DOE/ORO-2103

U. S. Department of Energy

Type B
Accident Investigation

Injury Resulting From
Violent Exothermic Chemical Reaction
at X-701B Site
Portsmouth Gaseous Diffusion Plant

Oak Ridge Operations

October 2000

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RELEASE AUTHORIZATION

This report is an independent product of the Type B Investigation Board appointed by G. Leah Dever, Manager, Oak Ridge Operations, U.S. Department of Energy. The Board was appointed to perform a Type B investigation of these incidents and to prepare an investigation report in accordance with DOE Order 225.1A, *Accident Investigations*.

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

This report neither determines nor implies liability.

INDEPENDENT REPORT

On August 23, 2000, I appointed a Type B Accident Investigation Board to investigate the August 22, 2000, violent chemical reaction involving an employee of the IT Corporation who received serious burns which required hospitalization. The employee was working on an environmental management technology deployment project at the Portsmouth Gaseous Diffusion Plant of the Department of Energy Oak Ridge Operations located in Piketon, Ohio. The responsibilities of the Board have been satisfied with respect to this investigation. The analysis, identification of contributing and root causes, and judgments of need resulting from the investigation were performed in accordance with DOE Order 225.1A, *Accident Investigations.*

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

G. Leah Dever

G. Leah Dever
Manager
Oak Ridge Operations

Date Accepted: 10/20/00

PROLOGUE

This Type B investigation is an important reminder that activities we carry out every day have important health and safety implications.

Many of the projects at Oak Ridge Operations share challenging characteristics with the project that is the subject of this investigation; that is, they involve multiple programs, multiple customers, and multiple contractors. Therefore, it is imperative that the guiding principles and core functions of integrated safety management are carried out from the highest level in the organization down to the work being completed. We need to ensure that clear lines of authority and responsibility are delineated throughout work planning and into project completion. The identification of potential hazards continues to be an area that needs improvement, and I expect significant improvement to be made.

I trust that all federal employees and contractors supporting Oak Ridge Operations will take the time to read this report, think about its applicability to their work, recognize that there is no such thing as a routine health and safety activity, and work with us to achieve an integrated safety management system.

G. Leah Dever
Manager
Oak Ridge Operations

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EXHIBITS, FIGURES, AND TABLES

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ACRONYMS

AHA	Activity Hazard Analysis
bisulfite	Sodium metabisulfite $NA_2 (S_2O_5)$
BJC	Bechtel Jacobs Company LLC
Board	Accident Investigation Board
COR	Contracting Officer's Representative
DEAR	Department of Energy Acquisition Regulations
DOE	Department of Energy
EM	Environmental Management
EPA	Environmental Protection Agency
ES&H	Environment, Safety, and Health
FRx	FRx Corporation
FR	Facility Representative
FY	Fiscal Year
HASP	Health and Safety Plan
HS	Health and Safety
HSO	Health and Safety Officer
ISCOR	In-situ chemical oxidation recirculation
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
IT	IT Corporation
MSDS	Material Safety Data Sheet
M&I	Management and Integration
ORO	Oak Ridge Operations
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Health and Safety Administration
OSU	Ohio State University
permanganate	Sodium permanganate
PM	Project Manager
PORTS	Portsmouth Gaseous Diffusion Plant
PPE	Personal protective equipment
thiosulfate	Sodium thiosulfate $Na_2 (S_2O_3)$
QAPjP	Quality Assurance Project Plan

SHSO	Site Health and Safety Officer
SME	Subject Matter Expert
SORC	Site Operations Review Committee
SSHS	Site Safety and Health Supervisor
STR	Subcontractor Technical Representative
TCE	Trichloroethene - C_2HCl_3
TWP	Technical Work Plan
USEC	United States Enrichment Corporation
USQD	Unreviewed Safety Question Determination
UT-Battelle	UT-Battelle, LLC
VOC	Volatile Organic Compound
WAD	Work Authorization Directive

Executive Summary

The Accident

On August 22, 2000, an accident occurred at the U. S. Department of Energy (DOE) Portsmouth Gaseous Diffusion Plant (PORTS) located in Piketon, Ohio. An employee of the IT Corporation (IT) working on an Environmental Management (EM) Technology Deployment Project received serious burns from a violent chemical reaction. The chemical reaction was initiated by the IT Laborer placing crystalline thiosulfate into a five-gallon bucket containing about three gallons of concentrated sodium permanganate solution. The exothermic reaction of the thiosulfate and the permanganate caused a steam bubble to eject the permanganate solution from the five-gallon bucket more than 15 feet into the air. The solution covered the front of the IT Laborer who was standing directly over the bucket. The front portion of the IT Laborer's 100% cotton blue jeans immediately ignited and disappeared into ash. The solution also splattered all over the back of the Driller's Assistant who was standing about 15 feet away adjacent to the drill rig.

The Driller's Assistant felt a burning sensation on his back and quickly went to the safety shower in the IT site office trailer. The Driller's Assistant was not seriously injured and did not require medical attention. The injured IT Laborer's coworkers reacted quickly by drenching him with water and washing his eyes with neutralizing solution. Because of the severity of his burns, the IT Laborer was airlifted to the Ohio State University Medical Center in Columbus, Ohio. He has since been released from the hospital, but he is facing additional medical treatment and physical therapy.

Emergency response to the scene was delayed by a failure to utilize the notification procedure in the Health and Safety Plan (HASP) and because the initial cellular telephone call to the Pike County 911 Operator indicated that the accident was at the Paducah Plant in Kentucky.

On August 23, 2000, the Manager, Oak Ridge Operations (DOE ORO), chartered a Type B Accident Investigation Board to investigate the accident. The Board arrived on site at Portsmouth on August 23, 2000, and they completed the investigation in September 2000. This report was presented to the DOE ORO Manager for acceptance on October 6, 2000.

Background

The project being conducted by IT at Portsmouth was intended to provide in-situ treatment of dense, nonaqueous phase liquids (primarily trichloroethene) in the low permeable Minford and Gallia formations. It required injections of sodium permanganate into the soil at multiple points to achieve treatment. The project site was located outside the plant fence at Portsmouth on the northeast side of the perimeter road above the contaminated groundwater plume.

IT is a subcontractor to UT-Battelle, LLC (UT-Battelle), performing work under an approved EM Technical Task Plan. The work was being performed at Portsmouth under agreement between UT-Battelle and Bechtel Jacobs Company LLC (BJC), the prime management and integration contractor for the Portsmouth site. Safety for the project site was the line responsibility of UT-Battelle. BJC was responsible for site support and oversight.

UT-Battelle and IT prepared a HASP, a HASP Addendum, and other project documentation which they submitted to BJC to use as the basis for their readiness review for the start up of the project. The project documentation reviewed and accepted by BJC did not identify all the involved hazards. There were no subsequent changes to the project documentation or further BJC evaluations to account for changes in the work processes or incidents that occurred. Project documentation was not current at the time of the accident. Project direction was provided by UT-Battelle, Grand Junction. The project had experienced multiple changes in leadership, with the most recent being less than two weeks before the accident.

Results and Analysis

Prior to field deployment of the project, UT-Battelle submitted its project documentation to BJC for readiness review. On July 19, 2000, the BJC Site Operations Review Committee readiness review team granted UT-Battelle and its subcontractor, IT, permission to proceed with field activities. Due to the complex organizational relationships for the project and the site, roles and responsibilities for project oversight were not clearly established. BJC did not supplement its readiness review with a field review prior to the start of operations or provide adequate field oversight during the execution of the project. No health and safety (HS) oversight was performed by DOE ORO.

The BJC readiness review team did not discover the inadequacies in the project documentation presented by UT-Battelle. The HASP, which was accepted by BJC, established project responsibilities for BJC personnel to serve as Project Manager, HS Manager, HS Advocate, and Subcontractor Technical Representative. The project documentation did not identify all tasks to be performed, resulting in unacceptable hazard analysis and inadequate development and implementation of controls. The preparers of the project documentation failed to obtain and follow the hazard control and personal protective equipment (PPE) recommendations of the permanganate supplier's most recent Material Safety Data Sheets (MSDSs) and fact sheets. Additionally, the hazard analysis did not identify and analyze neutralization of permanganate as a project activity. Because of these failures in the analysis process, the hazard controls in use at the project site were ineffective in preventing or mitigating the accident.

Personnel on the UT-Battelle project site did not comply with the HS requirements stated in the project documents. The UT-Battelle HS Officer, who was on the project the day of the accident, had not signed the project HASP. No one took responsibility for ensuring that critical project documents were controlled and kept up to date. Basic occupational HS and hazardous waste site deficiencies were allowed to continue unabated and unmitigated on the project site.

Conclusions

The Board concludes that this accident and the resulting injuries were preventable. This accident highlighted deficiencies in numerous aspects of safety management and emergency preparedness for the project.

The direct cause of the accident was the introduction of crystalline sodium thiosulfate into a five-gallon bucket containing concentrated sodium permanganate solution. Neither the UT-Battelle and IT line managers who were responsible for the workers' safety nor the BJC readiness review team adequately understood or analyzed the hazards of the job site. Therefore, they did not assure that adequate hazard controls were in place.

The Board identified four root causes for the accident.

- UT-Battelle, BJC, and IT management failed to analyze the hazards for all field activities. This failure resulted in inadequate development and implementation of control measures for and knowledge of the potential hazards.
- UT-Battelle, BJC, IT, and the IT subcontractors' project personnel failed to implement the hazard controls and requirements stated in the project documents.
- DOE ORO, UT-Battelle, BJC, and IT management did not establish clear roles and responsibilities for the planning, execution, and oversight of the project.
- DOE ORO, UT-Battelle, BJC, and IT management did not establish or ensure a safety culture that implements Integrated Safety Management (ISM) and encourages personnel to stop and re-enter the analysis phase when a change or unexpected condition arises.

Judgments of Need

Judgments of Need are the managerial controls and safety measures determined by the Board to be necessary to prevent and/or minimize the probability or severity of a recurrence. They flow from the causal factors, which are derived from the facts and analysis. Judgments of Need are directed at providing guidance for managers during the development of corrective action plans. See Table ES-1 for a list of the Judgments of Need.

Table ES-1: Judgments of Need

No.	Judgments of Need	Related Causal Factors
JON 1	BJC and UT-Battelle management need to ensure that unambiguous roles and responsibilities are established for every project from conception through field implementation.	• The roles and responsibilities for BJC, UT-Battelle, and IT were not clearly understood or executed. • Work control processes were inadequate. • There was no document control instituted for the project. • Compliance with basic HS requirements was not enforced on site. • The HASP, HASP Addendum, and Activity Hazard Analysis (AHA) were not in compliance with the MSDSs. • Turnovers for roles specified in the HASP and HASP Addendum were not effective, nor were they documented by changes to the documentation. • UT-Battelle failed to ensure ISM was established and maintained by its sub-contractors. • Field implementation of documented controls and assumptions was inadequate.
JON 2	BJC, UT-Battelle, and IT management need to ensure line management understands their responsibility for safety, including a safe work environment with personnel always being aware of the potential hazards and the freedom to call a time out for evaluation of an activity or situation that raises questions especially questions as to whether the event/activity has been properly addressed in the project documentation.	• The roles and responsibilities for BJC, UT-Battelle, and IT were not clearly understood or executed. • Lessons from previous incidents and other chemical accidents within DOE were not learned. • Management did not assure a safety culture where workers were willing to stop work and to re-enter the hazard identification and analysis phases when unexpected conditions were encountered. • Personnel knowledge and experience were with using

No.	Judgments of Need	Related Causal Factors
		potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.
JON 3	BJC, UT-Battelle, and IT management need to ensure that all activities to be performed are identified and the appropriate Subject Matter Experts (SMEs) perform a hazard analysis to determine potential hazards, resulting in the development and implementation of controls.	• The hazards associated with the chemicals on site and appropriate PPE were not adequately identified and analyzed. Proper controls were not developed and implemented. • Field implementation of documented controls and assumptions was inadequate. • The work planning and readiness review processes were inadequate. • The roles and responsibilities for BJC, UT-Battelle, and IT were not clearly understood or executed. • Lessons from previous incidents and other chemical accidents within DOE were not learned. • The HASP, HASP Addendum, and AHA were not in compliance with the MSDSs. • Personnel knowledge and experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.
JON 4	BJC needs to evaluate the adequacy of its readiness review process to ensure that technical correctness, complete hazard identification and analysis, development and implementation of controls, and readiness on the part of field personnel and equipment to actually execute the activity/project are reviewed prior to granting permission to proceed.	• The hazards associated with the chemicals on site and appropriate PPE were not adequately identified and analyzed. Proper controls were not developed and implemented. • The work planning and readiness review processes were inadequate.

No.	Judgments of Need	Related Causal Factors
		• Field implementation of documented controls and assumptions was inadequate. • Lessons from previous incidents and other chemical accidents within DOE were not learned. • There was no document control instituted for the project. • Compliance with basic HS requirements was not enforced on site. • The HASP, HASP Addendum, and AHA were not in compliance with the MSDSs. • Personnel knowledge and experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.
JON 5	BJC, UT-Battelle, IT, and IT's subcontractors field personnel need to ensure complete implementation of all controls and requirements contained in project documents and that only activities with appropriately documented and approved hazard analysis are performed.	• Field implementation of documented controls and assumptions was inadequate. • Training on the hazards of the chemicals on site was not effective. • Work control processes were inadequate. • No document control was instituted for the project. • Compliance with basic HS requirements was not enforced on site. • The HASP, HASP Addendum, and AHA were not in compliance with the MSDSs. • Turnovers for roles specified in the HASP and HASP Addendum were not effective, nor were they documented by changes to the documentation. • Personnel knowledge and

No.	Judgments of Need	Related Causal Factors
		experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.
JON 6	UT-Battelle management needs to ensure that expectations for implementation of requirements, especially HS requirements, set forth in subtier contracts are properly communicated to and executed by field personnel.	• The roles and responsibilities for UT-Battelle, and IT were not clearly understood or executed. • The contracting process did not adequately implement ISM requirements. • UT-Battelle failed to ensure ISM was established and maintained by its subcontractors.
JON 7	DOE ORO, BJC, and UT-Battelle management need to ensure oversight of operations is instituted from design and development through actual field performance and delivery of the desired product.	• The work planning and readiness review processes were inadequate. • Field implementation of documented controls and assumptions was inadequate. • DOE ORO and the PORTS Site Office failed to establish unambiguous lines of authority and responsibility for HS at all organizational levels. • The roles and responsibilities for BJC, UT-Battelle and IT were not clearly understood or executed. • UT-Battelle and IT management did not assure a safety culture where workers were willing to stop work and to re-enter the hazard identification and analysis phases when unexpected conditions were encountered. • Compliance with basic HS requirements was not enforced on site. • Turnovers for roles specified in the HASP and HASP Addendum were not effective,

No.	Judgments of Need	Related Causal Factors
		nor were they documented by changes to the documentation. • Personnel knowledge and experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.
JON 8	DOE ORO line managers need to ensure an unambiguous DOE line of authority is established for all projects. Once the line of authority is established, clear oversight roles and responsibilities need to be in place and implemented.	• DOE ORO and the PORTS Site Office failed to establish unambiguous lines of authority and responsibility for HS at all organizational levels. • Communication between the various DOE organizations was not adequately performed. • The work planning and readiness review processes were inadequate. • The contracting process did not adequately implement ISM requirements. • Compliance with basic HS requirements was not enforced on site.
JON 9	DOE ORO line management needs to evaluate the addition of Facility Representative(s) (FR) and/or additional HS SMEs to the DOE PORTS Site Office.	• DOE ORO and the PORTS Site Office failed to establish unambiguous lines of authority and responsibility for HS at all organizational levels. • Communication between the various DOE organizations was not adequately performed.
JON 10	DOE ORO needs to ensure personnel performing FR responsibilities are adequately qualified.	• Communication between the various DOE organizations was not adequately performed.

1.0 Introduction

On August 22, 2000, an employee working on an Environmental Management (EM) Technology Deployment Project received serious burns from a chemical reaction, which required hospitalization. On August 23, 2000, Leah Dever, Manager, U.S. Department of Energy Oak Ridge Operations (DOE ORO), appointed a Type B Accident Investigation Board (referred to as "the Board") to investigate the accident in accordance with DOE Order 225.1A, *Accident Investigations* (see Appendix A). The Board arrived on site on August 23, 2000. This report documents the facts surrounding the accident and the results and conclusions of the Board.

1.1 Facility Description

The Portsmouth Gaseous Diffusion Plant (PORTS) is located approximately 25 miles northeast of Portsmouth, Ohio, and about two and a half miles east of the Scioto River. The PORTS site is approximately 3,714 acres. The fenced area surrounding the gaseous diffusion plant facilities occupies about 640 acres. The DOE mission at PORTS was to enrich uranium for use in domestic and foreign commercial power reactors. In the past, the mission also included providing materials for weapons production and naval reactor fuel. In the fall of 1992, the Energy Policy Act (Public Law 102-486) amended the Atomic Energy Act of 1954 and established the United States

Exhibit 1-1. PORTS X-701B Site

Enrichment Corporation (USEC). USEC assumed responsibility for uranium enrichment operations at PORTS on July 1, 1994. The Nuclear Regulatory Commission performs regulatory oversight of USEC activities. The Occupational Safety and Health Administration (OSHA) regulates USEC occupational safety and worker health, and the State of Ohio and Environmental Protection Agency (EPA) regulates USEC environmental activities.

DOE remains the owner of the site and is responsible for all facilities not leased to USEC and for all environmental response and corrective actions with respect to contamination or releases arising from past operations. Bechtel Jacobs Company LLC (BJC) became the prime management and integration (M&I) contractor for DOE at PORTS on April 1, 1998.

