterials from process components or apparatus. Although the instructions noted that a defined passivation process must be in place, they did not contain guidance on how to validate the success of passivation prior to removing the equipment from the inerted environment.

The wipedown of the attritor vessel on the day of the accident was the first time this evolution had occurred with the attritor mill completely disassembled, exposing previously inaccessible areas such as the vessel cavity and boltholes to IPA outside the inerted environment. Again, personnel failed to stop work when presented with operations that had not been analyzed through the hazard assessment process or documented in applicable Work Instructions.

The Board concluded that process steps were performed during alanate processing activities that were not addressed by procedure, Work Instruction, JHA, or Notebook controls.

Potential for Personnel Exposure to IPA

As part of this investigation, the Board attempted to evaluate whether the potential existed for the uncontrolled exposure of personnel in D-1169 to IPA. Evidence collected by the Board indicates that impermeable gloves and respiratory protection were not used by personnel working with IPA outside the glovebox. In addition, the Board determined that no industrial hygiene monitoring was conducted for IPA at any time during the project, even though a potential for personnel exposure existed.

The Board concluded that, based upon evidence of chemical use and the absence of industrial hygiene monitoring in the workplace, the potential existed for an unmonitored exposure of personnel to IPA during attritor cleaning operations in D-1169.

3.6 Provide Feedback and Improvement

Feedback and improvement processes should be designed and utilized to provide information on the adequacy of work controls, to identify and implement opportunities for improving the definition and planning of work, and to utilize line and independent oversight processes to provide information on the status of safety. Line management is directly responsible for establishing and implementing feedback and improvement programs and processes to facilitate a culture that promotes ongoing examination and learning, while connecting the practical experiences of work that has been conducted to the planning for future work. The feedback and improvement function is intended to identify and correct processes or deviations that lead to unsafe or undesired work outcomes, confirm that the desired work outcomes were obtained safely, and provide managers and workers with information to improve the quality and safety of subsequent, similar work.

In evaluating how DOE and SRNL had analyzed performance information as part of lessons learned, feedback, and improvement, the Board reviewed previous accident investigation reports, the feedback provided by DOE and SRNL assessments, and site Occurrence Reporting and Processing System (ORPS) reports.

Site ORPS Reports

On February 14, 2005, at approximately 10 a.m., a fire alarm sounded in D-1169. Fire was discovered in the laboratory, involving a trashcan and the underside of a wooden laboratory bench. The fire involved the disposal of incompatible materials into the same trashcan, ultimately resulting in the ignition of the contents. In a February 15, 2005 *All SRNL Employees Bulletin,* SRNL management discussed possible causes of the fire, and stated, in part, that

> "Personnel should be knowledgeable of and understand the chemical properties of materials that are handled, stored or disposed. Materials with properties that could be reactive with other materials (e.g., metal powders, acids, bases), regardless of quantities, should be thoroughly evaluated prior to adding or mixing with waste streams to prevent reactions."

As required by ORPS, SRNL performed a causal factors analysis and developed corrective actions in response to the fire. The causal factors analysis noted a deficiency in the work procedure in use at the time, asking "What steps to ensure material was passivated were taken, or what was basis for assumption that material was passivated? Was any testing performed?" The resulting SRNL corrective action identified the need for an independent review of the hazard assessment for the work conducted in D-1169 to include passivation of reactive materials. The Board determined that this review, which was conducted on March 26, 2005, focused mainly on disposal of metal powders and did not consider the hazards associated with cleaning equipment outside the glovebox.

As part of the corrective actions from the February 2005 fire, SRNL senior management reviewed the alcohol use policy in D-1169. The SRNL Safety and Quality Council, in May 2005, directed that the use of IPA during the alanate processing be restricted to inside the inert glovebox only. This restriction was not incorporated into the Work Instructions or JHA for alanate processing, nor was it effectively communicated to the personnel conducting the alanate processing task.

On June 27, 2005, MS&T management conducted a resumption of operations briefing for all personnel assigned to perform materials work in D-1169. The briefing focused on:

- Conduct of R&D, including work activities covered, and any future work activities that are not covered under the existing Conduct of R&D packages; and

- Review of remedial actions from the February 2005 event, including materials passivation for waste disposal and alcohol management.

The Board concluded that the corrective actions implemented as a result of the February 2005 fire in D-1169 were narrowly focused and were not applied to a broader range of laboratory activities.

DOE-SR Assessment Activities

Between February and December 2005, DOE Facility Representatives (FRs) assigned to the SRNL were engaged in activities associated with the trashcan fire in D-1169 and participated in portions of the multidisciplinary safety inspection following that fire. Documentation provided to the Board indicates that during 2005, the FRs scheduled 97 oversight-related activities and completed 72. Of the six oversight modules used by the FRs, two contained ES&H review criteria. Records indicate that in general, the FRs conducted weekly tours in the SRNL facilities with a goal of touring D-Wing on a weekly basis. In addition, FRs performed monthly maintenance or operations activity observations in the SRNL, although no specific activities were observed in D-1169. Table 3-2 below provides a summary of FR oversight activities.

Table 3-2. Summary of FR activities at SRNL for calendar year 2005

	CO-20	MN-01	OP-2	OP-3	OP-4	OP-5
Scheduled	1	13	58	6	12	7
Performed	1	7	55	1	7	1
Percent completed	0	54	95	17	58	14

CO-20 Conduct of Operations activity
MN-1 Maintenance activity*
OP-2 Weekly facility tour*
OP-3 Monthly safety system tour
OP-4 Operations activity
OP-5 Surveillance activity

The FR OP-2 weekly facility tours include safety and health criteria such as evaluations of fire protection posture, control of ignition sources or excessive combustibles, and occupational safety control of hazards. The FRs stated that they had toured D-1169 during the performance of the OP-2 tours, but no work activity was ongoing.

The Board determined that the FRs are performing OP-2 weekly facility tours as required by their annual assessment plans. Although they attempt to tour all spaces, including non-nuclear low-hazard areas, FR priorities are focused on high-hazard nuclear work activities.

During calendar year 2005, senior DOE-SR personnel conducted approximately 50 management walkthrough inspections at the SRNL. Overall, documentation of the activities observed or conducted during the walkthrough inspections was minimal, to the extent that the scope of the walkthrough inspections could not be ascertained. For example, a number of the DOE-SR Management Walkthrough Reports described the Activities Observed as "SRNL visit," with no further documentation of the scope of the walkthrough effort. The Board also noted that documentation contained in the Results of the Surveillance sections of the Management Walkthrough Reports did not provide sufficient information to judge the effectiveness of the DOE walkthrough activity.

* Contains ES&H review criteria

The Board's interview with the Assistant Manager of Nuclear Materials Stabilization Project (AMNMSP) indicated that a number of briefings on the February 2005 trashcan fire took place with the SRNL Laboratory Director during the bimonthly SRNL Oversight and Steering Committee meetings. The Board reviewed the briefing packages for the Oversight and Steering Committee meetings from February through June 2005 and determined that the action items from the fire were being discussed and tracked to closure by the Committee. The AMNMSP monthly performance feedback meetings with SRNL also discussed the February 2005 fire.

The AMNMSP also stated that points of contact responsible for nanomaterial safety were established in both SRNL and the AMNMSP Nuclear Material Engineering Division in response to the May 2005 EH Safety & Health Bulletin *Good Practices for Handling Nanomaterials*.

The Board also noted that for calendar year 2005, DOE-SR had scheduled nine technical assessments, most dealing with high-hazard nuclear and vital safety system-related SRNL operations and activities. Four of the assessments were completed, including one general-area safety walkdown of SRNL outside areas, but none evaluated low-hazard facilities or non-nuclear activities of the type found in D-1169. The Board determined that four of the uncompleted technical assessments involved vital safety systems and were not completed because of competing priorities. DOE line management indicated that the engineering staff's priorities were focused largely on reviewing safety basis documents.

Based upon its review of these assessments, the Board requested additional information on the DOE-SR technical assessment program for calendar years 2003, 2004, and 2006, and discussed the program with DOE-SR line management. DOE line managers stated that they rely on FRs to identify general occupational safety and health issues, but did not consider them to be occupational safety and health SMEs. Instead, FRs are expected to know when an SME is needed and can report this need or contact the DOE-SR expert directly. The Board's review of the 2006 AMNMSP *Annual Assessment Plan* indicated no technical assessments had been planned for 2006 except for documenting reviews of safety basis documents, vital safety systems, and criticality safety. The Plan stated that technical assessments would generally be performed on a reactive basis in order to address existing and changing conditions.