The accident occurred outside the limited area of PORTS, near the north end of the perimeter fence and just east of the PORTS perimeter road near the intersection of the east access road (see Exhibit 1-1). The task in progress was a technology deployment project being performed by another DOE ORO prime contractor, UT-Battelle, LLC (UT-Battelle), for the DOE ORO Environmental Technology Group. Field operations were being done by IT Corporation (IT), under subcontract to UT-Battelle. IT was supported on site by personnel from two second-tier subcontractors, Miller Drilling and FRx Corporation (FRx).

The pilot-scale project being deployed at the time of the accident was in-situ chemical oxidation using lance permeation delivery of sodium permanganate ($NaMnO_4$) (permanganate). The lance permeation injection process uses high-pressure water and low-pressure permanganate solution. High-pressure water is used to fracture the ground formation and dilute the permanganate solution. The permanganate solution reacts with the trichloroethene (TCE), thereby achieving TCE plume reduction and treatment.

1.2 Scope, Purpose, and Methodology

The Board began the investigation on August 23, 2000, and completed the on-site phase of their investigation on August 30, 2000. The final report was submitted to the DOE ORO Manager on October 6, 2000. The scope of the Board's investigation was to review and analyze the circumstances of the accident to determine its causes. The Board also evaluated the adequacy of the safety management system and work control practices of UT-Battelle and BJC as they relate to the accident.

The purpose of this investigation was to determine the cause(s) of the accident, identify lessons learned, improve safety, and reduce the potential for similar accidents.

The Board conducted their investigation using the following methodology:

- Inspecting and photographing the accident scene and individual items of evidence related to the accident.
- Gathering facts through interviews, document and evidence reviews, and a walkdown of the area.
- Charting causal factors related to the five core functions and eight guiding principles of Integrated Safety Management (ISM), along with barrier

and change analysis techniques. (see Accident Analysis Terminology box).

- Developing Judgments of Need for corrective actions to prevent recurrence, based on analysis of the information gathered.

Accident Analysis 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(s) or conditions(s) that caused the accident; contributing causes, which are causal factors that collectively with other causes increase the likelihood of an accident, but that individually did not cause the accident; root cause(s), which is (are) the causal factor(s) that, if corrected, would prevent recurrence of the accident. The causal factors and events of this accident were examined and categorized within the five core functions and eight guiding principles of ISM.

Barrier analysis reviews 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, administrative, or supervisory.

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

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2.0 Facts

2.1 Overview

On August 22, 2000, IT and its subcontractors were engaged in deployment of in-situ remediation of ground formations (low permeability Minford and Gallia) in the X-701B Area of PORTS (see Exhibit 2-1 a & b). While pulling the rods from the third injection hole that morning, solution was pumped out of the first two rods into a five-gallon bucket. The rods were placed onto the storage rack, and the soil was washed off prior to proceeding to the next location. The drilling rig and rod storage rack were relocated to the fourth injection location of the day. The Driller noted solution coming out of one of the drill head ports. He placed a five-gallon bucket underneath the drill head for containment while personnel took a break for lunch.

Exhibit 2-1a. Lance Permeation Site Overview

Exhibit 2-1b. Lance Permeation Site Exclusion Zone

After returning from lunch, the Driller noted that the five-gallon bucket was at least two-thirds full of purple (permanganate) solution of unknown concentration. The five-gallon bucket containing the solution was moved from under the drill head by the Driller and handed to his assistant. The Driller's Assistant carried the bucket away from the drilling area, placed it on the ground, and returned to the drilling rig. The Driller drove the first rod down to the five-foot level and connected the second rod. After insertion of about one foot (a total of six feet) the Driller noted some bleed-up of permanganate solution through the rods. The insertion was stopped (see Exhibit 2-2). The second rod was pumped free of

Exhibit 2-2. Drilling Rig

Exhibit 2-3. Location of Drilling Rig at Time of Accident

liquid and removed from the hole. The first rod was pumped free of liquid and raised to ground level for examination of the threads between the head and rod (see Exhibit 2-3). The Driller, the Driller's Assistant, and an FRx Field Technician were examining the threads when the accident happened. A loud explosion was heard, and solution from the five-gallon bucket became airborne, rising at least 15 feet in the air. The Driller's Assistant's back, as well as the drilling rig, were sprayed by the airborne solution. The other two individuals at the drilling rig were shielded from the airborne solution by the Driller's Assistant. The most seriously injured individual, the IT Laborer, was located immediately adjacent to the bucket. He was sprayed on his front by the airborne solution. No other workers were adversely impacted by the solution. The Driller's Assistant was treated on site and did not encounter any lasting effects from the event. The IT Laborer received immediate on site first aid treatment and, because of the serious nature of his injuries, he was helicoptered to the Ohio State University (OSU) Medical Center Burn Unit. He received skin graphs and was released from OSU Burn Unit after approximately a month. On-going medical treatment continues, including physical therapy.

2.2 Contracts

BJC is the prime M&I contractor for DOE at the PORTS site. UT-Battelle is the DOE ORO prime contractor responsible for the EM Technology Deployment Project taking place when the accident occurred. UT-Battelle at Grand Junction, Colorado, was the UT-Battelle satellite office responsible for the project. Field operations were being done by IT under a subcontract to UT-Battelle. IT was supported on site by personnel from two second-tier subcontractors, Miller Drilling and FRx.

The Technical Task Plans for Fiscal Year (FY) 1999 and FY 2000 for this project were approved by Headquarters, EM, Office of Science and Technology (EM-50), and the DOE ORO EM Program Manager. The EM-50 funding for this project was sent from Headquarters EM-50 to the DOE ORO financial plan and then to the UT-Battelle financial plan.

Funding for this project was sent to UT-Battelle by BJC via Work Authorization Directive (WAD) Number WA20312, Revision 3, dated May 3, 2000. The original WAD and first two revisions dealt with the In-Situ Chemical Oxidation

Recirculation (ISCOR) Project. Since efforts to recover the injection well and resume recirculation in the ISCOR project were unsuccessful, it was agreed by the Oak Ridge National Laboratory (ORNL) prime contractor and BJC to redirect the remaining work authorization funds to support the vertical permeation effort to treat TCE in the deeper ground level (Gallia layer). A subtask was added to describe the lance permeation process to be performed via a subcontract between the ORNL prime contractor and IT. This WAD clearly states that health and safety (HS) and quality requirements for work to be performed will be in accordance with existing approved project plans and appropriate BJC policies and procedures. The WAD revision contains approval signatures from the following PORTS BJC personnel: HS, Quality Assurance, Project Controls, Procurement, Technical Manager, Functional/Project Manager (PM), and the Controller. Work acceptance approval was signed for by UT-Battelle management.

The DOE ORO EM Program Manager for this project did not coordinate the request for a UT-Battelle subcontract with the DOE UT-Battelle Contracting Officer's Representative (COR).

No person in the DOE ORO EM organization or the PORTS Site Office had either COR/Technical Representative authority over the UT-Battelle contract or any other contractual authority over UT-Battelle or its subcontractor, IT.

Both the BJC and UT-Battelle contracts with DOE ORO contain Department of Energy Acquisition Regulations (DEAR) Clause 970.5704-2, *Integration of Environment, Safety, and Health into Work Planning and Execution* (June 1997). The UT-Battelle contract passes the Integrated Safety Management System (ISMS) requirements down to the subcontractor, IT, by means of a reference in the subcontract's General Terms and Conditions. The General Terms and Conditions, Paragraph 2.1, states: "The following clauses are incorporated by reference: DEAR Clause 970.5204-2, *Integration of Environment, Safety, and Health into Work Planning and Execution* (June 1997) (if work is complex or hazardous) . . ." This requirement was available to IT only if its personnel accessed the UT-Battelle web site and retrieved the General Terms and Conditions. For IT personnel to find the requirements of DEAR clause 970.5204-2, they would then have to access the DEAR and look up the actual wording of that clause. No deliverable requirements for an ISMS description were included in the contract, and the Statement of Work did not indicate that the subcontractor was to operate under the UT-Battelle ISMS description.

2.3 Accident Description and Chronology

Although the chemical reaction and injuries occurred on August 22, 2000, the circumstances that led up to the accident began with the planning and preparation for the project (see Figure 2-1). This section describes the chronology of events leading up to the accident, the accident response, and the personnel injuries resulting from the accident. The event time line is shown in Figure 2-2.

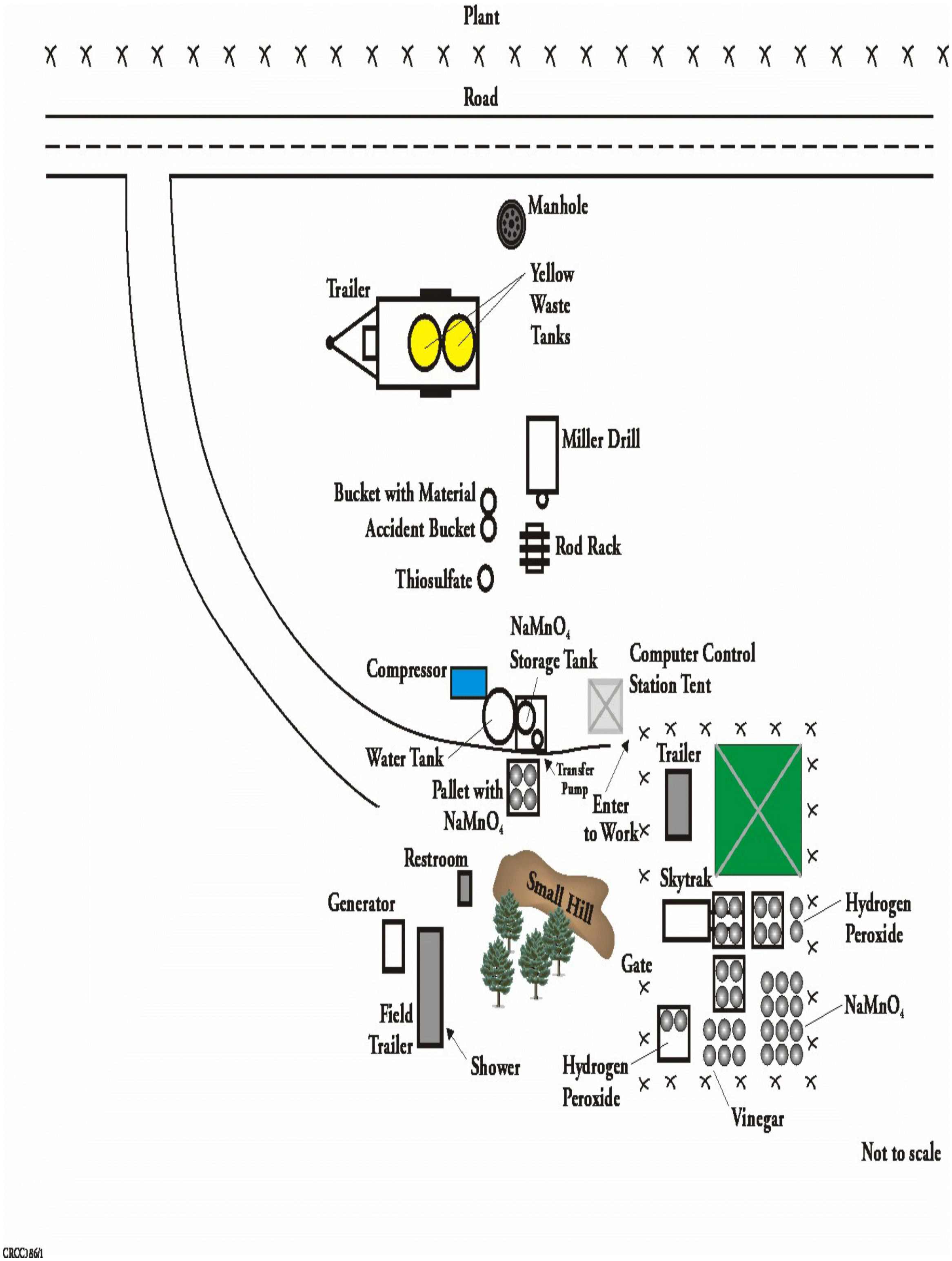


Figure 2-1. Project Site Layout

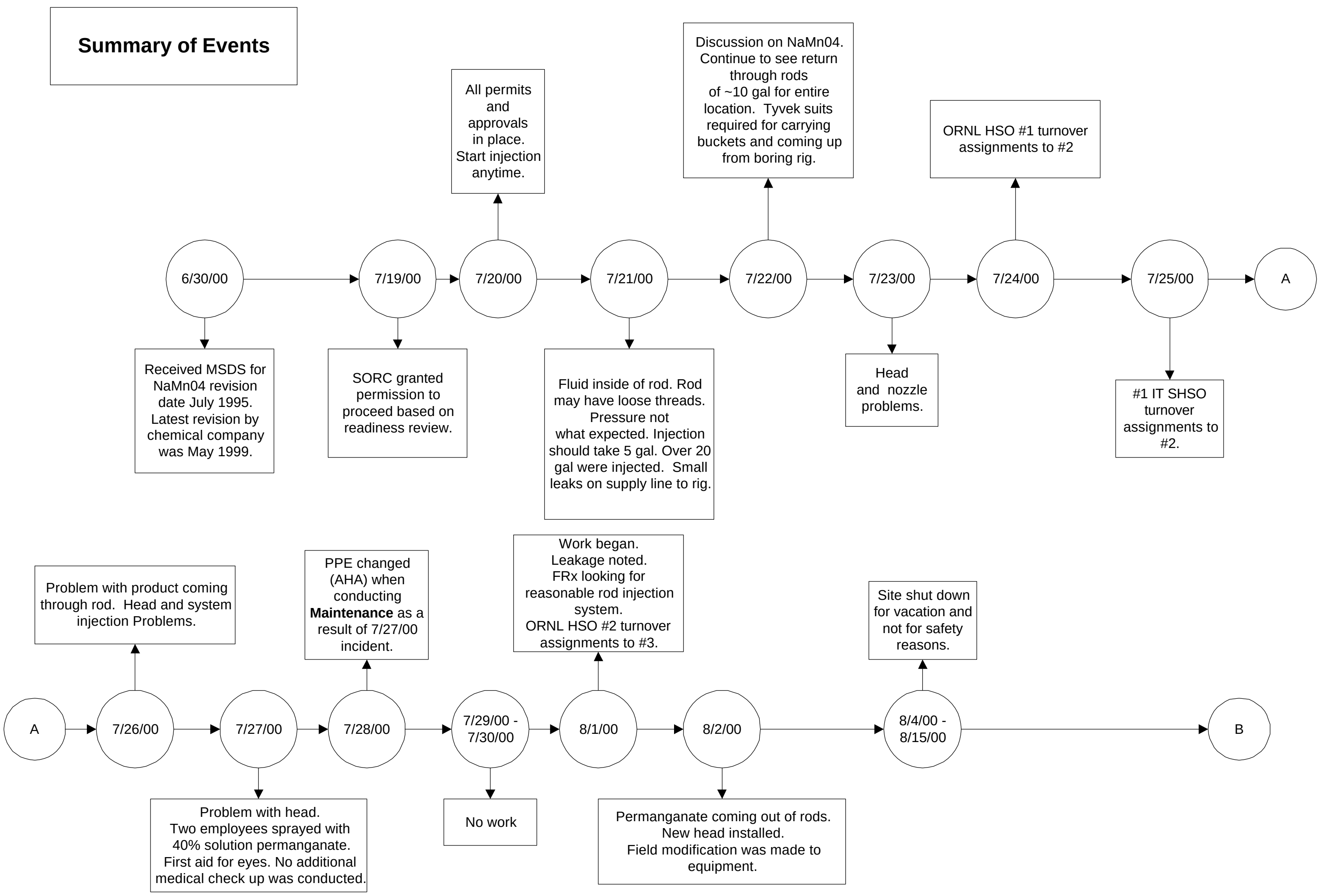
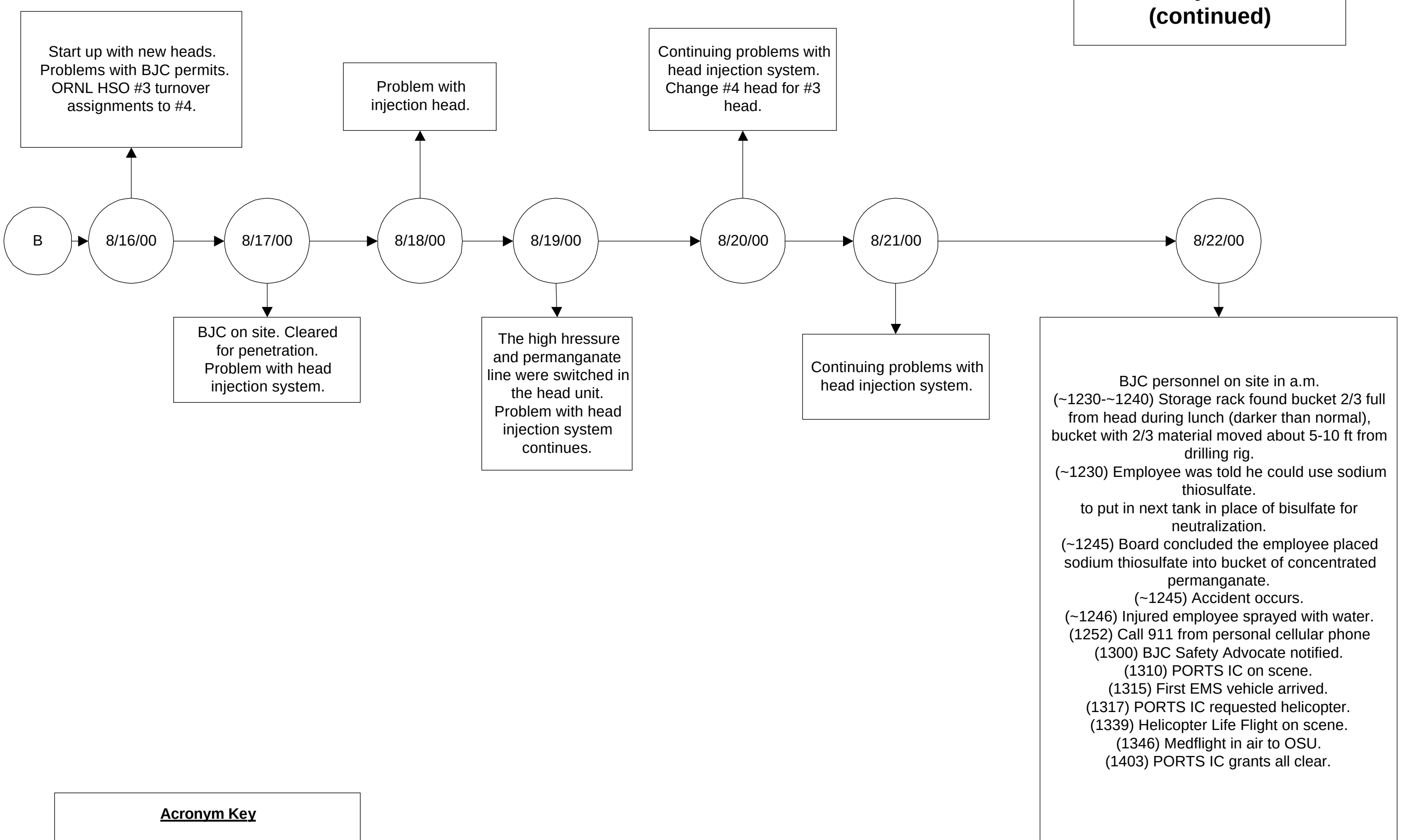


Figure 2-2. Time Line

Summary of Events (continued)



Acronym Key

AHA	Activity Hazard Analysis
EMS	Emergency Medical Services
HSO	Health and Safety Offier
IC	Incident Commander
MSDS	Material Data Safety Sheet
PPE	Personal Protective Equipment
SORC	Site Operations Review Committee

The Board has not had the opportunity to interview the severely injured IT Laborer. He was released from the OSU Burn Unit; however, he still has problems talking due to the removal of the breathing tube.

2.3.1 Work Planning and Preparation for Lance Permeation at X-701B

The BJC SORC approved the deployment of the ISCOR to be conducted east of perimeter road within the central portion of the X-701B plume on August 4, 1999. Three documents were prepared by the ORNL prime contractor to address this deployment.

- Health and Safety Plan (HASP), dated July 1999 - Prepared for use during the deployment of vertical lance permeation and ISCOR using vertical wells at the PORTS X-701B plume east of perimeter road. The HASP stated that the lance permeation portion would be performed by a commercial vendor under the supervision of ORNL and required the vendor to submit a Technical Work Plan (TWP) covering equipment and methods used. The following documents were required to be kept on site: a) *ORNL Environmental Technology Section Procedures Manual* (ORNL 1998) to be used for field activities described in the TWP; and b) *Generator's Waste Management Plan*, prepared by BJC, which described in detail the procedures that would be used for waste management during the project. The HASP also provided the HS requirements for protection of personnel during the work associated with lance permeation and ISCOR deployment. The HSO was authorized to modify the Level D personal protective equipment (PPE), which consists of work clothes, approved hard-toed boots, safety glasses, and appropriate gloves. Hard hats were required to be worn when performing work to set up equipment and in proximity to the drilling rig or other overhead hazards. The HASP did not require a safety shower or an eyewash station to be on site. The spill response for concentrated permanganate (40%) is delineated in Table 2-1 and for dilute permanganate (1000 to 6000 mg/L) in Table 2-2. A list of key project personnel and their responsibilities as contained in the HASP are provided in Appendix C, Table C-1.

- Quality Assurance Project Plan (QAPjP), dated July 1999 - The QAPjP was prepared for the ISCOR only.

- TWP, dated July 1999 - The TWP described the lance permeation and ISCOR deployment.

2.3.2 BJC SORC Readiness Review

Prior to deployment of the lance permeation portion of the contract, documents were submitted to BJC and a SORC readiness review was performed. The BJC SORC evaluated project readiness to start work through review of a SORC presentation package consisting of a summary description of the scope of work; review needs evaluation form; project schedule; project location; list of plans and relevant work; process controls; training requirements; AHA; USEC/other coordination issues; readiness evaluation checklist; and a list of special considerations. SORC attention was directed primarily at determining that all readiness evaluation checklist items were statused as closed by applicable project personnel and performing a final review of the AHA. Checklist items not closed were designated as "A" (complete prior to mobilization end) or "B" (complete after mobilization). Eight items were noted as "A," and none were noted as "B." Following closure of these eight items, the BJC SORC provided permission to proceed to UT-Battelle on July 19, 2000. The major documents reviewed for this deployment were the original three documents (HASP, QAPjP, and TWP), addendums to each document, and the AHA. The reviewed HASP Addendum was dated June 2000; the approved QAPjP Addendum was dated May 2000; and the TWP Addendum was dated June 2000. The reviewed AHA was dated June 2000. The Unreviewed Safety Question Determination (USQD) BJC/USQD-026R2, *Oxidant Injection Project - Across Perimeter Road East of X-701B,* Revision 2, dated June 7, 2000, was also reviewed by the SORC. The dates for these documents were obtained by interviews and review of record files. The Board was informed that no formal listing of documents reviewed and approved by the BJC SORC exists.

The HASP Addendum was prepared by IT and submitted to the ORNL prime contractor. This HASP Addendum did not cancel or supersede the original HASP, but it provided IT and its subcontractor project personnel with assignments and project HS requirements. The HASP Addendum included sections stating the following:

- "All necessary actions will be taken by BJC and ORNL to ensure total commitment to the ISMS with a goal of zero accidents, injuries, and illnesses for project personnel."

- Responsibilities for IT personnel are stated in Appendix C, Table C-2.

- Any chemicals brought on site shall be labeled in accordance with the BJC PM and HS Advocate and that all MSDSs will be kept on file.

- Two of the requirements during the permanganate injection process were, "The qualified engineer and/or field technicians must ensure that all pressure hoses are equipped with safety ties in critical locations to prevent movement or flapping in the event of a sudden rupture under pressure." and "All pressurized hoses must be buried or protected across access ways."

- The PM must execute and participate in the safety inspections.

- The Site Safety and Health Supervisor (SSHS), in conjunction with the PM, Field Team Leader, and Site Health and Safety Officer (SHSO), will conduct formal safety inspections at the site per IT policy and procedure HS021. In addition, there was a requirement to inspect site conditions and activities daily to identify changing conditions or potential hazards. The safety inspections are to be recorded and filed for reference by project.

Table 2-1: HASP Concentrated Permanganate Spill Response

HASP Concentrated Permanganate (40%) Spill Response:

- Evacuate the area and shut off all potential sources of ignition.
- Don protective eye wear and chemical-resistant gloves.
- Contain spill with noncombustible materials (pigs, hogs, soil, etc.).
- Cautiously acidify the spill to a pH of 2.0 using a 3% sulfuric acid solution.
- Gradually add a 50% excess (volume/volume) of aqueous bisulfite (or thiosulfate) solution and continuously mix.
- Monitor for a temperature increase which indicates the reaction is taking place. If there is no increase in temperature or the purple color remains, continue addition of bisulfite solution.
- The reaction will neutralize the oxidant, resulting in the formation of dark brown to black fine particulates (MnO_2 solids).
- After the spill has been completely neutralized, the solids may be disposed of to the ground surface if groundwater is not present in the spill.

Use caution when adding the bisulfite as a violent reaction may result if solid bisulfite (or thiosulfate) crystals are added directly to 40% oxidant solution.

Avoid contact of the concentrated permanganate with strong reducing agents, finely powdered metals, strong acids, organic materials, and combustible materials.

Harmful if swallowed, inhaled, or absorbed through the skin. Provide ventilation, and wash from the skin immediately as it may cause burns. Avoid contact with mucus membranes and eyes.

Table 2-2: HASP Dilute Permanganate Spill Response

HASP Dilute Permanganate (1000 to 6000 mg/L) Spill Response:

- Clear personnel from the spill area to avoid expanding the effected area.
- Don protective eye wear and chemical-resistant gloves.
- Contain spill with noncombustible materials (pigs, hogs, soil, etc.).
- Gradually add bisulfite (or thiosulfate) crystals and mix continuously.
- Continue addition of bisulfite/thiosulfate until the purple color is no longer visible.
- The reaction will neutralize the oxidant, resulting in the formation of dark brown to black fine particulates (MnO_2 solids).
- After the spill has been completely neutralized, the solids may be disposed of to the ground surface if groundwater is not present in the spill. If groundwater is present, decant the solution from the solids. Dispose of the solution at an approved treatment facility (Building 623 or Building 622-T). Place the solids in a container, absorb the excess moisture, and place in the 90-day storage area.

Avoid contact of the spill with combustible materials.

Avoid inhalation, ingestion, and skin contact. If there is contact with the skin, wash with soap and water. The brown stain can be removed with a mixture of one part over-the-counter hydrogen peroxide and three parts vinegar.

- The "SHSO will maintain and complete a daily safety log for each day's work. The daily safety log will document chronologically each day's HS activities in sufficient detail for future reference as needed. Other relevant data and field information will be recorded on separate log forms for air monitoring, sampling, equipment calibration inspections, and incident reporting. Documentation will be maintained that will provide a project record of the following information for each work shift's activities:
  - Worker's name;
  - Work area;
  - Duties performed;
  - Level of protection; and
  - Time in/time out.

  Visitors will be traced in the site log."

- The spill response and key personnel/ responsibilities were the same as that stated in the HASP.

- The HASP Addendum did not require a safety shower or an eyewash station on site. However, there was an eyewash station in the immediate work area, and a safety shower was available in the IT trailer.

The June 2000 AHA accepted by the BJC SORC provided the hazard analysis for the lance permeation and ISCOR deployment at X-701B. The potential hazards and associated control measures approved were stated in the AHA. Neither a safety shower nor an eyewash station was required by the AHA. The AHA did not identify the following as potential hazards: carrying five-gallon buckets containing permanganate; permanganate solution returning up the drill rods; pressurized line breakage (permanganate line and high-pressure water line); neutralization of permanganate on the ground; and neutralization of collected permanganate. Some of the hazards and control measures identified in the AHA are listed in Table 2-3.

The TWP Addendum described the technical approach for chemical oxidation using permanganate through vertical lance permeation of the lower permeability Minford member and the underlying silty, sandy Gallia. It also stated the work would be supervised and funded by the DOE Office of Science and Technology and the PORTS Site Office, with oversight and implementation by BJC and the current prime contractor for ORNL, UT-Battelle. The work scope was implemented by IT. Several safety requirements to provide prevention or protection from pressurized system hazards that must be maintained during operation and maintenance of the system were stated. Some of the stated requirements pertinent to this accident are:

- A certified operator would ensure that critical process safety devices are installed in accordance with the design.

- All the high-pressure components would be certified by the manufacturer prior to operation, and certification data must accompany the equipment.

- Bleed valves or pressure release valves at all service locations will be installed so that personnel can depressurize the system appropriately to bring it to a zero state prior to routine maintenance or repairs.

Table 2-3: AHA Hazards and Control Measures

Sequence of Basic Job Steps	Potential Hazards	Control Measures
General	Insects (Bees, wasps, ticks)	Care should be taken when removing hidden or covered equipment or materials. Bees and or wasps may have built a nest. Check clothing and person for ticks. It is advisable to apply insect repellant.
Lance Permeation Rig	Malfunction	Equipment will be inspected daily prior to use.
Lance Permeation Rig	Operation	Manufacturer's operating procedure will be maintained on site as a reference guide. The recommended practices and equipment specifications are provided in Appendixes C and D. Any adjustments, apart from operational procedures, shall not be conducted to perform maintenance or to adjust nuts, hose connections, fittings, etc., while the system is under pressure.
Lance Permeation Rig	Hoses	Hoses will be protected from excess wear, and worn or damaged hoses will be removed from service. Fittings and couplings on hoses shall not be tightened or tampered with while the hose is pressurized. Safe connectors (whip-checks) shall be used across all hose connections.
Lance Permeation Rig	Direct contact, chemical ($NaMnO_4$, sodium thiosulfate or sodium bisulfite)	Eye contact: flush eyes and call 911. Skin contact: wash exposed area with soap and water. Clothing: rinse concentrated chemical from clothing.
Lance Permeation Rig	Splash/leaks	PPE: safety glasses, safety shoes, and gloves. Notify the operator to suspend operations and assess the situation.
Lance Permeation Rig	Handling permanganate spills	PPE: coated Tyvek, hardhat, safety glasses, safety shoes, and gloves. Evacuate area and shut off all sources of ignition. Cautiously acidify the spill with a 3% solution of sulfuric acid to a pH of 2.0. Gradually add an aqueous sodium thiosulfate (or sodium bisulfite) solution (50% excess) to the spill. An increase in temperature will indicate that the reaction is taking place. Continue to add the sodium bisulfite solution until the area in neutralized. Personnel will avoid walking through the spilled material to the degree feasible.
Emergencies	Injuries	The Fire Department will be summoned for all injuries that need more than first aid by calling 911 or using radio frequency 2.
Emergencies	Fire	Call the Fire Department using radio frequency 2. If personnel are trained in the use of fire extinguishers and it is safe to do so, incipient stage fires may be extinguished using portable fire extinguishers.

- The operator responsible for operation of the permanganate injection system had to be appropriately certified and approved by IT and FRx. Operators and/or support personnel directly involved in the operation were required to understand where potential exposure points are located on the system. These personnel had to wear the prescribed PPE.

- A certified operator and/or field technician had to ensure that all pressurized hoses were equipped with safety ties in critical locations to prevent movement or flapping in the event of a sudden rupture under pressure.

- All pressurized hoses had to be buried or protected across access ways.

The TWP Addendum goes on to state that all containers, hoses, and pipes containing or transporting the permanganate would have secondary containment. This would include the permanganate feed tank, injection pump, and hoses/pipes that transport the product.

Neither the HASP, the HASP Addendum, nor the June 2000 AHA identified the hazards or appropriate chemical handling requirements for the following: neutralization of permanganate solution intentionally collected; the actual collection of permanganate solution from the drill rods or vented areas; permanganate solution venting and subsequent neutralization on the ground; and pressure line rupture.

USQD, *Oxidant Injection Project - Across Perimeter Road East of X-701B*, Revision 2, dated June 7, 2000 (BJC/USQD-026R2), prepared for this project contained numerous assumptions and controls for field conditions and operations. Review of the BJC/USQD-026R2 was part of the BJC readiness review. Once approved, the BJC/USQD-026R2 was discussed with the UT-Battelle PM and the BJC PM. Some of the assumptions and/or controls contained in the BJC/USQD-026R2 are listed in Table 2-4.

The meeting minutes of the BJC SORC for the X-701B Oxidant Injection Project Lance Permeation Phase did not record the version of the documents reviewed. The SORC presentation binder, dated June 29, 2000, presented to the Board did not contain a list of the documents accepted by the SORC for the readiness review. BJC, when requested by the Board, could not produce a list of the actual documents accepted by the SORC. Signatures were obtained on the Project Readiness Review Checklist, and permission to proceed was granted on July 19, 2000, by the SORC Chairperson. It should be noted that the AHA dated June 2000 provided to the Board in the SORC presentation binder dated June 29, 2000, is different than the June 2000 AHA provided with the HASP. Both of the AHAs are dated as “Final June 15, 2000"; however, the technical content of the two documents are not the same. As annotated in the SORC Project Readiness Review Checklist, the AHA was an open item. Based on conversations with the signature authority for the closure of the open item, changes were made to the AHA as a result of the SORC review process. Through conversations and interviews with BJC personnel, the Board verified that the June 2000 AHA in the SORC Presentation Binder was not the one approved. The AHA dated June 2000 transmitted with the HASP contained the

Table 2-4: BJC/USQD-026R2 Assumptions and/or Controls

- This material will be contained in approximately 35 55-gallon drums, which will be stored in groups not to exceed 4 per diked spill pallet.
- Each spill pallet will be separated from the others so that a common accident would not impact more than one spill pallet of up to 4 drums of approximately 220 pounds of permanganate each.
- The drum storage area is fenced to minimize potential accidents from vehicles, personnel errors, etc. Although unlikely, should an accident cause a drum to be spilled outside the spill pallets, the permanganate will be released onto the ground and soak into the soils where they are being injected to destroy Volatile Organic Compound (VOC) contamination in the groundwater. The expected TCE will yield a stable salt (NaCl) and carbon dioxide gas, both considered nonhazardous in this outdoor environment.
- The permanganate is stored outside with minimal or no available concentrations of combustibles.
- The process employs high-pressure water (10,000 psig) to dilute and inject the low-pressure (400 psig) permanganate. Pressures substantially above 10,000 psig are avoided by system design, operational requirements, the 11,000 psig relief, and the 14,000 psig rupture disk. High-pressure equipment specifications, daily system inspection requirements prior to use, and recommended operator practices are contained in the HASP. A manual for use of the high-pressure water jet and an AHA is included.
- The system is used only by trained, certified operators familiar with the high-pressure equipment and its hazards.
- Maintenance may not be performed on the system during operation. "Although the uncontrolled release of high-pressure could be considered a different type of unanalyzed event, appropriate controls are required to be in place to prevent such an event. For this reason, and because the lance permeation injection system is operated on a temporary basis by subcontracted personnel for whom this hazard is well understood and 'standard industrial,' it is determined that a different type of accident not previously evaluated is not created."
- Pressure-retaining components associated with the lance permanganate system are required to be certified for use on high-pressure systems.
- Pressure relief (at 11,000 psig) is to an enclosed blowdown tank.
- Standard safety ties at key pressure connections assure constraint in event of sudden pressure release. Failure of any of these components could release only pressurized water, not dilute permanganate, without off-site consequences.

changes the BJC SORC HS Representative stated she required prior to approval. No controlled list of accepted documents was maintained by the SORC.