The Board concluded that low-hazard non-nuclear work activities are not being assessed.

In 2003, matrixed environment, safety, and health (ES&H) functions were transferred from the DOE-SR safety organization to the line management organizations, which were assigned responsibility for providing occupational safety oversight through the DOE-SR Functions, Responsibilities, and Authorities Procedure (FRAP). For AMNMSP, the FRAP assigns SRNL safety oversight responsibilities, including OSHA, to the Nuclear Material Operations Division (NMOD). DOE line managers stated that an occupational safety and health SME has not been assigned to the line organization.

The FRAP states that the NMOD Facility Representative:

"*Oversees* conduct of operations by the contractor for assigned facilities. Performs surveillance in areas of operation including security operations, engineering, maintenance, procedures, radiation control, and *OSHA*. Oversees the contractor and environmental self-assessment programs."

The FRAP for the Nuclear Materials Engineering Division (NMED) states: "*Assists other divisions within the AMNMSP organization* through engineering analysis and interpretation of DOE requirements by providing guidance for implementation of contractor and DOE-SR programs, and through conduct of performance-based assessments of contractor programs. Provides engineering/technical support and advice to the responsible AMNMSP division in the following functional areas: Safety Documents, Environmental Protection, Quality Assurance, Configuration Management, Maintenance and Surveillance, Construction, Radiation Protection, Fire Protection, Emergency Preparedness, Independent Review and Oversight, Nuclear Criticality Safety, Testing, Issue Management, Packaging and Transportation, *OSHA*, and Waste Management."

The Board determined that since the ES&H function was transferred in 2003, one construction safety technical assessment was conducted in November 2005 by the NMED. Evidence was not provided by AMNMSP to indicate that other occupational safety and health technical assessments were conducted by NMOD at SRNL during the period examined.

The AMNMSP managers interviewed by the Board confirmed that safety and health oversight was the responsibility of the FRs under the NMOD even though the FRs are considered generalists and not safety and health SMEs. They also confirmed that NMED would assist the FRs in the areas of Fire Protection and Radiation Protection with NMED SMEs. The AMNMSP managers confirmed that neither NMOD nor NMED have a safety and health SME on staff. AMNMSP managers also stated that they relied upon the Savannah River Office of Environment, Safety, and Health (OESH) organization to provide safety and health support. Interviews with OESH managers indicated that they had not been asked to assist or perform safety and health assessments for the AMNMSP since the 2003 reorganization that eliminated OESH matrix support to the DOE-SR line organizations.

The Board determined that AMNMSP does not currently have a safety and health SME available to assist the FRs should significant safety and health deficiencies be identified. Safety and health deficiencies similar to those contributing to the cause of this accident are not being identified.

The Board concluded that AMNMSP does not have a safety and health SME that could assist the FRs and lead safety and health assessments in AMNMSP facilities.

SRNL Assessment Activities

The Board reviewed self-assessments of active HAPs (which include JHAs) that were conducted by MS&T line managers. The assessments indicated a continuing management presence in the workspaces, as well as direct involvement and interactions with employees on a regular basis. The Board noted that on May 2, 2005, the MS&T Director stressed to his personnel "the need to be deliberate and methodical on every action…no matter how routine." Additional tours of D-1169 were conducted by the MS&T Director on August 8, 2005, where passivation, housekeeping, and process activities were reviewed and discussed with assigned staff. In total, the Board's review of records indicates that the MS&T Director conducted walkthrough inspections of D-1169 on at least nine occasions between April 2005 and November 2005, during which laboratory-related activities and expectations were discussed with assigned staff personnel. Of note was the increase in the Director's involvement in laboratory operations following the fire in the same laboratory in February 2005.

The Board concluded that the MS&T Director was actively involved with personnel through the self-assessment program and other avenues.

Interviews conducted by the Board indicate that the MS&T Section Leader responsible for D-1169 conducted routine laboratory walkthroughs and regularly interacted with the staff during the performance of their duties. However, no requirement was established for managers at the Section Leader level and below to formally document their self-assessment activities.

Records reviewed by the Board indicated that the SRNL MS&T Directorate had implemented a comprehensive self-assessment process. Reports of completed self-assessment activities related to Conduct of R&D, Chemical Handling, Management of Safety, Training, and Housekeeping were reviewed as part of this investigation. The self-assessments were thorough and comprehensive in their scope and application. While some of the self-assessment activities specifically addressed D-1169, no significant issues were identified during these self-assessment activities.

The Board concluded that the MS&T Directorate had developed, implemented, and maintained an active self-assessment process.

3.7 Management Systems

In addition to the safety performance expectations established through the *Conduct of R&D Manual*, in early 2005, the MS&T Directorate published the *MS&T Safety and Housekeeping Implementation Plan 2005*. The Plan outlined the MS&T Director's expectations for safety during 2005, and provided MS&T staff with a number of tools to achieve and maintain a safe work environment both on and off the job. Within the Plan, the Director established his minimum expectations for the safe conduct of research:

- All research work will be done safely.
- All research personnel will take responsibility for safety.

The MS&T Director further stated that

> "The primary principle of safety in our laboratories is that all injuries are avoidable. We mean this literally and completely. We consider it perfectly practical for a large research laboratory to operate for many years without a serious injury. We must all share the conviction that all injuries are caused by inattention or poor judgment on the part of someone and, as such, can be avoided. It is everyone's responsibility to ensure the accomplishment of this objective."

The Board analyzed ISMS implementation as it related to the accident, examined the suitability of personnel to perform their function, and evaluated the safety management systems used by SRNL.

The objective of ISMS is to ensure that DOE and its contractors systematically integrate safety into management and work practices at all levels. The review of this accident considered all of the systems that implemented the ISMS at SRNL.

The Board's review of records associated with this accident indicated that, contrary to the requirements of the *Conduct of R&D Manual*, there was informality in how tasks were assigned, how instructions were transmitted to staff, and how personnel were assigned to positions of responsibility and authority. The Board noted:

- The use of e-mail to transmit safety-related information and controls associated with project work conducted in D-1169;
- Work scope documents were not kept current;
- Miscommunication of SRNL management expectations on the use of IPA;
- Attritor Instructions did not include all controls stipulated in the JHA;
- The Laboratory Notebook was not maintained in accordance with Procedure 7.16 of the L1 Manual;
- Approval signature on the HAP was obtained after the work was started; and

- One PI was not formally designated for the alanate work and did not understand his roles and responsibilities.

The Board also noted that the *Conduct of R&D Manual* identified numerous requirements for implementation by the Researcher (the PI) and the Laboratory Custodian. When the initial PI for work conducted in D-1169 retired, the Laboratory Specialist was assigned the objective of completing the fabrication of the processing equipment and the processing of the alanate in his Consolidated Assessment Process. Therefore, he was the second PI assigned to the alanate task. When the second PI left for medical reasons, the assignment of a third PI was informal (i.e., not documented). In fact, the Board determined that the Researcher was not aware of the fact that he had been designated as PI. The third PI did not receive a turnover briefing from the departing PI; however, he worked with his predecessor from project initiation on November 1, 2005, through November 17, 2005. The third PI was briefed on the Conduct of R&D HAP. However, the Board determined that MS&T management did not take the actions necessary to make the new PI fully aware of his increased responsibility and authority under the *Conduct of R&D Manual*, including:

- requirements to know the laboratory safety envelope,

- requirements to assess the work in progress for safety and technical issues, and

- requirements to discuss new or changing peripheral activities with the Laboratory Custodian to ensure conformance with the safety envelope.

The Board concluded that the formality of operations required by the SRNL Conduct of R&D Manual *was not effectively implemented for the alanate processing activity.*

3.8 Barrier Analysis

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

3.9 Change Analysis

Change analysis examines planned or unplanned changes that caused undesirable results related to the accident. This process analyzes the difference between what is normal, or expected, and what actually occurred before the accident. The results of the change analysis conducted by the Board are integrated into the events and causal factors chart to support the development of causal factors. Appendix C contains the Board's Change Analysis and reinforces the Barrier Analysis.