2.3.3 BJC Procedures

Several requirements for assignment of the BJC HS Advocate per procedure EH-5614, *Safety Advocate Program,* were not performed by BJC management or the HS Advocate. The project-specific duties and training requirements were not clearly defined by BJC upon assignment in the HASP of the HS Advocate position for this project. The BJC HS Advocate assigned in the HASP did not believe her role and responsibilities on this project were in accordance with this procedure. The "Environment, Safety, and Health (ES&H) Discipline/Interface Communication and Job Review" (Attachment A of procedure EH-5614), and the "Project-Specific Subcontractor Oversight Plan" per BJC procedure PQ-A-1450, *Subcontractor Oversight*, which became effective on June 30, 2000, were not completed. Additionally, the BJC PM assigned in the HASP for the lance permeation project did not develop, implement, and maintain the Subcontractor Oversight Plan.

The Subcontractor Technical Representative (STR) assigned to the project did not perform all of the requirements in BJC procedure FS-A-0012, *STR Requirements for Subcontract Execution*. The STR assigned in the HASP did not believe his role and responsibilities on this project were in accordance with this procedure. The STR did not maintain a list of approved documents for the project (i.e., HASP, HASP Addendum, AHA, AHA Addendum, QAPjP, QAPjP Addendum, etc.), nor did he maintain control of document modification or changes. The STR did not ensure the HASP was maintained and up to date regarding the assignment of key personnel. In fact, no one on the project maintained document control or initiated a change to the HASP Addendum when key personnel were changed out.

BJC procedure PQ-A-1510, *Readiness Reviews*, requires that functions, assignments, responsibilities, and reporting relationships be clearly defined, understood, and effectively implemented with line management responsibility for control of safety as a Minimum Core Requirement. Compliance with this procedure was not accomplished during the readiness review of this project.

2.3.4 General Site Information

The three main chemicals used on site were sodium permanganate (permanganate), sodium thiosulfate (thiosulfate), and sodium metabisulfite (bisulfite). Appendix D contains a description of their properties, hazards, and handling.

The BJC Radiation Protection Program personnel performed preliminary radiation surveys of all equipment and the site prior to the start of work activities. Various logs and survey forms demonstrate that equipment that left the site was surveyed prior to leaving. (The Board did not verify that all equipment that left the site was surveyed.)

On July 17, 2000, the BJC HS Advocate performed a site safety briefing for all personnel on the project. The briefing included general safety information. In the briefing, personnel were informed to obtain medical assistance by dialing 911 on any plant phone, pulling a fire alarm pull box, or using channel 2 on any plant radio. They were also informed they should have access to a plant radio. Interviews with the BJC PM and the UT-Battelle PM confirmed that a plant radio was provided to the site. Per the UT-Battelle PM, the plant radio was kept inside the on site trailer. The briefing notes also stated that an approved/signed copy of the HASP must be at the work site. This briefing was not provided to personnel reporting to the project after initiation.

The Board was provided documentation that BJC HS personnel had expressed safety concerns to senior BJC management over inadequate staffing to provide the level of safety oversight required by the M&I contract. At the time the documentation was prepared, there were 2 safety professionals to cover 15 active projects. Responsibilities of the safety professionals include: attend project planning meetings; review submittals, in some cases develop HS documents; provide project oversight; and perform assessments. A third safety professional was hired and has reported to the site to work the X-747H Scrap Metal Project. The personnel that submitted the documentation to the BJC HS Manager with copies to the BJC Site Manager, state "Additional resources are required to effectively implement ISMS, achieve 'Zero Accident Performance', and avoid a serious injury or fatality." The document provided to the Board is dated August 16, 2000.

The three logbooks (UT-Battelle's, IT's, and FRx's) obtained by the Board did not comply with the requirements in the HASP and HASP Addendum. The Board was not originally provided the Driller's logbook. (The Driller's logbook has since been provided to the Board.) Per personnel on site, no other logbooks existed for the on site project.

DOE ORO does not have any Facility Representatives (FRs) assigned to PORTS. The DOE Acting PORTS Site Manager stated HS oversight for the project was supposed to be performed by the DOE Construction Safety Engineer. However, this individual had not performed any oversight of the project. A review of the DOE Site Office field oversight reports revealed a lack of general HS oversight both programmatically and in the field.

It should be noted that personnel on site were not wearing Tyvek suits when carrying buckets of permanganate solution retrieved from the rods, vents, and tip leakage. The only place in the AHA and HASP/HASP Addendum that addresses permanganate neutralization was in the spill response section. The AHA requires Tyvek suits for handling spills.

2.3.5 Key Personnel Turnover

The following is the chronology of turnover of key on-site contractor personnel:

Role	Person#	Date of Transfer
UT-Battelle HSO	1 to 2	7/24/00
UT-Battelle HSO	2 to 3	8/01/00
UT-Battelle HSO	3 to 4	8/16/00
IT SHSO	1 to 2	7/25/00

Note: UT-Battelle HSO #2 also filled in for UT-Battelle HSO #1 on July 21, 2000.

The IT SHSO turnover was performed on site and face to face. The UT-Battelle HSO #1 is also the UT-Battelle PM. The turnover from UT-Battelle HSO #1 to #2 occurred face-to-face and on site. The turnover from UT-Battelle HSO #2 to #3 and #3 to #4 took place via e-mail and phone conversations.

2.3.6 Field Operations

A review of the UT-Battelle Project Logbook; IT Project Logbook; FRx Project Logbook; e-mails from the UT-Battelle PM; and interviews of field personnel revealed several observations, issues, and events that occurred in the field. Table 2-5 provides a list of several of the observations, issues, and events related to the accident.

Table 2-5: Field Observations, Issues, and Events for the Project

- Routine discussion on handling of permanganate, handling of the neutralizing agents and general HS issues were discussed during the daily safety meetings.
- Venting to the surface during the injection of permanganate was a recurring problem. The recommended solution was to stop injection at the first sign of venting. Drive two feet (i.e., skip an interval), and deliver the volume for both the intervals there. If continued venting was noted, the injection was to be stopped and the operation moved to a new location.
- Leakage of permanganate within the drill rods routinely occurred. Leakage was normally noted in the first two drill rods during removal of the rods. However, during initial insertion, permanganate solution was noted to be coming out of the top of the rods. The leakage was attributed to problems with the rod threads. The initial resolution was to replace the rods with new ones. A field solution for removal of the permanganate solution from the rods was to use a peristaltic pump (see Exhibit 2-4). They inserted a rubber hose into the rod and sucked the solution from the rod prior to removal. Neither the AHA nor the PPE requirements were modified as a result of this issue. The permanganate solution was collected in five-gallon buckets and hand-carried to a neutralization tank located on the corner of the job site. The amount of permanganate solution was limited to one-half of a full bucket for any bucket to be carried.
- The reliability and availability of the injection head was a continuous problem. Evaluations stated the problem with the injection tool was in the connection between the head and the subassembly, which connects the rods. The resolution of the problem was to have the unit preassembled by the machine shop and welded in place such that the connection did not weaken and cause failure from repeated pounding while driving the head. Spare heads were to be preassembled. If there was a problem during injection, the tool would be swapped out and returned to the machine shop for repairs. No further maintenance or repairs were to be conducted on-site at the expense of slowing the entire production down. This resolution was documented in an e-mail dated August 10, 2000, from the UT-Battelle PM to a UT-Battelle Team Lead. However, continued maintenance of the injection head continued on site. On August 22, 2000, an FRx Field Technician was performing maintenance on one of the injection heads in the fenced area at the time of the accident. The field logbooks indicate maintenance in the field was routine.
- The UT-Battelle logbook had several entries regarding treatment of the permanganate solution collected. On July 22, 2000, a log entry recording discussions about various injection delivery versus additional borings versus project budget schedule stated, "One extreme is numerous borings which may or may not provide insight. Other extreme is continuing w/process that clearly isn't behaving as predicted. . . . Agreed to continue to ask the question each day but that we need to go slow enough to understand but continue to push toward production type delivery." On July 24, 2000, it stated that the process for fluid returned up through the drill rods was to contain, neutralize, and place in yellow tank for disposal. On July 26, 2000, an entry stated that an FRx individual performed neutralization in the yellow tank. On July 27, 2000, it stated that the treatment did not work in the waste tank (yellow tank), and they would continue to add water and treat that night before demobilizing the crew. On August 22, 2000, the 12:35 p.m. entry states, "Break for lunch over talk earlier to" [the IT Team Leader] "about lack of neutralization agent. Told" [IT Laborer] "he could use thiosulfate to put in neutralization tank in place of bisulfite for neutralization."
- The IT logbook has several log entries concerning permanganate solution. On July 22, 2000, it stated that Tyvek suits would be worn while carrying buckets of permanganate. No other log entry was noted to reduce the PPE level while carrying buckets. Another entry on July 22, 2000, statesdthat after the permanganate was reduced, it would be transferred into a yellow container and disposed of in accordance with the UT-Battelle PM's direction.

Table 2-5: Field Observations, Issues, and Events for the Project (Continued)

- The FRx logbook on July 26, 2000, stated that at 15 feet of insertion, they started getting return up the rods even before injection of permanganate. The color was not too concentrated. During the injection, they had about 30 seconds of watery flow at 5-10 gpm. Then, after injection, they had 10 seconds of 3-4 gpm flow of high concentration of permanganate from the rods. "Something is very wrong. Going to advance one foot and watch closely and will shut down at first sign of returns and look at the head and lines." On August 2, 2000, the logbook noted that after a 24-foot injection, they noticed a lot of permanganate coming out of the rods. Inspection of the rods revealed that they all seemed tightly joined, so the crew speculated it might be a busted line. When they checked, the hoses were all fine, but the head had backed off a bit from the subassembly. Teflon tape was applied to help form a seal. Throughout the logbook, problems with the equipment and return of dark/concentrated permanganate up the drill rods are recorded.
- On August 19, 2000, the FRx logbook states that a head service station was set up and personnel had been working all afternoon trying to get to a regular service routine and schedule.
- On July 22, 2000, the UT-Battelle PM made it clear to field personnel the operation was NOT a Research and Development project but a deployment of technology.
- On July 23, 2000, the UT-Battelle PM/HSO recorded the responsibilities for general data recording as follows: (1) FRx - "target/actual flow and pressure for both H_2O and $NaMnO_4$; eq. inspections;" (2) Miller - equipment inspections, location, interval, time and date, some notes on activity; (3) IT - activities, task/staffing, design verification, HS monitoring, sampling and related calibrations/inspections; (4) UT-Battelle - general daily activity, general HS, waste management (i.e., gallons in tank, when to Building 623, etc.).

The UT-Battelle PM was on site overseeing operations at the initiation of the project. She stated that all collected permanganate solution was to be treated as concentrated. She also stated that she was aware of the assumptions contained within BJC/USQD-026R2. While on site, she made sure all USQD assumptions were maintained. Neither the UT-Battelle HSO #4 nor anyone else assigned on site to the project at the time of the accident, were aware of the USQD or any assumption that needed to be maintained. The UT-Battelle HSO #4 stated that he and the IT SHSO #2 shared the responsibilities in the HASP.

The IT SHSO #2 stated the permanganate solution collected from the drilling rig and lance was treated as dilute. He did qualify his statement by noting that prior to performing neutralization, he would verify the solution was 6% or less permanganate. He stated that he was the only one on the job site authorized to use the spectrophotometer required to determine permanganate concentration of a solution for neutralization. He also stated that he was the only person on the job site allowed/authorized to perform permanganate neutralization of collected solution; however, it was acceptable for any crew member to carry a five-gallon bucket containing permanganate solution to the yellow tank. Once at the yellow tank, the five-gallon bucket would be set inside the trailer. The worker would then step into the trailer, pick up the bucket, and pour the contents into the top of the 250-gallon yellow tank.

The IT SHSO #2 further stated that it was an acceptable practice for any crew member to place neutralizer on permanganate on the ground. He stated that he had personally taken VOC readings, noise readings, and other HS monitoring values while on site. He informed us that, on the day of the accident, UT-Battelle HSO #4 informed him they were out of bisulfite; however, there was some thiosulfate present on site from a previous project that could be used. After discussion, they agreed the thiosulfate would be used for neutralization as allowed by the HASP and HASP Addendum.

Problems grouting the injection holes were encountered. On July 21, 2000, over 20 gallons of grout were pumped into the hole when the hole should have only taken about 5 gallons. Problems with venting through previously grouted injection locations were repeatedly noted. The solution from the wells was placed inside the yellow neutralization tank.

Some of the deficient HS observations made by the Board during an inspection of the site are presented in Table 3-1.

The notebook of documents obtained from the field trailer contained the following: [Note: None of these documents contained approval signatures, and no approval documentation existed in the notebook. When the Board requested approval documentation, they were informed no official approval documentation other than the SORC Readiness Approval signatures existed.]

- A July 1999 HASP and signature page showing the 19 individuals that had read the HASP;

- A May 2000 HASP Addendum that obtained pages 8 and 11, dated "Final June 15, 2000." No signature sheet was located with this HASP Addendum;

- Amendment 1 to the AHA dated July 28, 2000, which contained the date of May 2000 in the body; and,

- A manual published by the WaterJet Technology Association entitled, *Recommended Practices For The Use of Manually Operated High Pressure Waterjetting Equipment*, copyright 1994.

The notebook entitled "MSDS Log Book Haz Mat Inventory" contains a list of FRx hazardous material inventory, location, container, quantity, and whether or not an MSDS was contained. All MSDSs listed in the index were contained in the binder except the one for permanganate monohydrate 97+%. Some additional MSDSs for material not listed in the index were contained in the binder. The MSDS for permanganate is listed as "sodium permanganate monohydrate 97+%." Interview statements indicate that the MSDS from the binder was provided to Emergency Response personnel. The actual material on site is sodium permanganate 40. The two materials are NOT the same (i.e., one is a dry compound and the other a solution). Other materials observed on the job site (but not part of this particular project) were not listed in the index nor were the MSDSs present (i.e., concentrated hydrogen peroxide and vinegar).

The disposal considerations section of the MSDS for permanganate monohydrate 97+% (this compound was NOT present on the job site) directs the reader to cautiously acidify a 3% solution or a suspension of the material to pH 2.0 with sulfuric acid. Gradually add a 50% excess of aqueous sodium bisulfite, with stirring at room temperature. An increase in temperature indicates that a reaction is taking place. If no reaction is observed on the addition of about 10% of the sodium bisulfite solution, initiate it by cautiously adding more acid. If manganese, chromium, or molybdenum are present, adjust the pH of the solution to 7.0 and treat with sulfite to precipitate for burial as hazardous waste. Destroy excess sulfide, then neutralize and flush the solution down the drain. Observe all federal, state, and local environmental regulations. The concentrated permanganate neutralization process in the HASP/HASP Addendum and AHA were based on this MSDS.

The July 1995 MSDS supplied by BJC as the most current for permanganate was the same one used for the USQD evaluation; however, that MSDS, dated July 1995, is not the most current for the material. The Board contacted the manufacturer and obtained the latest MSDS, which is dated May 1999. The current MSDS added "rubber or plastic apron" to the recommended PPE.

2.3.7 July 27, 2000, Incident Involving Spraying of Permanganate on Two Individuals

On July 27, 2000, two employees of the project were sprayed with 40% permanganate while cleaning a clog in the delivery line of the permanganate. After the incident, the employees used an emergency shower in the IT office trailer and personal neutralization solution of water, hydrogen peroxide, and vinegar. Their eyes were flushed for approximately five minutes, and medical attention was not deemed necessary. As a result of this accident, changes were made to the AHA on July 28, 2000. The changes are shown in Table 2-6. It should be noted that the change to the AHA was made on a May 2000 version, which was different than the June 2000 version accepted by the BJC SORC. No evaluation or modifications were made to any other activities on site as a result of the July 27, 2000, spraying event. The AHA Addendum was reviewed by the BJC STR, BJC HS Advocate, UT-Battelle HSO #2, and IT SHSO #2.

An Occurrence Report, ORO–ORNL-X10LIFESCI-2000-0003, *Near Miss - Two Subcontractor Employees Sprayed with Sodium Permanganate*, was filed for this event. A DOE ORNL Site Office person accepted the FR notification. (This individual normally deals with ORNL non-nuclear occurrences as the FR; however, this individual is not a trained, qualified FR.) This individual did not communicate the event to either the DOE ORNL Site Office Environmental Program Manager or the EM Program Manager. Additionally, no follow-up on root cause and corrective actions was performed. The opportunity to identify and correct fundamental problems with the project was missed as a result of the inadequate follow-up.

Table 2-6: AHA Changes in Hazards and Control Measures

Sequence of Basic Job Steps	Potential Hazards	Control Measures
Lance permeation rig	Direct contact, chemical ($NaMnO_4$, ~~sodium thiosulfate or sodium bisulfite~~ *Use household vinegar and drug store hydrogen peroxide*)	Eye contact: flush eyes and call 911. Skin Contact: wash exposed area with ~~soap and water~~ *mixture (1 part house vinegar, 1 part drug store hydrogen peroxide, and 1 part water).* Clothing: rinse concentrated chemical from clothing. *As listed above.*
Lance permeation rig	*Performing Maintenance on Permanganate Equipment*	PPE: Coated Tyvek, hardhat, safety glasses, face shields, safety shoes, and gloves

Note: The strike-through items indicate deletions, and the italicized items are additions.

2.3.8 The Accident

The personnel on site at the time of the accident and those participating were as follows:

- The IT Laborer was located over one of the five-gallon buckets containing permanganate;
- Three individuals were at the drill rig (the Driller, the Driller's Assistant, and an FRx Engineer);
- An FRx Engineer was located in the fenced area;
- The UT-Battelle HSO was at the entrance to the exclusion zone;
- The IT SHSO #4 was off site at the time of the accident. When he called the site, he was informed of the accident and immediately returned to the site to aid in on site emergency response;
- Two individuals from the UT-Battelle Grand Junction Office, who were not associated with the project, arrived on site to deliver some parts.

Thiosulfate was being used for neutralization during the first few days of the project because it was available and the bisulfite had not been delivered. The neutralization agent was changed to bisulfite because that was the preferred IT neutralizer. On August 22, 2000 (date of the accident), the supply of bisulfite ran out, and the neutralizing agent was changed to thiosulfate.

After about an hour lunch break, the Driller removed the five-gallon bucket which had been collecting solution dripping from the drill head. The Driller informed the FRx technician of the excessive amount of dark purple solution collected during lunch, approximately two-thirds of a bucket (about three gallons). The Driller handed the five-gallon bucket to the Driller's Assistant. The Driller's

Assistant moved the bucket out of the drilling area. The IT Laborer yelled at him to set the bucket down and he would take care of it. When the Driller's Assistant sat the bucket down, it was the only item in that area (i.e., no other bucket or cardboard container was present). At some point, a second five-gallon bucket containing purple permanganate solution and a cardboard container of thiosulfate were placed near the first five-gallon bucket, which contained permanganate solution with a deep purple color (see Exhibit 2-4). Interviews of on-site personnel did not clarify where the second bucket and cardboard container came from or who placed them at the scene.

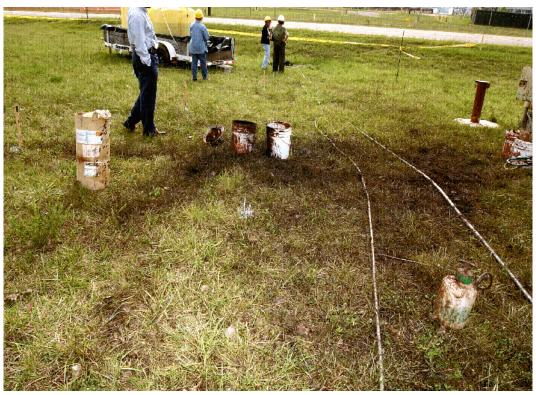


Exhibit 2-4. Thiosulfate Container and Two Five-gallon Buckets of Permanganate Solution.

The IT Laborer was standing over one of the five-gallon buckets when a violent exothermic chemical reaction occurred in the bucket. Permanganate solution was blown from the bucket up at least 15 feet in the air. The solution went all over the front of the IT Laborer. The front portion of the IT Laborer's 100% cotton blue jeans instantaneously ignited. No holes were noted in his 66% polyester/34% cotton shirt. The solution splashed onto the back of the Driller's Assistant. The Driller's Assistant was standing in front of the Driller and an FRx technician, thereby blocking them from the airborne solution. The solution cascaded onto the drilling rig and ground in a directed waterfall pattern.

2.3.9 Emergency Response and Medical Transport

Immediately following the violent chemical reaction, the injured IT Laborer ran about 15 feet and dropped face down on the ground. He was wearing rubber gloves, safety glasses, rubber boots, his shirt with sleeves rolled up to his elbows, and what was left of his pants. His hard hat had blown off during the accident. Personnel at the scene immediately grabbed a nearby water hose and started to wash him off. Once they got the injured IT Laborer off the ground, they removed his shirt while continuing to wash him down. The IT Laborer removed his rubber gloves. Personnel washing him down noted that he had permanganate on his safety glasses. They instructed the injured employee to close his eyes and, as they sprayed his head, he removed his safety glasses. About this time, the FRx Technician who operated the water blaster arrived on the scene and realigned the charger pump to provide a second hose for wash down. They continued to spray the injured worker down and walked him over to the entrance of the controlled area. At this time the IT Lead Engineer/SHSO #4 arrived. At the controlled area entrance, they began using neutralization spray bottles containing a mixture of vinegar, drug store grade hydrogen peroxide, and water on his body. After a few minutes the FRx Technician cut the back section of the pant legs off of the injured IT Laborer. The injured employee refused to utilize the eyewash station at the site. The IT Lead Engineer/SHSO #4 obtained a bottle of saline eyewash (the temporary type), and the injured IT Laborer allowed this to be used. The personnel assisting the injured worker continued to wash him down, spray him with the neutralizing solution, and use the saline eyewash. Finally, personnel convinced the injured worker to remove his belt and the rest of his pants; however, the injured worker would not take off his underwear.

The second individual injured was the Driller's Assistant. When he heard the explosion and noted the area getting darker, he took off running. As he was running, he began to feel a burning sensation on his neck, shoulder, and under the hairline on the back of his neck. He immediately went to the IT trailer, which is located across the gravel road, and removed his shirt. Once inside the trailer, he grabbed a spray bottle of neutralizer and sprayed the areas he felt burning. He entered the shower, grabbed a shower bag, and began to rinse himself. This shower was the only shower/drenching facility available on site.

After showering and applying the neutralizer, the Driller's Assistant exited the trailer. The Driller joined him to check on his injuries. The Driller noticed permanganate on the Driller's Assistant's pants. The Driller's Assistant removed his pants and, with assistance, neutralized and rinsed all observed permanganate. The Driller's Assistant donned a Tyvek suit for modesty and did not require any additional treatment from emergency response personnel. He did not exhibit any blisters, redness, or any serious discomfort subsequent to neutralization and rinsing. He checked himself that night and the next two days, and no visible or physical sign of redness, burning, or injury was noted.

A summary of notifications and response by site and off-site emergency personnel are as follows:

- Approximately 1245, accident occurred.
- At 1252, an FRx Technician called 911 on his cellular phone. This call went to the Pike County Sheriff's Department. The Technician inadvertently informed them the accident was at Paducah (he had been working previously at Paducah).
- Approximately 1255, the FRx Technician tried to contact the BJC STR but was unsuccessful. He left a message. (The STR returned the phone call some time later and was informed of the accident.)
- Approximately 1300, a UT-Battelle Grand Junction Group Leader arrived on the site about the time the injured employee reached the entrance to the controlled area. He tried to contact the BJC STR but got no answer, so he paged him.
- Approximately 1300, the UT-Battelle Grand Junction Group Leader contacted the BJC HS Advocate and informed her of the accident.
- 1310 PORTS IC on scene.
- 1312 Contacted USEC Safety Department.
- 1315 Pike County EMS on scene.
- 1317 PORTS IC requested helicopter for transport.

- 1332 Pike County Sheriff on scene.
- 1339 Helicopter on scene.
- 1346 Medical flight departure.
- 1403 PORTS IC grants all-clear.

2.3.10 Lessons Learned/Feedback and Improvement

The feedback on lessons learned from chemical accidents on site and off site was not utilized to effect continuous improvement. The lessons learned concerning PPE from the July 27, 2000, incident in which two employees were sprayed with permanganate was only implemented for permanganate maintenance activities. The lessons learned were not extended to other project activities. In addition, there were numerous permanganate leaks on the delivery line; however, no engineering or administrative actions were taken to limit potential exposure to permanganate. The lesson learned from an earlier PORTS stand down on penetration permits was not extended to activities outside of penetrations. The penetration stand down at PORTS was due to deficiencies in the hazard analysis and development and implementation of controls. The corrective actions for the penetration permit problems were limited in scope to penetration permit issuance. Off-site lessons learned from a 1999 sodium potassium (NaK) accident at the Y-12 Plant were not considered by the BJC SORC or UT-Battelle in reviewing the HASP for this project. The use of up-to-date technical information in establishing proper PPE controls was not learned. The most current MSDS for permanganate, which contained tighter PPE controls, was not used in determining appropriate PPE.

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3.0 Analysis

3.1 Contractual Authority

3.1.1 DOE Oak Ridge Operations

UT-Battelle is the DOE ORO prime contractor responsible for the PORTS EM Technology Deployment Project where the accident occurred on August 22, 2000. UT-Battelle was chosen to perform this project on the basis of a Technical Task Plan which was approved by Headquarters, EM, Office of Science and Technology, and the DOE ORO Office of the Assistant Manager for EM (EM-90).

The DOE ORO EM Program Manager for this project did not coordinate any aspect of the project with anyone on the staff of the DOE ORO Office of Assistant Manager for Laboratories, which is the DOE COR for the UT-Battelle contract. The DOE ORO EM Program Manager was not aware that as a DOE line manager she had any responsibility or accountability for HS over the project. She indicated that she assumed that the contractor, UT-Battelle, was responsible for the safety of its work and that project oversight was the responsibility of the PORTS Site Office and BJC.

No person in the DOE ORO EM organization or the PORTS Site Office had either COR/Technical Representative authority over the UT-Battelle contract or any other contractual authority over UT-Battelle or its subcontractor, IT.

Contributing Cause

DOE ORO EM-90 failed to establish clear and unambiguous lines of authority and responsibility for ensuring that HS was established and maintained at all organizational levels within DOE ORO and its contractors for this project.

3.1.2 UT-Battelle, LLC

The UT-Battelle contract passes the ISM requirements down to the subcontractor, IT, for this project by means of a reference in the subcontract's General Terms and Conditions. The Statement of Work indicates that the General Terms and Conditions (Fixed Price) apply. The General Terms and Conditions Paragraph 2.1 states: "The following clauses are incorporated by reference: DEAR clause 970.5204-2, *Integration of Environment, Safety, and Health Into Work Planning and Execution* (June 1997) (if work is complex or hazardous)." This requirement was available to IT only if its personnel accessed the UT-Battelle web site and retrieved the General Terms and Conditions. For IT personnel to find the requirements of DEAR clause 970.5204-2, they would then have to access the DEAR and look up the actual wording of that clause. This method of passing requirements to a subcontractor may be contractually binding, but it is NOT effective in emphasizing the importance of ISM. Neither the IT personnel nor its subcontractor personnel were familiar with the requirements of ISM.

Contributing Cause

UT-Battelle failed to ensure that ISM requirements were established and maintained at all organizational levels by its subcontractors for this project.

3.1.3 Bechtel Jacobs Company LLC

Funding for this project was sent to UT-Battelle by BJC via WAD Number WA20312, Revision 3, dated May 3, 2000. The original WAD and the first two revisions dealt with the ISCOR Project. Since efforts to recover the injection well and resume recirculation in the ISCOR project were unsuccessful, it was agreed by UT-Battelle and BJC to redirect the remaining work authorization funds to support the vertical permeation effort to treat TCE in the deeper ground level (Gallia layer). A subtask was added to describe the lance permeation process to be performed via a subcontract between UT-Battelle and IT. This WAD clearly states that HS and quality requirements for work to be performed will be in accordance with existing approved project plans and appropriate BJC policies and procedures. The WAD revision contains approval signatures from the following PORTS BJC personnel: HS, Quality Assurance, Project Controls, Procurement, Technical Manager, Functional/Project Manager, and the Controller. Work acceptance approval was signed for by UT-Battelle management.

The BJC PM for PORTS stated in his interview that BJC was responsible for oversight of the UT-Battelle Lance Permeation Project where the accident happened and that BJC had the right to review and approve the plans and procedures for the UT-Battelle project. The BJC HS Manager for PORTS stated in his interview that he was not familiar with the HASP for the project and that BJC was NOT responsible for ES&H oversight, but BJC was to provide requested support on the UT-Battelle project. The BJC HS Advocate, assigned by the HASP, stated in her interview that she was responsible for participating in the SORC readiness review, providing support to the project, and coordinating safety issues for the project with the site. She did not believe that she had the same level of ES&H oversight responsibilities for the UT-Battelle project that she would have had for BJC subcontract projects. She further indicated that a formal oversight plan, required by BJC procedure EH-5614, *Safety Advocate Program*, was not prepared for the project, since it was not a BJC subcontract.

Contributing Cause

BJC failed to establish and maintain ES&H oversight of this project that was adequate to assure that all work performed at PORTS by UT-Battelle and its subcontractors was in accordance with the approved project plans and the appropriate BJC policies and procedures.

3.2 Safety Analyses and Reviews

3.2.1 Activity Hazard Analysis

The AHA is intended to provide a systematic review of the planned work to identify the associated hazards and preventative measures to control those hazards. The format of the AHA provides in column form the "Sequence of Basic Job Steps," "Potential Hazards," and "Control Measures." This format allows workers to be cognizant of the potential hazards at every phase of the activity and the control measures approved by qualified

HS SMEs for prevention/ mitigation. An AHA is required for all operations at PORTS. An AHA for this project was reviewed during the BJC SORC readiness review. There were numerous potential hazards present on the job site that were not identified in the AHA. In addition, changes in field activities were not properly evaluated and incorporated into the AHA. The lack of specific "potential hazard" recognition in the AHA for various phases of the operation and failure to perform appropriate hazard review for changing field conditions (which would result in a change to the AHA) demonstrates a lack of rigor during the hazard analysis. Since the hazards were not properly identified, controls were not properly developed and implemented.

Changing field conditions (i.e., permanganate solution returning up the rods and permanganate solution leaking from the drill tip) were not properly communicated to the various project personnel, resulting in inadequate implementation. If the changing field conditions had been properly reported into the system and an adequate hazard analysis performed which resulted in the development and implementation of appropriate controls, the likelihood of this accident occurring would have been decreased. Enhanced worker involvement in the AHA process aids in the recognition of potential hazards during field operations and in the development and implementation of controls. The workers were not effectively involved in the AHA process.

On-site safety analysis and compliance with controls and requirements were performed by various personnel. Per documentation, this responsibility lies with the IT SHSO, the IT SSHS, the IT Field Team Leader, the BJC STR, BJC HS Advocate, and the UT-Battelle PM/HSO. (It should be noted that at the time of the accident, the three IT positions were being performed by one individual. The combining of these responsibilities to one individual was normal for the project.) These individuals did not recognize noncompliance with basic HS requirements on the job site. They also failed to document the proper identification and analysis of all potential hazards. Some of the on site basic HS noncompliances noted by the Board are listed in Table 3-1. Individuals on site did not ensure compliance with the stated controls and requirements in the HASP and HASP Addendum during project execution. Additionally, these individuals did not initiate and ensure changes were made to maintain the site HS documents up to date. The list of Key Project Personnel and Responsibilities in the HASP and the process for concentrated permanganate neutralization process are among the known deficiencies in the HS documents. *The above demonstrates lack of effective implementation of hazard analysis; development and implementation of controls; safe performance of work; and feedback and improvement.*

Contributing Cause

UT-Battelle and IT failed to execute an adequate hazard analysis for the project. Numerous activities were never identified; therefore, they did not enter the hazard analysis process. This resulted in a lack of development and implementation of controls. Some identified activities were incompletely analyzed for potential hazards, resulting in inadequate development and implementation of controls. BJC failed to ensure the above processes were adequately performed during the SORC readiness review process.