3.10 Causal Factors Analyzed

The Events and Causal Factors Analysis is a systematic process that uses methods to determine Causal Factors of an accident. Causal Factors are the significant events and conditions that produced or contributed to the Direct Cause, the Contributing Causes, and the Root Causes of the accident. This investigation followed the processes described in the DOE Workbook *Conducting Accident Investigations*, Revision 2, where the direct, contributing, and root causes are defined as:

- The direct cause is the immediate event or condition that caused the accident.
- Root causes are causal factors that, if corrected, would prevent recurrence of the same or similar accidents.
- Contributing causes are events or conditions that collectively with other causes increased the likelihood of an accident but that individually did not cause the accident. Appendix D contains the Board's Events and Causal Factors Analysis. Other contributing factors are identified in Appendices B and C.

The **Direct Cause** of the January 10, 2006 accident was the ignition of IPA vapors by reactive alanate during attritor vessel cleaning operations outside the inert glovebox. The burning vapors came into contact with the FLM, causing first- and second-degree burns.

The **Root Cause** was the failure to define the complete scope of work, resulting in a failure to identify and mitigate the IPA hazard during cleaning operations.

Contributing Causes:

- Failure to broadly apply the lessons learned and corrective actions from the February 2005 trashcan fire.
- Laboratory management allowed informal work activities.
- Vessel passivation was ineffective at removing all alanate residue due to inadequate instructions.
- Alternate glovebox or laboratory hood was not used for cleaning operations.
- A nonflammable cleaning agent was not used.
- Failure to remove all alanate from the vessel boltholes.
- Concentration of IPA vapors exceeded the lower flammability limit (LFL).

- Workers were not wearing necessary PPE for the work being performed.
- Stop-work authority was not used because workers did not recognize they were outside the safety envelope.
- Skill-of-the-craft was used involving unanalyzed hazards.
- Lab supervision authorized the use of IPA in D-1169.
- Industrial hygiene monitoring not identified.
- The attritor mill was disassembled when removed from the glovebox.

4 JUDGMENTS OF NEED

Judgments of Need are managerial controls and safety measures believed necessary to prevent or minimize the probability of a recurrence. They flow from the causal factors and are directed at guiding managers in developing corrective actions. The Executive Summary identifies the Board's Judgments of Need. The conclusions and Judgments of Need are provided in Table 4-1.

Table 4-1. Board Conclusions and Judgments of Need

Conclusions	Judgments of Need
Equipment cleaning and restoration was not included in the work scope for processing alanate. Because the scope of work for alanate processing was incomplete, the Hazards Assessment failed to identify and mitigate the hazard of isopropyl alcohol use outside the glovebox. Because the scope of work was never fully defined, line management failed to ensure the development and implementation of adequate controls to protect workers during the cleaning of the attritor vessel with isopropyl alcohol outside of the inert glovebox. Based upon evidence of chemical use and the absence of industrial hygiene monitoring in the workplace, the potential existed for an unmonitored exposure of personnel to isopropyl alcohol during attritor cleaning operations in D-1169.	WSRC needs to ensure that the scope of work for R&D activities at SRNL is defined in sufficient detail such that the hazard assessment process can be effectively applied.
The corrective actions implemented as a result of the D-1169 fire on February 14, 2005 were narrowly focused and were not applied to a broader range of laboratory activities.	WSRC needs to determine why the corrective actions taken in response to the February 2005 fire were not effective in preventing this accident.

Conclusions	Judgments of Need
The formality of operations required by the SRNL *Conduct of R&D Manual* was not effectively implemented for the alanate processing activity.	WSRC needs to ensure that SRNL R&D activities are conducted with the level of rigor and formality required by the *Conduct of R&D Manual*. WSRC needs to ensure that SRNL includes the controls identified in the hazards assessment process in the procedure or instructions used to conduct the work.
Process steps were performed during alanate processing activities that were not addressed by procedure, Work Instruction, JHA, or Notebook controls.	WSRC needs to ensure that skill-of-the-craft activities are identified for SRNL R&D projects so that the hazard assessment process can identify appropriate controls.
Although their actions were commendable, Operations first responders placed themselves at risk by entering an unknown and uncharacterized environment without knowledge of the hazards that could be present.	WSRC needs to develop, implement, and institutionalize mechanisms to ensure that SRNL Operations first responders are provided with accurate and sufficient information to make informed decisions regarding their prospective actions in responding to an incident.
The Board concluded that low-hazard, non-nuclear work activities are not being assessed.	DOE-SR needs to re-evaluate assessment priorities related to low-hazard, non-nuclear work activities when developing their annual assessment plans to ensure that the appropriate level of oversight is provided.
The Board concluded that AMNMSP does not have a safety and health SME that could assist the FRs and lead safety and health assessments in AMNMSP facilities.	DOE-SR needs to ensure that oversight and assistance responsibilities contained in the FRAP are adequately staffed to ensure that safety and health work activities are assessed.
The procedures used for accident scene management required by DOE Order 225.1A were adequate, timely, and effective.	
The emergency response was timely and well coordinated.	
The MS&T Director was actively involved with personnel through the self-assessment program and other avenues.	

Conclusions	Judgments of Need
The MS&T Directorate had developed, implemented, and maintained an active self-assessment process.	

5 BOARD SIGNATURES

(signature on file)
William T. Cooper, Jr., CSP*
DOE Accident Investigation Board Chairperson
U.S. Department of Energy
Office of Facility Operations Support

(signature on file)
Mark A. Smith*
DOE Accident Investigation Board Member
U.S. Department of Energy
Savannah River Site

(signature on file)
Michael J. Thomas*
DOE Accident Investigation Board Member
U.S. Department of Energy
Office of River Protection

(signature on file)
Thomas E. Williams*
DOE Accident Investigation Board Member
U.S. Department of Energy
Office of Analytical Studies

* Trained Accident Investigator

6 BOARD MEMBERS, ADVISORS, AND STAFF

Chairperson	William T. Cooper, Jr., CSP, DOE-HQ, EH-24
Member	Mark A. Smith, DOE-SR
Member	Michael J. Thomas, DOE Office of River Protection
Member	Thomas E. Williams, DOE-HQ, EH-32
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Advisor	Rick E. Ledtje, WSRC
Legal Liaison	Lucy Knowles, DOE-SR
Coordinator/Technical Editor	Elaine Merchant, Parallax, Inc.
Photographer	Angela W. Bowser, WSRC
Court Reporter	Andrea L. Gregory, Augusta West Reporting

Appendix A
Board Appointment Memorandum

DOE F 1325 8

United States Government **Department of Energy (DOE)**

memorandum **Savannah River Operations Office (SR)**

DATE: JAN 1 2 2006

REPLY TO ATTN OF: OESH (Clendenning, 803-952-6302)

SUBJECT: Type B Investigation of Employee Burn Injury in the Savannah River National Laboratory (SRNL) at Savannah River Site (SRS) on January 10, 2006

TO: William T. Cooper, CSP, Safety Manager, EH-24

You are hereby appointed Chairperson of the Type B Accident Investigation Board I have convened to investigate the subject incident which occurred on January 10, 2006, in the SRNL at SRS. The investigation and report shall conform to requirements detailed in the Department of Energy (DOE) Order 225.1A, Accident Investigation and DOE G 225.1A-1, Implementation Guide for Use with DOE O225.1A, Accident Investigations. The Board will be comprised of the following members:

- Mark A. Smith, DOE-SR – Investigator/Analyst
- Lakshmi P. Singh, DOE-SR- Technical and Management Advisor
- Thomas E. Williams, DOE-HQ, EH-32 – Investigator/Analyst
- Michael Thomas, DOE-ORP – Investigator

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

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

The final investigation report should be provided to me by February 17, 2006. Any delay in 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.

If you have any questions, please contact me or Randy Clendenning of my staff at (803) 952-6302.