Table 3-1: On-Site Basic HS Conditions
(compared with 29 CFR 1926)

The following table provides the standard technical requirement and on site conditions at the time of the accident:

Requirement	On-site Condition
29 CFR 1926.59(b)(3)(ii) Hazard Communication - Maintain MSDSs received with incoming shipments of hazardous chemicals.	• The MSDS for hazardous chemicals utilized on site were contained in an on-site MSDS logbook. No MSDS for permanganate was present in the logbook. The index in the MSDS logbook states the product is "Sodium permanganate monohydrate, 97+%." This compound is a dry powder and is not present at the site. Interviews indicate the MSDS for permanganate was provided to emergency response personnel. The Board was not able to verify the exact MSDS provided to the emergency response personnel. • The Board requested BJC and IT to provide the latest MSDS present on site for permanganate. A sodium permanganate 40 MSDS and fact sheet, along with a sodium permanganate monohydrate, 97+% MSDS, were provided to the Board. The sodium permanganate 40 MSDS provided to the Board was the same one utilized for BJC/USQD-026R2 and was dated July 1995. The Board contacted the manufacturer and requested a copy of the latest MSDS and fact sheet via fax. The MSDS and fact sheet provided by the vendor were dated May 1999. • The on-site MSDS logbook did not contain MSDSs for on-site chemicals that were not being utilized for this project. These chemicals were in the fenced area being utilized by the project to store chemicals.
29 CFR 1926.59(e)(1) Hazard Communication - Written hazard communication program shall be developed, implemented, and maintained at the work site.	• The HASP Addendum, Section 1.1, states ". . . the *ORNL Environmental Technology Section Procedures Manual* (ORNL, 1998) contains standard operating procedures (SOP) for field activities described in the WP." Section 1.2 states ". . . All PORTS environmental, health, and safety standards will be followed." • Section 4.10 of the HASP addendum states "Any chemicals brought on site shall be labeled in accordance with guidance from the Bechtel Jacobs Company LLC, PM and health and safety advocate." • Neither the BJC procedures nor the UT-Battelle procedures for hazard communications were on site. The subcontractors were not

Table 3-1: On-Site Basic HS Conditions
(compared with 29 CFR 1926)

Requirement	On-site Condition
	trained on these procedures. The BJC PM and HS Advocate visited the site periodically and did not raise the issue of improperly labeled containers.
29 CFR 1926.59(e)(2)(i) Hazard Communication - Methods shall be designed to provide other contractors and subcontractors access to MSDS.	• BJC received the material from the manufacturer. The MSDS on site for sodium permanganate 40 was not the most current by the manufacturer.
29 CFR 1926.59(f)(9) Hazard Communication - Labels or other form of warning shall be prominently displayed on containers.	• The positioning of the drums on pallets did not allow personnel to read the labels. • The small neutralizing agent spray bottles did not have proper labeling. These bottles did have Sharpie marker writing to indicate the contents; however, the labeling does not meet requirements (see Exhibit 3-4). • The large sprayers on site did not have any labeling. Labeling is required for all chemicals transferred from the original shipping container.
29 CFR 1926.59(h)(3)(ii)&(iii) Hazard Communication - Training on physical and health hazards of the chemicals in the work area and the measures that can be taken to protect workers shall be provided.	• Training on the hazards of sodium permanganate 40 was not adequate. Personnel on site were familiar with the hazards of potassium permanganate. Potassium permanganate at ambient temperature cannot be concentrated over 8% in water; however, sodium permanganate at ambient temperatures can be concentrated over 40% in water. • Training on the potential hazards associated with neutralization of the concentrated sodium permanganate was not well understood by personnel on site.
29 CFR 1926.50 Medical Service and first aid - Suitable facilities for quick drenching or flushing of the body are required within the work area for immediate emergency use	• A portable eyewash station was located in the work area and was easily accessible to personnel on site. • The only safety shower on site was located in the IT trailer. The trailer was not within the exclusion zone and available for immediate emergency use. The location of the safety shower did not meet requirements. • There was a common garden hose on site that could provide potable water. This hose was utilized during emergency response actions by

Table 3-1: On-Site Basic HS Conditions
(compared with 29 CFR 1926)

Requirement	On-site Condition
	personnel on site. The garden hose does not meet OSHA requirements for a quick-drench facility. Personnel awareness of the job site and quick thinking to utilize the garden hose, since a quick-drench facility was not available, are commendable. • The valve alignment for the charger pump was manipulated by the FRx Technician to obtain a second water supply hose for on-site emergency treatment. This realignment demonstrates knowledge of equipment and quick thinking by the FRx Technician.
29 CFR 1926.250 General Requirements for storage - Storage areas shall be kept free from accumulation of materials that constitute hazards from tipping, fire, explosion, or pest harborage	• In the fenced area, there were two 30% hydrogen peroxide drums adjacent to the permanganate storage pallets. Hydrogen peroxide is incompatible with permanganate. • The permanganate drums are shipped and stored on wooden pallets. The MSDS for permanganate states that it may ignite wood. One of the wooden pallets, with four drums stored on top, had burned areas.
29 CFR 1926.150(a)(3) Fire Protection - Fire equipment shall be conspicuously located.	• The fire extinguisher for the drilling rig was located in a compartment on the side of the rig. Equipment was located on top of the fire extinguisher.
29 CFR 1926.403(b)(1) General Requirements (electrical) - Electrical equipment throughout the site shall be free from recognized hazards likely to cause serious physical harm or death .	• The control unit adjacent to the air compressor was made out of parts of extension cords and a receptacle switch box. The extension cords could be damaged by the edges of the receptacle boxes. • Flexible cords located in a plastic piping system were run across the road used for traffic. The open ends were not protected to prevent damage to the cords.
29 CFR 1926.405(g)(1)(iii)(C) Flexible Cords and Cables - Prohibited from running through doorways, windows, or similar openings.	• The power supply cord for the peristaltic pump was run to the drill rig battery compartment. The door to the battery compartment creates a pinch point (see Exhibit 3). • The extension cord leading to the generator was run through the top access door. This creates a pinch point between the generator door and the cord.

Table 3-1: On-Site Basic HS Conditions
(compared with 29 CFR 1926)

Requirement	On-site Condition
29 CFR 1926.405(j)(2)(ii) Receptacles, Cord Connections, and Attachment Plugs - Receptacles installed in wet or damp locations shall be designed for the location.	• Electrical receptacles located in wet and/or damp places were not designated for that type of application.
29 CFR 1926.405(g)(2)(iii) Flexible Cords and Cables - Flexible cords shall be used in continuous length without splice or tap.	• Extension cords were lying on the ground and had been repaired with black electrical tape.
29 CFR 1926.405(g)(2)(iv) Flexible Cords and Cables - Flexible cords shall be connected to devices and fittings so that strain relief is provided to prevent pull from being directly transmitted to joints or terminal screws.	• Flexible cords used on the control unit adjacent to the air compressor were not equipped with strain relief devices.

The following table provides additional conditions noted by the Board:

Concerns	On-site Conditions
The MSDS states permanganate may ignite wood	• Drums of permanganate on top of wooden pallets (as shipped from the manufacturer).
The USQD states drums are separated so as to prevent more than four drums being involved in any accident.	• In the fenced area, multiple spill pallets of drums located immediately adjacent to one another. • Numerous permanganate drums without "empty" stickers on them sitting in the corner of the fenced area. (Note: The drums did not contain free liquid, but they had not been rinsed.)
The HASP, HASP Addendum, and TWP Addendum require all pressurized hoses to be buried or protected across access ways.	• Pressurized hoses were not buried nor protected across access ways.
The HASP, HASP Addendum, and TWP Addendum require safety tips in critical locations to prevent movement or flopping in the event a pressurized hose suddenly ruptures.	• All pressure hoses were not properly equipped with safety ties in critical location to prevent movement or flopping in the event of a sudden rupture.

Concerns	On-site Conditions
The TWP Addendum requires that all containers, hoses, and pipes containing or transporting permanganate to have secondary containment.	• The only secondary containment noted on site was a trough located under the permanganate lines running from the supply to the distribution system and a plastic baby pool under the distribution system (see Exhibit 2-5).

3.2.2 Readiness Review

The purpose of the BJC SORC readiness review is to provide a consistent and objective review of the activity and ensure that objectives are well established, procedures and personnel are ready to implement the scope of work, and programmatic objectives are accomplished prior to initiation of field activities. A BJC readiness review was performed on June 29, 2000, for the Lance Permeation Project. Permission to proceed with the X-701B Oxidant Injection Program Lance Permeation Phase was granted by the BJC SORC Chairperson on July 19, 2000. BJC uses the readiness review process on all activities seeking to demonstrate readiness to initiate field activities or other activities as directed by DOE ORO or BJC management. BJC procedure PQ-A-1510, *Readiness Review*, provides the process for completing these reviews. The overall project scope was well defined; however, the scope of actual field work activities was not well defined. The readiness review did not identify inadequacies and conflicts between the various documents. A Project Readiness Review Checklist was developed and completed by BJC. Several of the checklist items did not identify all the required information for the process, and others provided incorrect information. For example, the HASP and HASP Addendum place requirements for industrial hygiene monitoring; however, the checklist stated that none was required. The checklist also stated the "HASP is approved" and the "AHA is approved"; however, no signatures documenting approval were obtained. The previous examples are representative of the types of problems found in the checklist for this project. USQD BJC/USQD-R2, *Oxidant Injection Project - Across Perimeter Road East of X-701B*, was approved by the SORC during the readiness review; however, the controls and assumptions contained within the USQD were not incorporated into project document(s). All readiness reviews performed at PORTS by BJC are administrative. No field operational review was performed once the project was initiated to ensure field readiness and implementation of project requirements.

Assignment of BJC personnel to key project functional roles in the HASP was not well understood by the members of the readiness review team. The readiness review team did not properly identify and evaluate the reporting and functional roles and responsibilities of all personnel participating on the project to ensure adequate implementation of ISM. The above information indicates inadequate performance in hazard analysis and development and implementation of controls. The inadequate communication between the field and project personnel resulted in a breakdown of feedback and improvement. The readiness review team did not identify the following: (1) the documents reviewed did not contain authorization signatures; (2) the permanganate MSDS disagreed with the HASP and HASP Addendum on neutralization of concentrated permanganate; (3) the fact that the AHA did not provide the general safety requirements for the chemicals present (i.e., incompatible materials, safety shower and eyewash requirements, fire fighting hazards, etc.); and (4) that protective and mitigative controls identified in the HASP and HASP Addendum were not contained in the AHA.

Clear roles and responsibilities of the various contractors (i.e., UT-Battelle, BJC, and IT) were not adequately communicated in the documents presented. The BJC readiness review team did not perform an adequate document review to ensure proper implementation of ISM for the project prior to granting authorization to proceed. Additionally, the BJC readiness review team did not initiate a field review to make sure ISM was operationally implemented.

Contributing Cause

BJC SORC readiness review team failed to ensure that all hazards for the project were identified and that controls were developed and implemented. Numerous deficiencies went unidentified during the document review for readiness, and no field validation was performed. The checklist used during the review did not completely identify the items needing validation prior to proceeding. Additionally, the readiness review team failed to identify significant weaknesses in all five core functions and eight guiding principles of ISM that should have been identified during a formal detailed readiness review.

3.2.3 Health and Safety Plan

The HASP and HASP Addendum were reviewed and accepted by BJC during the SORC readiness review. Appendix C, Table C-3, provides a tabulated assessment of regulatory compliance with 29 CFR 1926.65. The foundation for requirements is present; however, full compliance with required documentation was lacking.

The HASP and HASP Addendum state various requirements and controls that are to be complied with during execution of the project. All personnel on the job site are required to read and understand the contents of the HASP and HASP Addendum prior to initiation of work activities. Numerous controls and requirements specified in these two documents were never implemented in the field. Some of the information in these documents was incorrect. The only place in the HASP and HASP Addendum that addresses neutralization is during permanganate spill response. If personnel utilize this process for neutralization, the controls for a spill in the AHA should be followed. Personnel handling the five-gallon buckets of permanganate solution did not wear coated Tyvek as required by the AHA for "handling permanganate spills." The concentrated permanganate neutralization process is not technically correct for a 40% permanganate solution. The concentrated permanganate neutralization process contained in the documentation was based on (but not identical to) the MSDS for sodium permanganate monohydrate, 97+ %, which is a powder. Powder permanganate was not present on site; however, the MSDS was listed in the site MSDS logbook.

Personnel on site recognized several of the inaccuracies contained in the documents; however, no change(s) to the documents were initiated to correct the deficiencies. Personnel lacked a questioning attitude regarding compliance with basic work documents. Personnel on site did not have a comprehensive understanding of the HASP and HASP Addendum, resulting in noncompliance with the stated requirements and controls. The HASP and HASP Addendum did not adequately identify all field work activities and potential hazards. These shortcomings demonstrate a lack of implementation for defining the scope of work, analyzing the hazards, and development and implementation of controls. The lack of compliance with stated requirements and controls demonstrates a weakness in performing work safely. The lack of a questioning attitude and inadequate communication resulted in lack of feedback and improvement.

Contributing Cause

The HASP and HASP Addendum did not provide adequate HS guidance for safe execution of the project. Neither document was ever formally approved. The lack of complete identification of major work activities; the technically incorrect concentrated permanganate spill response neutralization process; the ineffective implementation of stated controls and assumptions; and the lack of formality to maintain the documents contributed to the accident.

3.2.4 Unreviewed Safety Question Determination

USQD BJC/USQD-R2, *Oxidant Injection Project - Across Perimeter Road East of X-701B*, was performed to evaluate the increase of approximately 20 drums of permanganate required for the injection project, injection of the permanganate via lance permeation, and the deletion of work at the X-701C Neutralization Pit. The Board is not making any conclusions on the need for a USQD for this project, only on the adequacy of the one prepared. Controls were assumed during the development of the USQD that were not present in any project document (i.e., storage configuration for the permanganate drums). The USQD also states that ". . . Although the uncontrolled release of high pressure could be considered a different type of unanalyzed event, appropriate controls are required to be in place to prevent such an event. For this reason, and because the lance permeation injections system is operated on a temporary basis by subcontracted personnel for whom this hazard is well understood and 'standard industrial,' it is determined that a different type of accident not previously evaluated is not created." The USQD process does not allow for controls to prevent an accident of a new type to be credited in the analysis of "Could the change or as-found condition create the possibility of a different type of accident than any previously evaluated in the authorization basis?" The crediting of controls is not allowed because the accident is possible without the controls in place; therefore, the accident is possible. Controls only reduce the probability of occurrence or reduce the consequence, but the accident is still possible without the controls. The potential hazard of a high-pressure rupture accident was disregarded due to the fact the operating pressure (10,000 psig) is substantially below the design pressure (40,000 psig). However, field personnel state that the rupture of the high-pressure line is a potential hazard from which personnel must be protected. The statement in the justification to question seven states: "Failure of any of these components could release only pressurized water, not dilute $NaMnO_4$, without off-site consequences." This statement is not correct. A rupture in the high-pressure water line in route to the drilling rig could create a break in the concentrated permanganate line running to the drilling rig, which would result in a release of concentrated permanganate. The two lines, permanganate and high-pressure water, along with the low-pressure water line are tied together and run as a bundle from the permanganate distribution center to the drill rig. This configuration makes a rupture of the permanganate line a more credible accident subsequent to a high-pressure water line rupture. BJC did not ensure the assumptions and/or controls stated in their USQD were implemented in the field. The fact that no one on site at the time of the accident was aware of the USQD or the controls/requirements stated therein indicates a breakdown in performing work safely and feedback and improvement.

Contributing Cause

The controls and assumptions stated in the BJC USQD were not flowed down into project documents. Fundamental logic flaws are evident in the USQD that were not identified during SORC readiness review team review and approval.

3.3 Conduct of Operations

The Board determined that effective formality of operations was not implemented for this project. Personnel on the job site were not in compliance with the HASP and HASP Addendum. These documents are the basic controls for project operations. The IT SHSO on site at the time of the accident stated he assumed the basics of the HASP and HASP Addendum were acceptable because the operation was already functioning when he arrived. Numerous controls and requirements contained in the HASP and HASP Addendum were not being properly implemented in the field. The official logs for the operation were not being kept in accordance with the requirements stated in the HASP and HASP Addendum. BJC personnel did not believe they had to comply with the BJC procedures for the responsibilities assigned to them in the HASP. This confusion apparently stems from the fact that UT-Battelle is also a DOE prime contractor. The BJC HS Advocate and STR believed they were not really filling the assigned roles because of the involvement of another DOE prime contractor. However, no deviation from the BJC procedures was stated in the HASP. Clear lines of authority were not evident at the site.

The Board determined that personnel assigned to the project did not place significant priority on the content and accuracy of the HASP and HASP Addendum. No approval signatures for these documents were obtained. No one questioned the fact that no approval signatures existed on site for the documents. The UT-Battelle PM was informed by BJC that the approval for these documents was the SORC readiness review signatures. However, when BJC was questioned, they stated that the SORC readiness review signatures are only to indicate the review team accepts the submitted documents as adequate evidence to proceed with operations. BJC personnel could not explain how they accepted unsigned/unapproved documents as the evidence to allow the project to proceed. The notebook on site contained a May 2000 version of the HASP Addendum in lieu of the June 2000 version. At least some of the project personnel were aware that the concentrated permanganate spill response procedure was incorrect. No attempt was made to modify the document. No attempts were made to keep these documents up to date with changing field conditions and personnel. No changes were made to these documents even though there were four changes in UT-Battelle HSO and two changes in IT SHSO. Additional personnel identified in these documents were incorrect and had been incorrect from the initiation of the project.

The HASP and HASP Addendum clearly stated that all project personnel are required to read and follow the procedures and protocols contained within and to sign an acknowledgment of compliance. No one is allowed on the site without first reading the HASP and HASP Addendum and signing the acknowledgment form. A review of the signatures on the HASP/HASP Addendum acknowledgment form revealed that two UT-Battelle HSOs were on site performing HSO functions without signing in on the HASP and HASP Addendum. UT-Battelle HSO #2 filled in for UT-Battelle HSO #1 on July 21, 2000; however, UT-Battelle HSO #2 did not sign the acknowledgment form until July 24, 2000, which was the day he took over full-time responsibility for the operation. UT-Battelle HSO #4 who took over on August 16, 2000, never signed the acknowledgment form at all. This clearly shows a lack of appreciation for the documents, as well as poor communication and formality of turnovers. The BJC HS Advocate did not sign the acknowledgment form. During her interview, she stated she visited the site and "checked on them." In later communications with her, she confirmed she did not actually go into the exclusion area where work was being performed. Performance of the BJC HS Advocate role cannot be adequately achieved without entering the site exclusion area.

UT-Battelle HSO #1 was very knowledgeable of the general HS requirements for the project and proper handling of materials. While on site, UT-Battelle HSO #1, along with IT SHSO #1, implemented controls in addition to those in the HASP, HASP Addendum, and AHA. However, UT-Battelle HSO #1 and IT SHSO #1 did not make sure the controls stated in the HASP and HASP Addendum, as well as additional controls for the equipment, were implemented prior to initiation of field activities.

Turnover between the various UT-Battelle HSOs was not adequate. The decisions to not perform any maintenance of the drilling equipment on site; to handle all permanganate collected as concentrated; and the controls and/or assumptions contained in the USQD are examples of items that were not properly communicated during turnovers from UT-Battelle HSO #1 down the chain to UT-Battelle HSO #4. The Board determined the formality and depth of turnover performed by UT-Battelle was inadequate.

No DOE personnel signed the HASP/HASP Addendum acknowledgment sheet. Interviews and field logbooks verify that the DOE PORTS Program Manager visited the site and kept up with project status. No DOE personnel performed HS oversight for the project. Additionally, no DOE personnel read any of the site logbooks for the project. DOE PORTS does not have any FRs assigned to the site. The Acting DOE PORTS Site Manager stated that he expected the DOE Construction Safety Engineer to perform HS oversight on jobs like this. The DOE Construction Safety Engineer never visited the job site. A review of DOE PORTS Site Office documentation demonstrates a weakness in the extent of oversight of field activities. When detailed field oversight was performed, problems with the activity were identified. The DOE PORTS Site Office was not performing adequate HS oversight for either field compliance or fundamental HS program implementation.

Contributing Causes

(1) The general lack of appreciation for safety documentation (HASP, HASP Addendum, AHA, USQD, etc.) along with an overall lackadaisical attitude by the various contractors are contributing causes for the accident.

(2) Clear roles and responsibilities were NOT established between the various contractor organizations.

(3) The magnitude of noncompliance with the HASP, HASP Addendum, TWP Addendum, and AHA, along with the inadequacy of these documents, demonstrates a breakdown in all aspects of ISM by the various contractor organizations.

(4) Clear DOE line management authority did not exist.

(5) DOE ORO EM, as the funding source, did not satisfactorily establish clear lines of communications or roles and responsibilities between the various DOE parties for the project. DOE ORO EM did not perform or assure the performance of adequate HS reviews.

3.4 Chemical Analysis of the Accident

The Board determined the chemical reaction that occurred on August 22, 2000, was initiated by the IT Laborer placing crystalline thiosulfate into a five-gallon bucket of concentrated permanganate (see Exhibit 3-1).

Exhibit 3-1. Five-gallon Bucket Where Reaction Took Place

When the crystalline thiosulfate was added to the concentrated permanganate, initially nothing happened because the dissolution of thiosulfate into water is a mildly endothermic reaction. When the thiosulfate started reacting with the concentrated permanganate, a violent exothermic reaction was initiated. The water in the immediate vicinity of the crystalline thiosulfate was almost instantaneously heated to above the boiling point (100ºC/212ºF). The temperature rise in the localized area depends on the actual permanganate concentration at the time. The actual concentration is not known; however, the Board concludes the concentration was somewhere between 16 to 20% permanganate. Due to the high energy yield from the reaction, a super-heated steam bubble was created. The reason for the super heating is the excess amount of permanganate available for reaction with the thiosulfate and the almost instantaneous release of energy. The violent release of the steam bubble caused the permanganate solution to be ejected from the five-gallon bucket over 15 feet into the air and onto the IT Laborer who was standing directly over the bucket.

PRIMARY REACTION BETWEEN SODIUM THIOSULFATE AND SODIUM PERMANGANATE

$3\ Na_2S_2O_3 + 8\ NaMnO_4 + H_2O = 8\ MnO_2 + 6\ Na_2SO_4 + 2\ NaOH$

The reasons this reaction produced a more violent chemical reaction, resulting in the steam bubble, than other potential prior neutralizations in five-gallon buckets are:

- The change from bisulfite to thiosulfate. The neutralization reaction with the bisulfite would generate approximately the same amount of heat for the overall reaction as that for the thiosulfate. The permanganate MSDS states that the bisulfite may require some dilute sulfuric acid to promote neutralization. No sulfuric acid was present at the job site to lower the pH. Therefore, at the pH of the collected permanganate solution, the thiosulfate produces a more rapid reaction.

- The physical structure of the thiosulfate as compared to the physical structure of the bisulfite. A small fine granular (like sugar) bisulfite was used on the site for neutralization prior to the day of the accident. On the day of the accident the neutralizing agent was changed to thiosulfate, which has a larger, courser granular structure (like rock salt). The addition of the small fine granular neutralizer would create a dispersed insertion of material, thereby decentralizing the heat that is generated, whereas the larger course granular neutralizer would create localized heating. The difference in grain size would also make it easier to grasp more thiosulfate with a rubber gloved hand.

- The concentration of permanganate in the five-gallon bucket. The depth of color is an indication of concentration (the darker the color, the more concentrated); however, color cannot be used to visually determine the actual concentration. The depth of purple color of the collected permanganate solution was known to vary during the operation from a milk-of-magnesia color to a dark purple color. Personnel stated the material collected from the dripping drill head during lunch on the day of the accident was some of the darkest purple they had collected.

Exhibit 3-2. Cotton Pants Worn by IT Laborer

Exhibit 3-3. 66% Polyester/34% Cotton Shirt Worn by IT Laborer

The 100% cotton pants worn by the IT Laborer were practically disintegrated (see Exhibit 3-2), whereas, the 66% polyester/34% cotton shirt was not disturbed (see Exhibit 3-3). The Board concluded the reason was due to ignition of the cotton. The permanganate MSDS clearly states that permanganate can spontaneously ignite cloth or paper. The violent spraying of the heated solution onto the cotton pants caused the pants to ignite. The normal ignition temperature for cotton is around 255-400ºC/490-750ºF. The normal ignition temperature for polyester is 450-560ºC/840-1040ºF. The Board concludes the polyester/cotton shirt worn by the injured IT Laborer directly reduced his injuries and potentially saved his life. The use of proper PPE would have reduced the severity of injury resulting from the accident.

3.5 Emergency Response

In general, the emergency response to this accident was adequate to ensure that the most injured IT Laborer was given appropriate medical treatment. There was a short delay in the initiation of the emergency response; however, emergency actions by the employees on site attending to the victim were excellent. The immediate work area was not provided with the appropriate facilities for quick drenching or flushing of the body for emergency use. In order to use the provided safety shower, workers were required to leave the work area, cross a small road, travel up a small hill, through large trees, and enter the field trailer. Only the quick thinking of on-site personnel to provide quick flushing of the body by water hoses reduced the severity of the injuries. Workers in the area of the accident demonstrated determination in mitigating the accident and attending to the injured IT Laborer. During the initial chaotic minutes of the accident, one worker reconfigured the equipment to provide a much needed second water line. The injured IT Laborer refused to utilize the eyewash station; however, the IT SHSO immediately obtained bottled eyewash solution and provided it to the injured IT Laborer as an alternative. The injured employee allowed the individual bottle of eyewash to be used to flush his eyes. Personnel on the scene also utilized neutralizing solution after a period of flushing with water. They alternated spraying the injured employee with neutralizing agent and drenching him with water hoses. The quick thinking and knowledge of available resources by the employees helped to mitigate the seriousness of the situation.

The injured Driller's Assistant went immediately to the safety shower in the field trailer. The Driller's Assistant rinsed and neutralized his upper body in the shower. When the Driller's Assistant left the trailer, the Driller joined him to evaluate his condition. The Driller noticed permanganate on the pants of the Driller's Assistant. The Driller's Assistant removed his pants and, with assistance, rinsed and neutralized his lower body. The Driller demonstrated good safety consciousness by checking on the Driller's Assistant once the injured IT Laborer had sufficient personnel taking care of him. The Driller's Assistant demonstrated level-headed thinking in handling his injuries. His extensive training in emergency response was obvious.

The requirements for emergency response for an injured employee are contained in the AHA, HASP, HASP Addendum, and the safety briefing provided by the BJC HS Advocate. The AHA states to call 911 or use radio frequency 2; however, it fails to add the caveat that a plant phone must be used. The HASP and the HASP Addendum requires emergencies which occur off site be reported by 911 to the Pike County Sheriff. Emergencies on site should call the PORTS emergency phone number 911 from any plant phone. This accident occurred on what is considered "on-plant." The safety briefing by the BJC HS Advocate stated medical assistance could be obtained by dialing 911 on any plant phone, pulling a fire alarm pull box, or using channel 2 on any plant radio. Personnel are required to read and be cognizant of the HASP and HASP Addendum prior to going to work. No one, including the BJC HS Advocate, pointed out the inconsistency between the AHA and the HASP/HASP Addendum. There was a radio on site in the IT trailer, which is located outside the exclusion zone and across a gravel road; however, the radio was not utilized during the accident. Personnel used cellular phones to make all emergency notifications. The initial report to the Pike County Sheriff at approximately 12:52 p.m. incorrectly stated the accident was at the plant in Paducah, Kentucky. An ambulance was not dispatched until 12:58 p.m. Also, it is not clear who called the Sheriff's Department with the correct location of the accident. The delay in dispatching an ambulance was about six minutes. Once initiated, the emergency response was satisfactory. Incomplete emergency information in the AHA demonstrates a deficiency in ISM core function 3, Development and Implementation of Controls. Failure of personnel to implement the requirements of the HASP/HASP Addendum reveals a deficiency in ISM core function 4, Perform Work Safely. The fact that the inconsistencies between the documents were not identified represents a deficiency in ISM core function 5, Feedback and Continuous Improvement.

3.6 Analysis Techniques

Several analytical techniques were utilized to determine the causal factors of the accident. Event and causal factors were charted using ISM core functions and guiding principles, and barrier and change analysis techniques were used to analyze facts and identify the accident causes. The causal factors, based on the weaknesses identified with ISM core functions and guiding principles, collectively contributed to the accident. The analysis techniques used complement and cross-validate one another. Section 4 discusses the Judgments of Need.

3.6.1 Integrated Safety Management Systems

Management systems were examined as potential contributing and root causes of the accident. The Board reviewed the roles of DOE ORO, BJC, and UT-Battelle management in promoting and implementing ISM in this project. The Board also reviewed line management's role at the DOE PORTS Site Office and BJC at PORTS in selected areas, including the role of the SORC in preparing for and approving the work activities of this project, readiness reviews, lessons learned, communication of hazards, and project oversight. The ISMS provides a formal, organized process for planning, performing, assessing, and improving the safe conduct of work. Properly implemented, ISM is a "standards-based approach to safety" requiring rigor and formality in the identification, analysis, and control of hazards. The system establishes a hierarchy of components to facilitate the orderly development and implementation of safety management throughout the DOE complex. The guiding principles and core functions of ISM are the primary focus for contractors in conducting work efficiently and in a manner that ensures the protection of workers, the public, and the environment. The accident investigation program requires that accidents be evaluated in terms of ISM to foster continued improvement in safety and to prevent additional accidents.

The ISM program at ORNL has been contractually required since 1998. UT-Battelle assumed those ISM requirements when it took over as the management and operating contractor for ORNL on April 1, 2000. BJC became the M&I contractor for the EM Program at DOE ORO on

April 1, 1998. Both UT-Battelle and BJC have approved ISMS descriptions and have passed their Phase I verifications. Focused Phase II validations have recently been performed on both contractors.

Notwithstanding these efforts to implement ISM, this accident highlighted deficiencies in work planning and controls that contributed directly to both this accident and the incident which occurred at the same site on July 27, 2000, in which two employees were sprayed with permanganate. The deficiencies were evident in work definition, planning, hazard identification, hazard analysis, developing adequate controls, and application of lessons learned. A number of controls for ensuring safe work conduct were bypassed or overlooked in planning and conducting the work. The weaknesses spanned multiple organizations and demonstrated a lack of consistent application of the guiding principles and core functions of ISM to the work activities of this project.

Table 3-2 summarizes deficiencies in the application of the five core functions of ISM as they relate to this accident. Table 3-3 summarizes the weaknesses in the application of the eight guiding principles of ISM.

3.6.2 Barrier Analysis

Barrier analysis is based on the premise that hazards are associated with all accidents. Barriers are developed into a system or work process to protect personnel and equipment from hazards. For an accident to occur, there must be a hazard that comes into contact with a target because barriers or controls were not in place, not used, or failed. A hazard is the potential for an unwanted energy flow to result in an accident or other adverse consequence. A target is a person or object that a hazard may damage, injure, or fatally harm. A barrier is any means used to control, prevent, or impede the hazard from reaching the target, thereby reducing the severity of the resultant accident or adverse consequence. The results of the barrier analysis are used to support the development of causal factors. Appendix B, Table B-1, contains the barrier analysis.

Table 3-2: Weaknesses in Implementation of the ISM Core Functions

Significant weaknesses in the implementation of the five core functions of ISM caused this accident. These weaknesses include:

Core Function 1
Define the Work

- DOE line management roles and responsibilities were not clearly developed and implemented between the various ORO DOE organizations involved in the project.
- The scope and responsibility for oversight was not clearly and unambiguously defined between UT-Battelle and BJC.
- UT-Battelle, BJC, and IT failed to define all tasks to be performed during execution of the project in the field. The extent of and responsibility for work was not well defined in the HASP and HASP Addendum
- The AHA did not define all "Basic Job Steps" to be performed. All hazards associated with the work with chemicals on site were not defined. The hazards associated with the neutralization process of collected permanganate solution was not well defined. Critical MSDS information was not captured in the hazard analysis.
- The BJC readiness review team failed to identify weaknesses in the documentation submitted for readiness to proceed.
- When field activities deviated from expected conditions, a time out was not called by UT-Battelle or IT to define the new work activities and properly incorporate them into project documentation.

Core Function 2
Analyze the Hazards

- UT-Battelle, BJC, and IT did not adequately analyze the potential reactivity of concentrated sodium permanganate. Technical understanding of reactivity of concentrated sodium permanganate and neutralization was lacking.
- UT-Battelle, BJC, and IT failed to adequately analyze the hazards associated with many tasks required to be performed during the project (i.e., permanganate solution return up the drill rods, neutralization of collected permanganate solution, neutralization of permanganate from ground fissures, pressurized line breakage, handling five-gallon buckets containing permanganate solution, etc.).
- The most current MSDS was not obtained from the supplier of the permanganate and was not analyzed to understand the hazards and PPE requirements.
- The neutralization and handling requirements from the MSDS that was used for the project were not correctly stated in AHA, the HASP, or the HASP Addendum.
- The TWP did not identify hazards associated with all aspects of the work.
- The hazards associated with the handling and neutralization practice on site were not analyzed.
- The hazards of the high-pressure hose and permanganate line were not properly analyzed in the AHA.
- The hazards of potential contaminants in the ground were not properly analyzed.
- The hazards of materials present from previous activities were not properly analyzed.
- The BJC readiness review team failed to ensure the hazards were properly analyzed and control measures developed and implemented.
- UT-Battelle and BJC failed to provide adequate technical reviews of the AHA, the HASP, and the HASP Addendum, resulting in a failure to adequately identify and analyze the hazards.

Table 3-2: Weaknesses in Implementation of the ISM Core Functions

<u>Core Function 3</u>
Develop and Implement Controls

- DOE ORO and the PORTS Site Office were not adequately involved in the review of the documentation and field activities associated with the project.
- Roles and responsibilities for oversight were not clearly developed and implemented between UT-Battelle and BJC. The roles and responsibilities for BJC, UT-Battelle, and IT were written into the project HASP and HASP Addendum, but they were not clearly understood or executed in an acceptable manner by the responsible individuals or organizations.
- Critical MSDS information on permanganate, thiosulfate, and bisulfite was not integrated into work activities.
- The controls and requirements stated in the HASP, HASP Addendum, and TWP Addendum were not implemented in the field (i.e., secondary containment for all containers, hoses, and pipes containing or transporting sodium permanganate; IT SHSO daily safety log; UT-Battelle HS logbook; equipment certification and documentation; BJC HS Advocate; etc.).
- Controls were not developed and implemented for numerous activities being performed on site. (i.e., permanganate solution return up the drill rods, carrying five-gallon buckets of permanganate, neutralization of collected permanganate solution, neutralization of permanganate from ground fissures, the drilling, etc.).
- There was a failure to implement appropriate PPE requirements.
- The controls for work were not adequately developed and specified during the approval of the HASP, HASP Addendum, and AHA.
- A suitable shower that was readily available within the immediate work area was not provided.
- There was a failure to properly implement controls on pressurized lines to prevent movement upon rupture.
- The hazard controls for neutralization of permanganate solutions on the ground were not developed.
- Safety controls for carrying buckets of permanganate solution were not developed.
- The control of documents with revisions were not maintained.
- Equipment certification and maintenance requirements were not developed.
- Hazard controls identified early in the project were not implemented. The HSO turnover contributed to this deficiency.
- OSHA hazard communication requirements were not implemented.

Table 3-2: Weaknesses in Implementation of the ISM Core Functions

Core Function 4
Perform Work Safely

- Numerous problems were encountered in the field. When field activities deviated from expected conditions, a time out was not called by UT-Battelle or IT to define the new work activities and properly incorporate them into project documentation.
- Workers were unaware of the hazards associated with concentrated sodium permanganate.
- Pre-job briefings were not documented in accordance with the HASP and HASP Addendum and were not effective in conveying the extent of hazards.
- UT-Battelle failed to adequately evaluate the root cause and provide adequate changes as a result of the July 27, 2000, incident in which two project workers were sprayed with permanganate.
- There was inadequate control of the system equipment configuration.
- The neutralization process did not verify that the solution was dilute prior to neutralization.
- The injured worker was performing work outside of the scope of duties assigned by his immediate supervisor.
- BJC personnel did not perform the duties as assigned in the HASP in accordance with established procedures.
- The UT-Battelle HSO, IT SSHO, and BJC HS Advocate did not perform their duties in accordance with the HASP and HASP Addendum.
- The controls for double containment were not properly implemented in the field for pressurized systems.
- Field maintenance continued even after the UT-Battelle PM and IT PM decided all maintenance would be performed by the maintenance shop.
- Proper turnovers were not performed during multiple change out of UT-Battelle personnel.
- Work was not performed within the controls identified in the USQD.
- Controls for ensuring that incompatible materials would not be adjacently stored were absent.

Core Function 5
Feedback and Improvement

- Lessons learned from a 1999 NaK accident at the Y-12 Plant were not considered by the BJC SORC or by UT-Battelle in reviewing the HASP and HASP Addendum for this project.
- The lessons learned concerning PPE from the July 27, 2000, incident in which two employees were sprayed with permanganate were not implemented outside of maintenance activities.
- There were many opportunities available, due to daily project events, to improve operational safety. No one took time to properly evaluate changing conditions.
- Changing field conditions were not fed back into the hazard analysis phase to improve safety of operations.
- Personnel lacked a questioning attitude, thereby preventing adequate feedback for improvement.
- The spraying of two individuals on July 27, 2000, failed to provide adequate improvement due to the narrow analysis performed.
- Improper and informal turnover between UT-Battelle HSOs resulted in unacceptable feedback and improvement.
- The penetration stand down at PORTS was due to deficiencies in the hazard analysis and development and implementation of controls. The corrective actions for the penetration permit problems were limited in scope to penetration permit issuance. The lessons were applicable to issues outside of penetration permit problems.