William J. Spader
for Jeffrey M. Allison
Manager

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Appendix B
Barrier Analysis

Hazard: Flash Fire **Target: FLM**

What were the barriers?	How did each barrier perform?	Why did the barrier fail?	How did the barrier affect the accident?
Available laboratory glovebox or hood to perform cleaning on vessel	Not used	Glovebox or laboratory hood was not utilized because hazards associated with the cleaning operation were not identified	Glovebox or laboratory hood was not used
Use of a nonflammable cleaning agent	Not used	Flammable cleaning agent was used to clean the attritor vessel because the hazards were not identified	Flammable cleaning agent was used
Passivation of the vessel boltholes	Not completed	Passivation ineffective	Failed to remove alanate material that collected in the vessel boltholes, which provided the ignition source for the flash fire
D-1169 is well-ventilated	Insufficient air flow; stagnant conditions existed at the cleaning location	Stagnation allowed concentration of IPA vapor to exceed LFL	IPA vapor concentration exceeded the LFL, which provided the fuel source
Industrial hygiene monitoring	Not performed	Industrial hygiene monitoring was not identified for the cleaning operations	IPA vapor concentration exceeded the LFL, which provided the fuel source
Proper PPE donned to protect workers from hazards	Only PPE worn were safety glasses and safety shoes	Hazards requiring PPE were not identified	Exposed unprotected FLM to flash fire and subsequent first- and second-degree burns
Comprehensive JHA	Ineffective	JHA preparers did not define the complete scope of work, which precluded subject matter experts and managers from identifying appropriate controls	Cleaning operation was performed outside the glovebox without the proper work controls and PPE
Attritor work instructions	Incomplete	The attritor work instructions did not contain all necessary work steps to complete restoration activities safely; workers relied on skill of the craft	Controls were not in place for vessel cleaning outside the glovebox

What were the barriers?	How did each barrier perform?	Why did the barrier fail?	How did the barrier affect the accident?
Corrective actions from the D-1169 fire on February 14, 2005	Failed	Narrowly focused and not applied to a broader range of laboratory activities	Failed to prevent recurrence of a fire in the laboratory
Employee stop-work responsibility	Failed	Not used	Work was conducted outside the analyzed safety envelope
Alcohol use prohibited outside the glovebox	Not used	Not communicated to the workers	IPA vapors provided the fuel source
Fully assembled attritor mill	Not used	Attritor mill was disassembled when it was removed from the glovebox	Exposed alanate to oxygen and provided the ignition source

Appendix C
Change Analysis

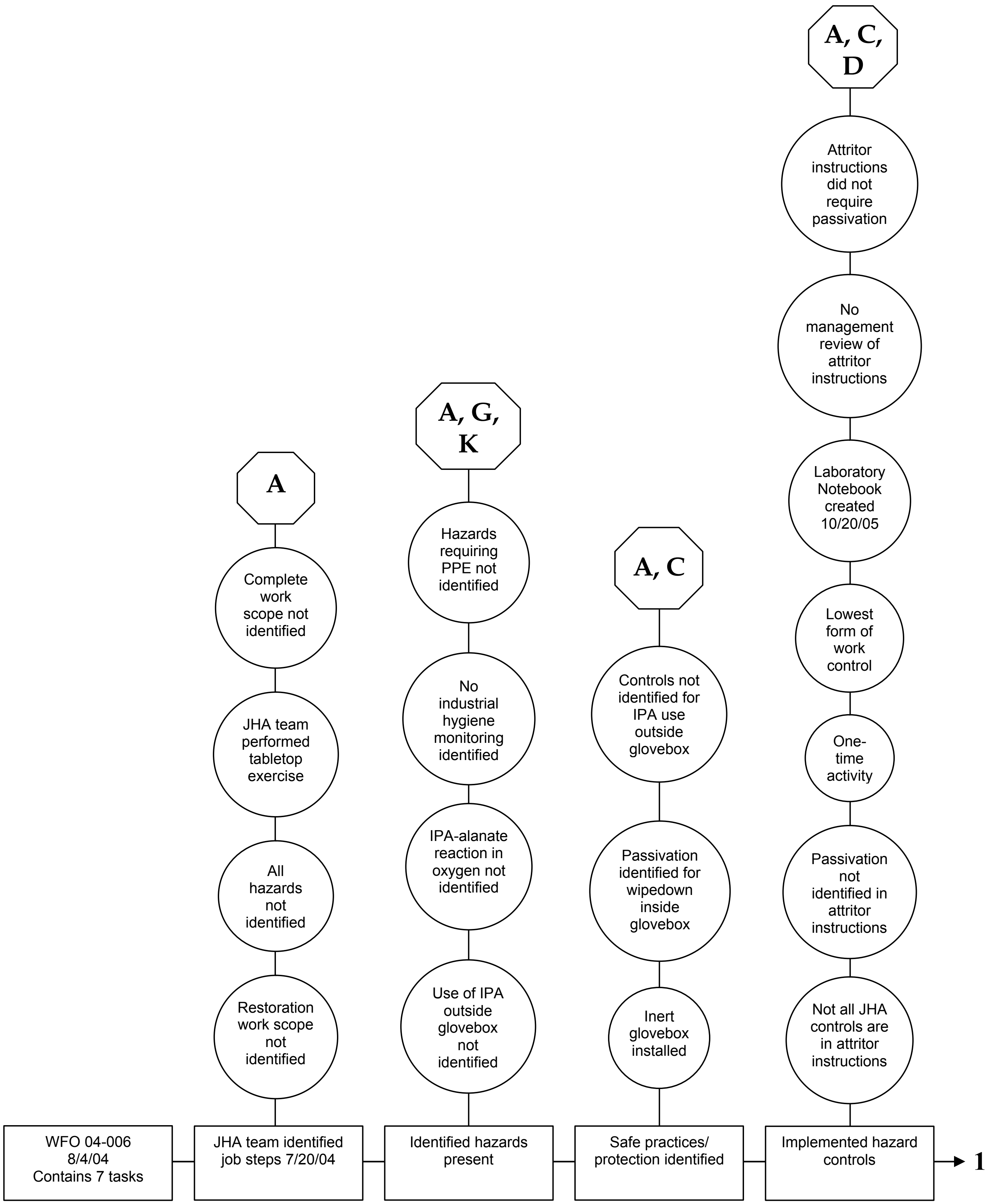
Accident Situation	Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
Original JHA was approved (Revision 0) on July 20, 2004	• Key job steps identified • Job hazards identified • Preventive or control measures identified and implemented	• Restoration activities were not identified as key job steps • Hazards associated with use of IPA outside of glovebox were not identified • Preventive or control measures to address the fire hazard were not identified	Cleaning operation was performed outside the glovebox without the proper work controls and PPE
JHA revised (Revision 1, dated 4/26/05) after 02/14/2005 trashcan fire in D-1169	• Key job steps identified • Job hazards identified • Preventive or control measures identified and implemented	• Restoration activities were not identified as key job steps • Hazards associated with use of IPA outside of glovebox were not identified • Preventive or control measures to address the fire hazard were not identified	Cleaning operation was performed outside the glovebox without the proper work controls and PPE
Disassembled attritor mill vessel removed from glovebox without written instructions establishing hazard controls	• Written instructions with hazard controls developed for restoration activities • Stop work before removing vessel from glovebox	• Written instructions with work controls not developed • Stop work not exercised	• Provided ignition source and fuel for the flash fire • Introduced unanalyzed hazard into the work environment
IPA used in D-1169 outside the glovebox	Strict controls on the use of flammable materials in D-1169	Controls not established	Provided fuel for the flash fire
Attritor mill assembly and disassembly allowed alanate inside boltholes	• No alanate would be permitted to accumulate in the boltholes • Boltholes effectively passivated	Alanate was present in the boltholes outside the glovebox	Provided the ignition source for the flash fire
Skill of the craft was used for attritor mill cleaning operations outside the glovebox	• Formal work instruction developed and used • Personnel have the competence commensurate with the responsibilities for cleaning operations	• There were no work instructions for use of IPA • Personnel did not recognize the hazard of using IPA outside the glovebox	Allowed an unanalyzed hazard (IPA) to be present to fuel the flash fire

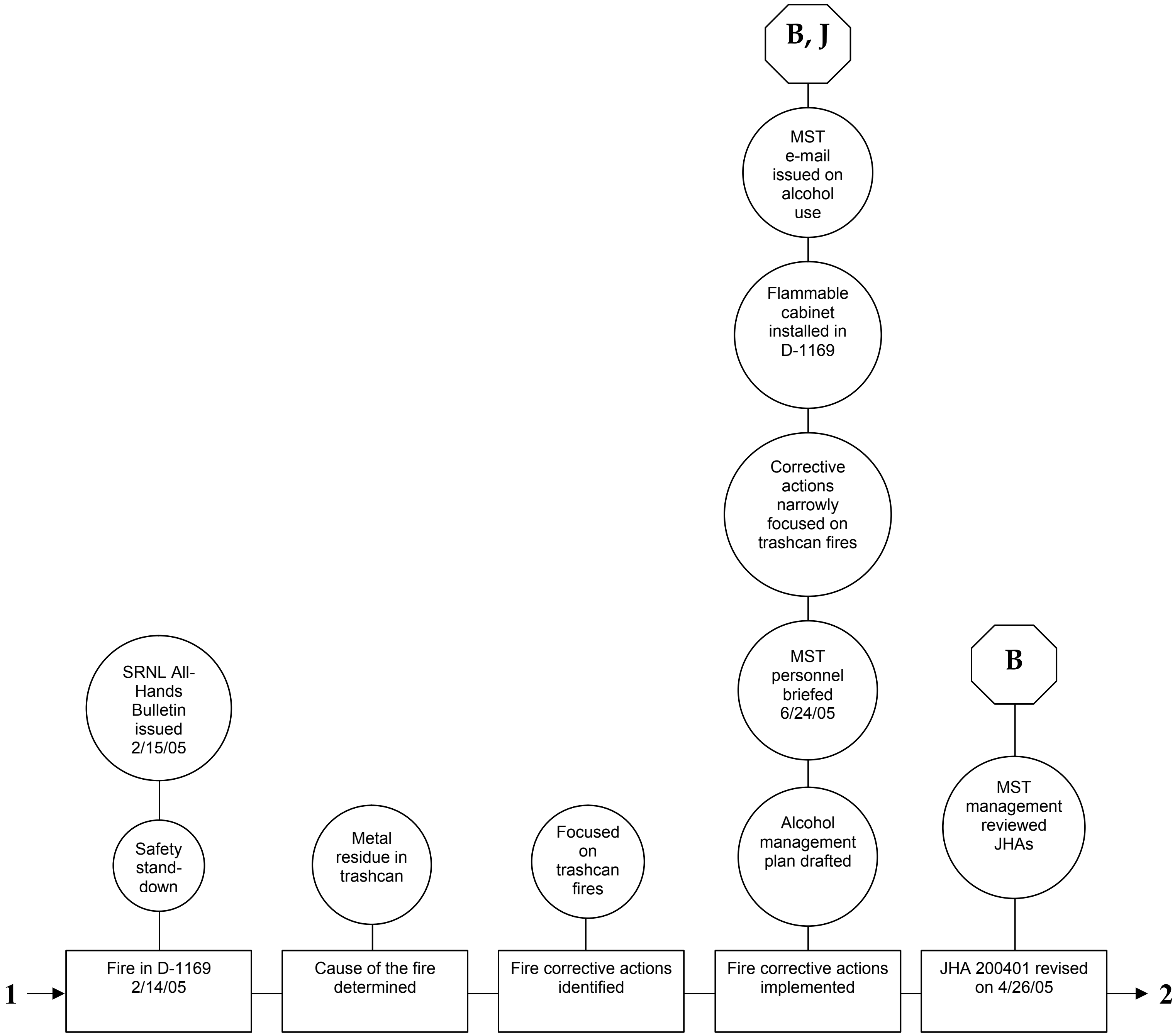
Accident Situation	Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
Passivation instructions were less than adequate	Passivation instructions (JHA, rev. 1, Task 17) would have addressed all exposed equipment, components, job waste, etc.	The instructions only address job waste which allowed unpassivated alanate to be present on the vessel outside the inert glovebox	Provided the ignition source for the flash fire
Cleaning of the vessel outside the inert glovebox with IPA	• Cleaning operation conducted in glovebox • Cleaning operation performed in well-ventilated area or in hood • Use a nonflammable solvent for cleaning operations	• Cleaning operation was considered by workers as necessary every time upon removal from the inert glovebox • Vapors generated during the cleaning operation not dispersed • Flammable solvent used	• Provided fuel for the flash fire to occur • Allowed IPA vapor concentration to exceed LFL • Provided sufficient oxygen level for the flash fire to occur
FLM received first- and second-degree burns from the flash fire	• Fire was prevented • FLM wore appropriate PPE such as fire-retardant clothing and face shields	• Fire not prevented • Fire-retardant PPE not worn	FLM was exposed to the flash fire without protection
Corrective actions developed in response to trashcan fire event of February 14, 2005 were not effective in preventing fire	Fire was prevented	Corrective actions were narrowly focused and not applied to a broader range of laboratory activities	Flash fire occurred

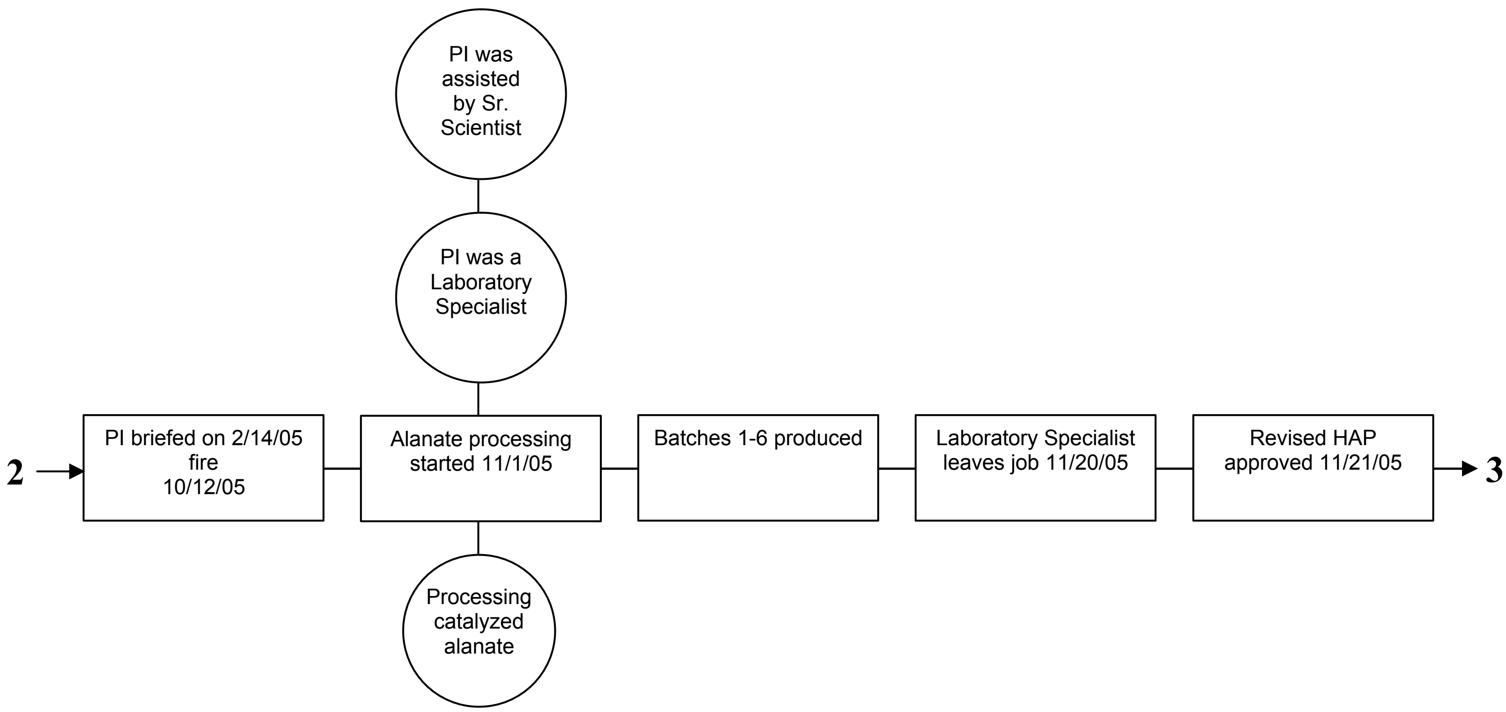
Appendix D
Events and Causal Factors Analysis

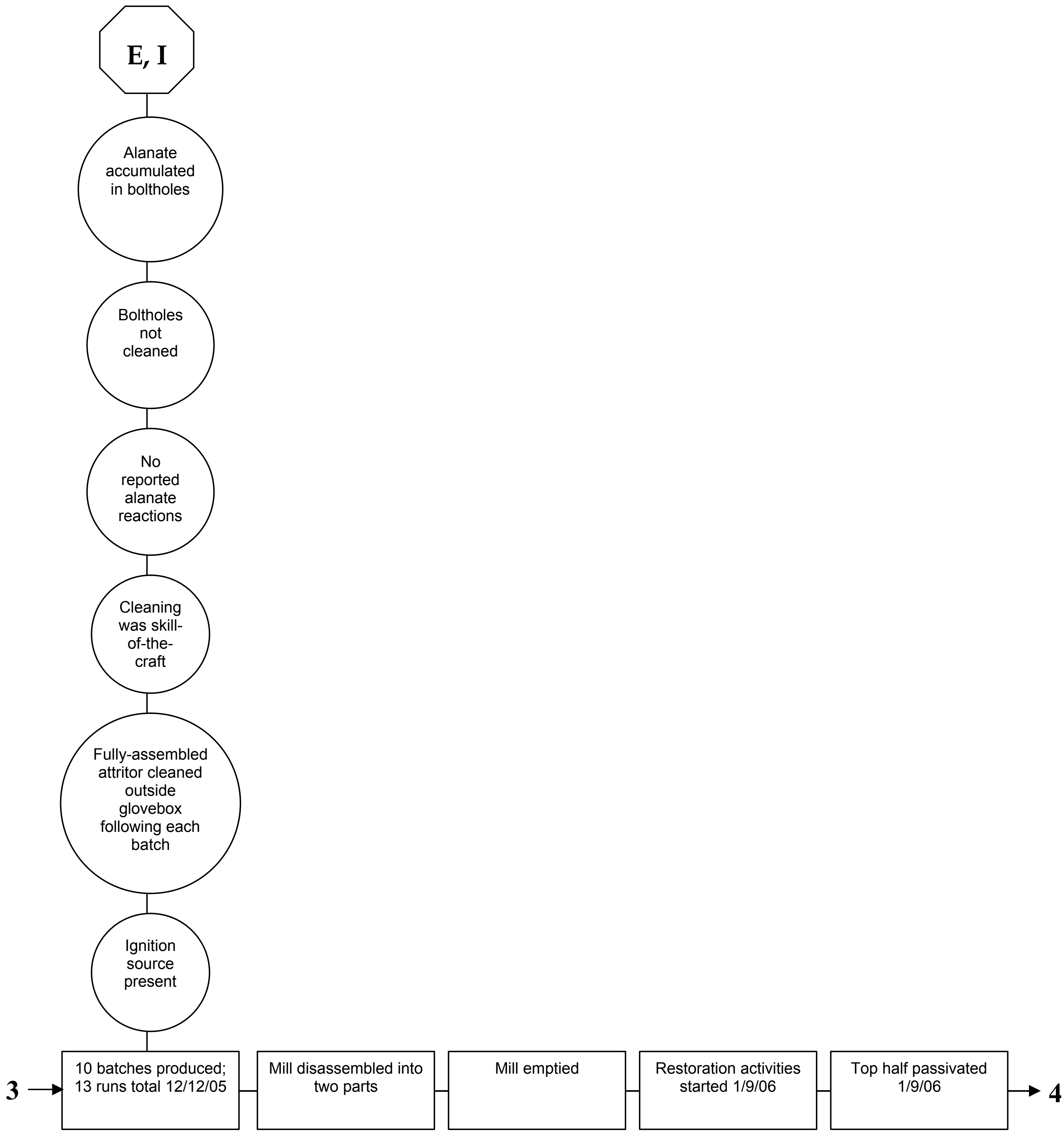
Figure D-1. Events and Causal Factors Chart

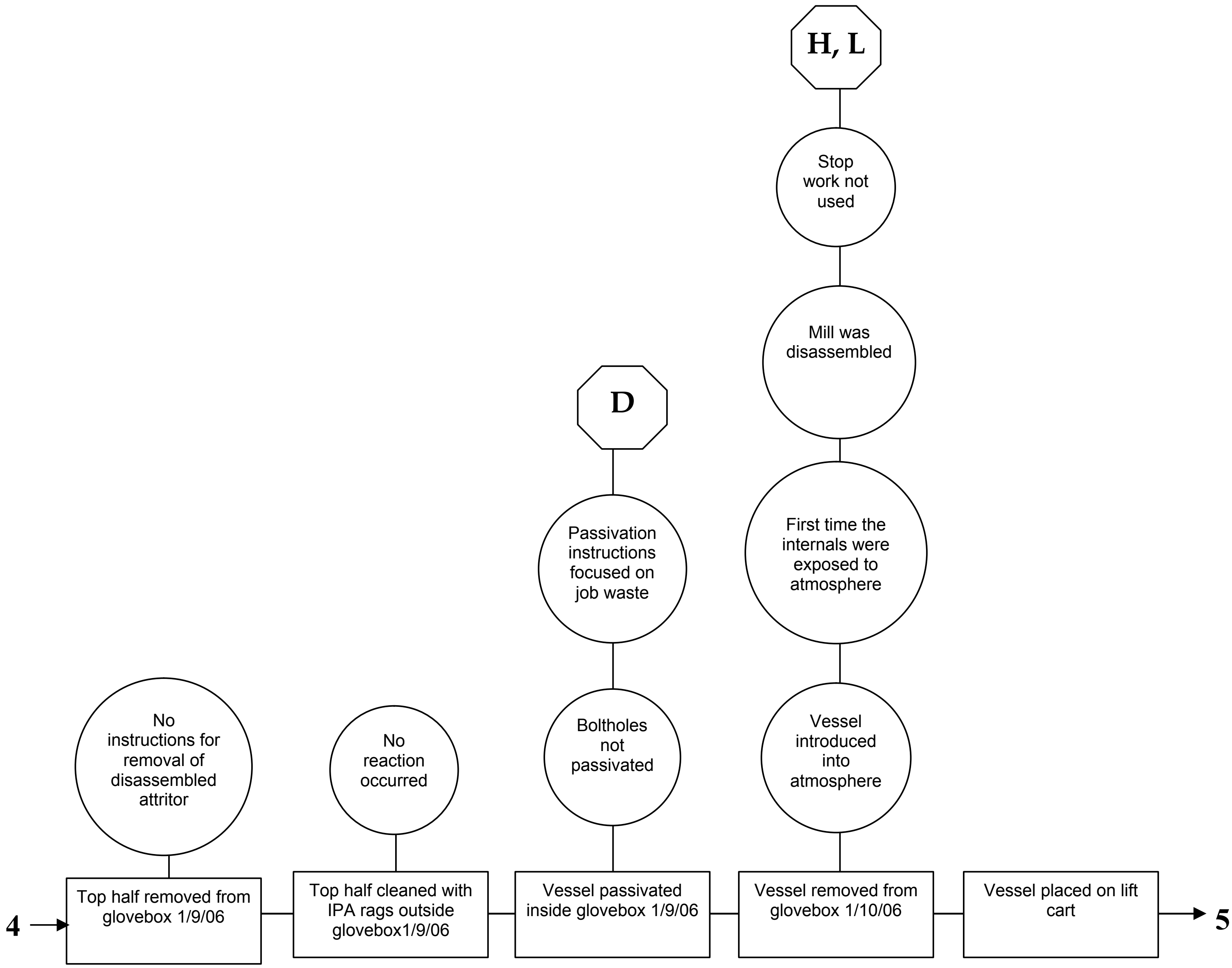
A	Failure to define complete scope of work
B	Failure to apply lessons learned from February 2005 trashcan fire in D-1169
C	Laboratory management allowed informal work activities
D	Vessel passivation was ineffective at removing all alanate residue due to inadequate instructions
E	Failure to remove all alanate from vessel boltholes
F	Concentration of IPA vapors exceeded the lower flammability limit
G	Workers were not wearing necessary PPE for the work being performed
H	Stop-work authority was not used
I	Skill-of-the-craft was used involving unanalyzed hazards
J	Laboratory supervision authorized the use of IPA in D-1169
K	Industrial hygiene monitoring not performed
L	Attritor mill disassembled from glovebox

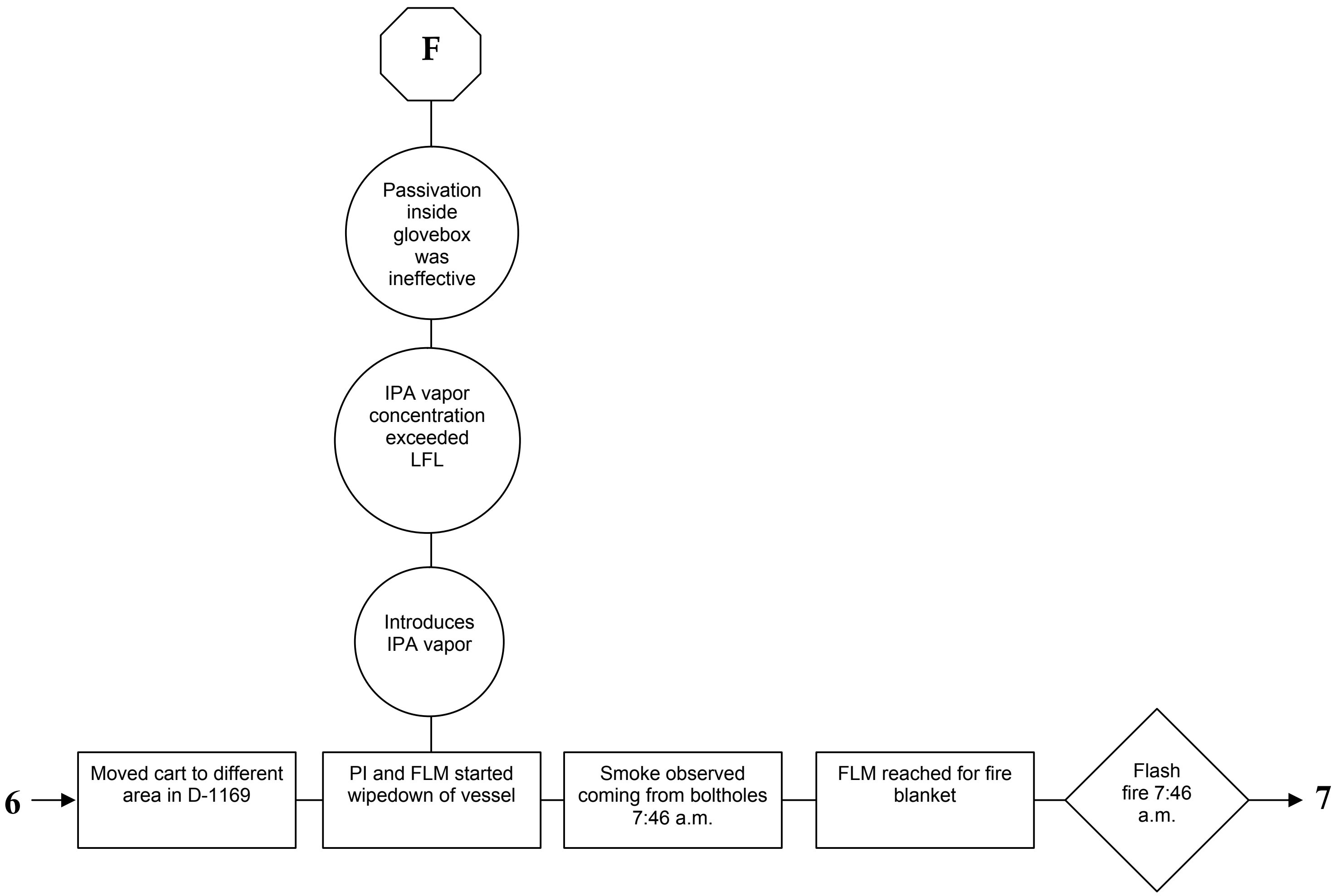

A
Complete work scope not identified
JHA team performed tabletop exercise
All hazards not identified
Restoration work scope not identified
A, G, K
Hazards requiring PPE not identified
No industrial hygiene monitoring identified
IPA-alanate reaction in oxygen not identified
Use of IPA outside glovebox not identified
A, C
Controls not identified for IPA use outside glovebox
Passivation identified for wipedown inside glovebox
Inert glovebox installed
A, C, D
Attritor instructions did not require passivation
No management review of attritor instructions
Laboratory Notebook created 10/20/05
Lowest form of work control
One-time activity
Passivation not identified in attritor instructions
Not all JHA controls are in attritor instructions
WFO 04-006 8/4/04 Contains 7 tasks
JHA team identified job steps 7/20/04
Identified hazards present
Safe practices/ protection identified
Implemented hazard controls
1

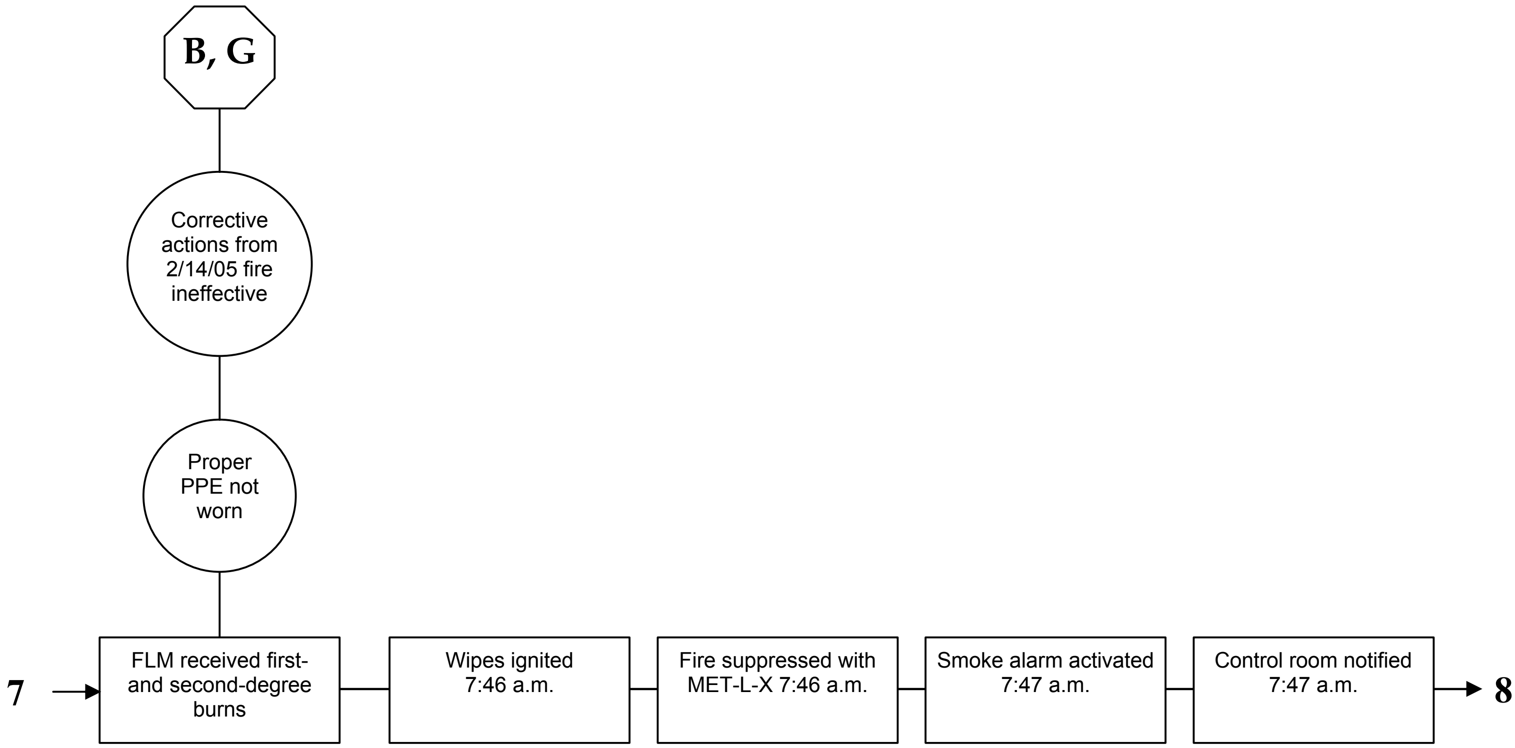

B, J
MST e-mail issued on alcohol use
Flammable cabinet installed in D-1169
Corrective actions narrowly focused on trashcan fires
MST personnel briefed 6/24/05
B
SRNL All-Hands Bulletin issued 2/15/05
Safety stand-down
Metal residue in trashcan
Focused on trashcan fires
Alcohol management plan drafted
MST management reviewed JHAs
1
Fire in D-1169 2/14/05
Cause of the fire determined
Fire corrective actions identified
Fire corrective actions implemented
JHA 200401 revised on 4/26/05
2

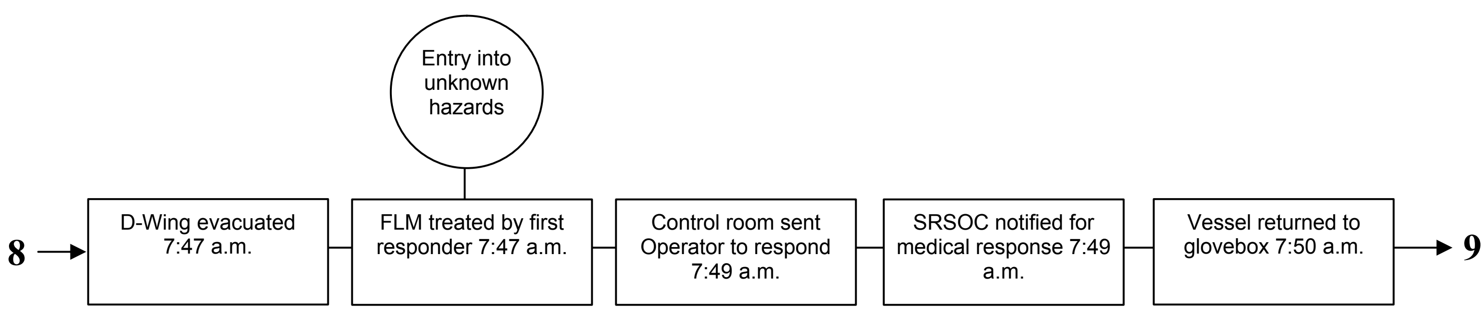

PI was assisted by Sr. Scientist
PI was a Laboratory Specialist
2
PI briefed on 2/14/05 fire 10/12/05
Alanate processing started 11/1/05
Batches 1-6 produced
Laboratory Specialist leaves job 11/20/05
Revised HAP approved 11/21/05
3
Processing catalyzed alanate

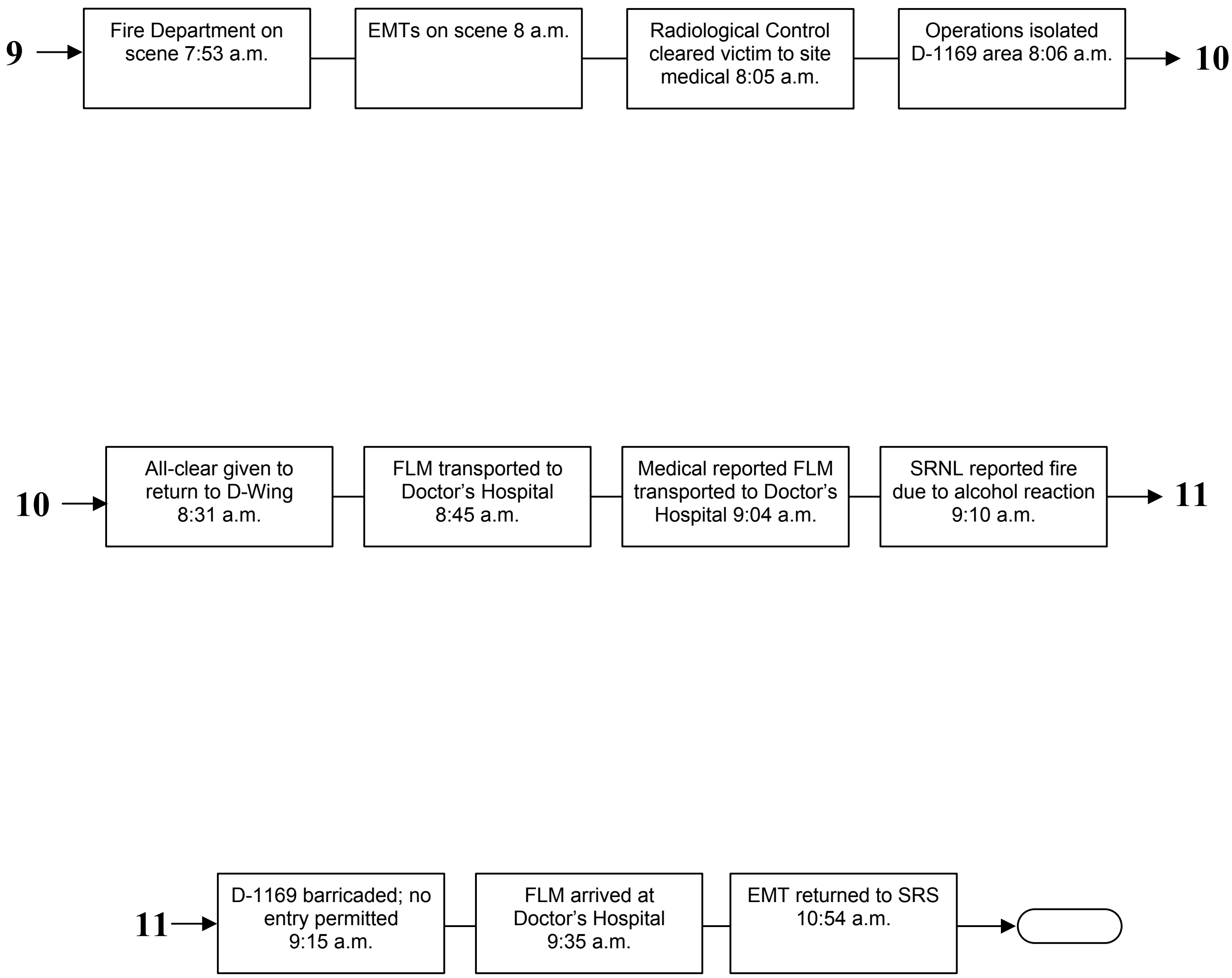

E, I
Alanate accumulated in boltholes
Boltholes not cleaned
No reported alanate reactions
Cleaning was skill-of-the-craft
Fully-assembled attritor cleaned outside glovebox following each batch
Ignition source present
3
10 batches produced; 13 runs total 12/12/05
Mill disassembled into two parts
Mill emptied
Restoration activities started 1/9/06
Top half passivated 1/9/06
4


H, L
Stop work not used
Mill was disassembled
D
First time the internals were exposed to atmosphere
Passivation instructions focused on job waste
No instructions for removal of disassembled attritor
No reaction occurred
Boltholes not passivated
Vessel introduced into atmosphere
4
Top half removed from glovebox 1/9/06
Top half cleaned with IPA rags outside glovebox1/9/06
Vessel passivated inside glovebox 1/9/06
Vessel removed from glovebox 1/10/06
Vessel placed on lift cart
5


F
Passivation inside glovebox was ineffective
IPA vapor concentration exceeded LFL
Introduces IPA vapor
6
Moved cart to different area in D-1169
PI and FLM started wipedown of vessel
Smoke observed coming from boltholes 7:46 a.m.
FLM reached for fire blanket
Flash fire 7:46 a.m.
7


B, G
Corrective actions from 2/14/05 fire ineffective
Proper PPE not worn
7
FLM received first- and second-degree burns
Wipes ignited 7:46 a.m.
Fire suppressed with MET-L-X 7:46 a.m.
Smoke alarm activated 7:47 a.m.
Control room notified 7:47 a.m.
8


Entry into unknown hazards
8
D-Wing evacuated 7:47 a.m.
FLM treated by first responder 7:47 a.m.
Control room sent Operator to respond 7:49 a.m.
SRSOC notified for medical response 7:49 a.m.
Vessel returned to glovebox 7:50 a.m.
9


9
Fire Department on scene 7:53 a.m.
EMTs on scene 8 a.m.
Radiological Control cleared victim to site medical 8:05 a.m.
Operations isolated D-1169 area 8:06 a.m.
10
10
All-clear given to return to D-Wing 8:31 a.m.
FLM transported to Doctor's Hospital 8:45 a.m.
Medical reported FLM transported to Doctor's Hospital 9:04 a.m.
SRNL reported fire due to alcohol reaction 9:10 a.m.
11
11
D-1169 barricaded; no entry permitted 9:15 a.m.
FLM arrived at Doctor's Hospital 9:35 a.m.
EMT returned to SRS 10:54 a.m.

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