Table 3-3: Weaknesses in Implementation of the ISM Guiding Principles

Significant weaknesses in the implementation of ISM and the eight guiding principles caused this accident. Weaknesses existed in all guiding principles and at several levels within the organizations involved. These weaknesses include:

Guiding Principle 1

Line management is directly responsible for the protection of the public, workers, and the environment.

- DOE ORO management has not effectively implemented clear lines of authority for EM Technology Demonstration and Deployment projects.
- DOE ORO and the PORTS Site Office management did not provide adequate oversight for this project.
- BJC and UT-Battelle management have failed to effectively apply the known lessons learned from previous chemical events and accidents in order to prevent this accident and to mitigate the impact on worker health and safety.
- BJC, UT-Battelle, and IT management have not established effective mechanisms for hazard communication.
- BJC, UT-Battelle, and IT management have not assured a safety culture where workers are willing to stop work and to re-enter the hazard identification and analysis phases of ISM when unexpected conditions are encountered.
- UT-Battelle depended upon a reference to the ISM DEAR clause in the General Terms and Conditions to adequately flow down to the subcontractors the requirements for ISM, which was not effective.
- Contract line management chain was not clearly established.

Guiding Principle 2

Clear and unambiguous lines of authority and responsibility for ensuring safety shall be established and maintained at all organizational levels within the Department and its contractors.

- The roles and responsibilities of the ORO EM Program Manager for this project were not clearly understood or executed in an acceptable manner.
- The roles and responsibilities of the DOE PORTS Site Office personnel were not clearly understood or executed in an acceptable manner.
- BJC's facility management roles and responsibilities associated with being the landlord at PORTS were not well understood or properly implemented.
- The roles and responsibilities for both BJC and UT-Battelle were written into the project HASP, but they were not clearly understood or executed in an acceptable manner by the responsible individuals or organizations.
- BJC and UT-Battelle management have failed to establish effective accountability for adherence to institutional controls for HS documents and hazard control processes.
- Neither the UT-Battelle HSO, IT HSO, nor the BJC HS Advocate for the project were performing the functions and duties specified for them in the HASP and HASP Addendum.
- UT-Battelle was placing too much reliance on informal work controls to prevent accidents.

Table 3-3: Weaknesses in Implementation of the ISM Guiding Principles

<u>Guiding Principle 3</u>
Personnel shall possess the experience, knowledge, skills, and abilities that are necessary to discharge their responsibilities.

- There was no documented turnover of responsibilities between the UT-Battelle HSO and his predecessor. This was the fourth person with these duties in a six-week period.
- The injured worker was performing duties outside those authorized by his immediate supervisor.
- Site personnel wrongly assumed that the permanganate solution was dilute (less than 6% in water), when concentrations up to 40% were possible.
- Hazard identification, analysis, and control were ineffectively performed throughout the project.
- Knowledge of differences in sodium permanganate and potassium permanganate were not fully understood by all on site personnel.

<u>Guiding Principle 4</u>
Resources shall be effectively allocated to address safety, programmatic, and operational considerations. Protecting the public, the workers, and the environment shall be a priority whenever activities are planned and performed.

- DOE, BJC, and UT-Battelle failed to prioritize the resources necessary to effectively conduct the work safely.
- BJC, UT-Battelle, and IT failed to assure the use of appropriate PPE for personnel working with permanganate, including Tyvek suits or aprons, goggles, face shields, and appropriate respirators.
- The atmosphere on the project site indicated that production and schedule took precedence over safety and health.

<u>Guiding Principle 5</u>
Before work is performed, the associated hazards shall be evaluated and an agreed-upon set of safety standards shall be established that, if properly implemented, will provide adequate assurance that the public, the workers, and the environment are protected from adverse consequences.

- The change from bisulfite to thiosulphate was not evaluated.
- Sodium permanganate was stored on wooden pallets and adjacent to peroxides. Both of these are incompatible materials.
- A readily available safety shower was not identified as a requirement.
- Personnel did not fully understand the hazards of sodium permanganate and sodium thiosulphate.
- The hazards identification and analysis process were inadequate in identifying and mitigating the hazard.
- The technical information related to PPE requirements was not integrated into work activities.
- The neutralization and handling requirements from the MSDS were not correctly stated in the AHA or the HASP.
- Not all workers on the site were aware of the extent of the hazards associated with neutralization of permanganate.
- Deficiencies are evident in the implementation of EPA, OSHA, DOE, and site requirements in the areas of hazard communications and hazardous waste site requirements.
- The controls and assumptions utilized in the USQD were not maintained or controlled on the job site.
- The differences between neutralization of permanganate by bisulfite and thiosulfate was not adequately identified, analyzed, or controlled.

Table 3-3: Weaknesses in Implementation of the ISM Guiding Principles

<u>Guiding Principle 6</u> **Administrative and engineering controls to prevent and mitigate hazards shall be tailored to work being performed and associated hazards.** • Failure to implement the controls identified in the HASP Addendum, AHA, TWP Addendum, and the previous incident of July 27, 2000. • The process in the HASP and HASP Addendum for the neutralization of permanganate was not adequately verified, validated, or technically accurate. • The most conservative assumptions for protection were not used for all work activities involving permanganate. • The safety shower was not readily available in the immediate work area. • Controls for verifying the concentration of permanganate were not performed prior to neutralization. • PPE requirements were not adequately established for all work activities.
<u>Guiding Principle 7</u> **The conditions and requirements to be satisfied for operations to be initiated and conducted shall be clearly established and agreed upon.** • The USQD information was not shared/conveyed to anyone at the job site. • Because of the failure to identify the hazards present, the TWP and TWP Addendum for the project were not effective in identifying and assuring the provision of the PPE necessary to protect the workers from injury and exposure. • There was inadequate oversight and control of system equipment configuration. • Line management did not assure that personnel involved in the project were cognizant of the hazards associated with the work that required precautions and protective equipment. • The daily tailgate briefings were not sufficient to assure an adequate understanding of the hazards involved and the necessary controls to perform work safely. • The readiness review process was not adequately performed. • Document control was not established. • Prior to neutralization of permanganate solutions, the verification of permanganate concentration to 6% or less was not performed.
<u>Guiding Principle 8</u> **Workers will be involved in all phases of work planning and execution.** • Workers were not adequately involved in analyzing and controlling the hazards associated with this project.

3.6.3 Change Analysis

Change is anything that disturbs the "balance" of a system which is operating as planned. Change is often the source of deviations in system operations. Change can be planned, anticipated, and desired, or it can be unintentional and unwanted. Change analysis examines planned or unplanned changes that caused undesired results or outcomes related to the accident. This process analyzes the difference between what is normal (or "ideal") and what actually occurred. The results of the change analysis are used to support the development of causal factors. Appendix B, Table B-2, contains the change analysis.

3.6.4 Causal Factors Analysis

A causal factor analysis was performed in accordance with the DOE Workbook *Conducting Accident Investigations,* Revision 2. Events and causal factors analysis requires deductive reasoning to determine which events and/or conditions contributed to the accident. Causal factors are the events or conditions that produced or contributed to the occurrence of the accident and consist of direct, contributing, and root causes.

The **direct cause** is the immediate events or conditions that caused the accident. **Contributing causes** are events or conditions that collectively with other causes increased the likelihood of the accident but that individually did not cause the accident. **Root causes** are events or conditions that, if corrected, would prevent recurrence of this and similar accidents. A summary of the Board's causal factors analysis is presented in Table 3-4.

Table 3-4: Causal Factors

DIRECT CAUSE
The direct cause of the accident was the introduction of crystalline thiosulfate into a five-gallon bucket containing concentrated permanganate solution.

No.	Contributing Causes	Discussion	Related Judgment of Need
CC-1	The hazards associated with the chemicals on site and appropriate PPE were not adequately identified and analyzed. Proper controls were not developed and implemented.	• The neutralization process for collected solution of permanganate was not contained in any project documents. • The differences between the use of thiosulfate and bisulfite for neutralization was not understood. • The potential for return of permanganate up the drill rods was not identified in any project documents. • The AHA, HASP, and HASP Addendum did not identify all activities performed in the field. Since the activities were not identified, they were not analyzed for development and implementation of controls. • Critical MSDS and other technical information were not captured in either the AHA or the HASP/HASP Addendum. • Appropriate PPE was not utilized while handling and working with the various chemicals on site. • Permanganate drums were left on wooden shipping pallets during use and storage. The MSDS states that permanganate can ignite wood.	JON 3 JON 4
CC-2	The work planning and readiness review processes were inadequate.	• The planning failed to identify various field activities needing analysis (i.e., neutralization of permanganate from ground fissures, permanganate return up the drill rods, carrying five-gallon buckets of permanganate, etc.). • The BJC readiness review process did not identify inconsistencies in the documentation presented for permission to initiate field activities. • The BJC readiness review process failed to ensure actual field implementation and readiness. • The AHA did not identify all the potential hazards associated with the project. • The technical information in the HASP, HASP Addendum, and AHA for neutralization of concentrated permanganate solution was incorrect. • Communication between the various contractors did not establish clear functional roles and responsibilities for the project.	JON 3 JON 4 JON 7 JON 9

Table 3-4: Causal Factors

No.	Contributing Causes	Discussion	Related Judgment of Need
		• The proper PPE was not identified for all potential hazards listed in the AHA. • The controls and assumptions stated in the USQD were not incorporated into the work documents for the project. • No controls were identified and implemented to protect personnel from pressurized line ruptures. • No project documents required an eyewash and/or safety shower in the immediate work area. There was a suitable eyewash station in the work area; however, the safety shower on site was not within the immediate work area. The MSDSs for thiosulfate and bisulfite specifically state to have an eyewash station and safety shower. The MSDS for permanganate requires flushing of the eyes and immediate washing with water.	
CC-3	Field implementation of documented controls and assumptions was inadequate.	• Controls stated in the HASP and HASP Addendum, such as double containment for all lines carrying permanganate and certification of all equipment, were not implemented in the field. • Basic hazardous communication labeling of chemicals transferred from the original shipping container was inadequate. • Logbooks for the project were not kept in accordance with requirements stated in the HASP and HASP Addendum. • The equipment operating manuals and certifications were not developed and maintained in accordance with the HASP Addendum and TWP Addendum. • USQD controls and assumptions were not implemented in the field.	JON 1 JON 3 JON 4 JON 5
CC-4	DOE ORO and the PORTS Site Office failed to establish unambiguous lines of authority and responsibility for HS at all organizational levels.	• Clear and accountable DOE line management authority for the project was not established by DOE ORO EM-90. • DOE HS oversight for the project was not properly planned. • No DOE personnel performed HS oversight during the planning and/or field implementation of the project.	JON 7 JON 8 JON 10
CC-5	The roles and responsibilities for BJC, UT-Battelle, and IT were not clearly	• The BJC HS Advocate was assigned in the HASP. The function performed by this HS Advocate was not in compliance with the BJC HS Advocate procedure.	JON 1 JON 2 JON 6 JON 7

Table 3-4: Causal Factors

No.	Contributing Causes	Discussion	Related Judgment of Need
	understood or executed.	• The BJC STR was assigned in the HASP. The function performed by this STR was not in compliance with the BJC STR procedure. • The UT-Battelle HSO and IT SHSO did not maintain the site logbooks in accordance with the requirements in the HASP and HASP Addendum. • The inadequate and incomplete turnover between the UT-Battelle HSOs resulted in inadequate performance of responsibilities. • Personnel deviated from the roles and responsibilities assigned in the HASP and HASP Addendum, but documents were not modified to adequately define roles. This led to confusion on who was responsible for what during the project. • Lack of responsibility for project document control led to the breakdown of procedure control. • The ambiguous roles and responsibilities resulted in failure to establish and maintain ES&H oversight by UT-Battelle and BJC for this project.	
CC-6	Training on the hazards of the chemicals on site was not effective.	• Personnel were not adequately trained on the hazards of concentrated permanganate solution, thiosulfate, and bisulfite. For example, personnel were unaware that permanganate could spontaneously ignite cloth or paper. • Personnel were not adequately trained on potential hazards of the permanganate neutralization process.	JON 1 JON 3
CC-7	Lessons from previous incidents and other chemical accidents within DOE were not learned.	• The lessons concerning PPE from the July 27, 2000, incident in which two employees were sprayed with permanganate were not implemented outside of maintenance activities. The feedback was not utilized to effect continuous improvement. • The lessons from the 1999 NaK accident at the Y-12 Plant were not considered by the BJC SORC or by UT-Battelle in reviewing the HASP and HASP Addendum for the project. • There were many opportunities to improve operational safety, but no one took time to properly evaluate the daily changing conditions involving the use of permanganate.	JON 2 JON 3 JON 4
CC-8	UT-Battelle and IT management did not assure a safety culture	• When a situation occurred where permanganate solution returned up the drill rods, personnel did not stop operations and perform effective hazard	JON 2 JON 7

Table 3-4: Causal Factors

No.	Contributing Causes	Discussion	Related Judgment of Need
	where workers were willing to stop work and to re-enter the hazard identification and analysis phases when unexpected conditions were encountered.	analysis. • The lack of borehole sealing and subsequent permanganate seepage was not evaluated for potential hazards. • Personnel were aware of inaccuracies in the HASP, HASP Addendum, and AHA; however, no one, including the supervisor and oversight personnel, initiated a change. • Basic OSHA and fundamental safety noncompliances existed on site. These noncompliances were not identified by either site personnel or oversight personnel to implement corrections. • The numerous problems with the drilling operation and equipment did not prompt re-evaluation. • The supply of bisulfite was exhausted. Some thiosulfate was on site from a previous project. The change to thiosulfate as the neutralizing agent was not discussed with project personnel. A safety briefing covering the differences was not performed.	
CC-9	Work control processes were inadequate.	• The concentration of the permanganate solution was not verified prior to neutralization. • The UT-Battelle PM and the IT PM decided early in the project that all assembly, repair, or modification of the injection head subassembly would be done at the manufacturing machine shop and would NOT involve on-site field staff. However, maintenance continued to be performed on site by field staff up to the day of the accident. • The concentration of collected permanganate solution was "assumed" to be dilute by personnel on site at the time of the accident.	JON 1 JON 5
CC-10	No document control was instituted for the project.	• BJC did not document the revisions of the documents reviewed during the SORC readiness review. • No signatures exist for approval of the HASP, HASP Addendum, TWP Addendum, and AHA. • The binder containing the documents on site did not contain any approval signatures. • The latest MSDS revision for sodium permanganate 40 was not available on site. • DOE ORO oversight did not enforce adequate work planning and subsequent document controls for the project.	JON 1 JON 5 JON 9

Table 3-4: Causal Factors

No.	Contributing Causes	Discussion	Related Judgment of Need
CC-11	Compliance with basic HS requirements was not enforced on site.	• The safety shower on site did not meet OSHA requirements for a quick-drench/safety shower in the immediate work area. • Labeling of containers in accordance with hazard communication requirements was not performed.	JON 1 JON 4 JON 5 JON 9
CC-12	The HASP, HASP Addendum, and AHA were not in compliance with the MSDSs.	• The neutralization process for concentrated permanganate spill response in the HASP and HASP Addendum does not reflect information in the MSDS for sodium permanganate 40. • The only neutralization process addressed in the AHA is under "handling permanganate spills." The "Control Measure" column provides the process for concentrated permanganate spill response. The process is the same as that stated in the HASP and HASP Addendum, which does not comply with the MSDS. • The control measures stated in the AHA for the potential hazards of direct chemical contact do not fully implement the controls stated in the MSDSs. • The documents do not identify that permanganate can ignite wood or cloth. This is an important fact that should have been considered during analysis of potential hazards.	JON 1 JON 3 JON 4 JON 5 JON 10
CC-13	Turnovers for roles specified in the HASP and HASP Addendum were not effective, nor were they documented by changes to the documentation.	• The turnovers that occurred between the UT-Battelle HSOs were incomplete and informal. Information that was crucial to the operation was lost during the various turnovers. Work process and safety controls suffered as a result of the poor turnovers. • Key project personnel changes were made; however, no changes were made to document the changes. • The Site Health and Safety Organization Chart in the HASP Addendum was never completely filled out. Key names were missing.	JON 1 JON 5 JON 7 JON 9
CC-14	The contracting process did not adequately implement ISM requirements.	• The contract with IT did contain the ISM DEAR clause. However, communication from UT-Battelle to the subcontractor on ISM expectations and implementation did not occur.	JON 6 JON 9
CC-15	Communication between the various DOE organizations was not adequately performed.	• The DOE ORO EM Program Manager who issued the Task Order for the project to UT-Battelle did not communicate with the DOE COR for UT-Battelle. • The DOE ORO EM Program Manager did not feel responsibility for DOE line management	JON 8 JON 9 JON 10 JON 11

Table 3-4: Causal Factors

No.	Contributing Causes	Discussion	Related Judgment of Need
		oversight of the contract, nor was communication initiated with any other DOE personnel to ensure adequate DOE ORO oversight. • The spraying of two individuals on July 27, 2000, was not communicated to all DOE personnel having interest. A DOE ORNL Site Office individual accepted notification as the FR for the event. This individual did not communicate with either the DOE EM Program Manager or the DOE ORNL Program Manager for Environmental and Life Science work. • The DOE ORNL Site Office individual that accepted notification for the occurrence report as a FR is not a FR and has not been adequately trained on reporting requirements.	
CC-16	Personnel knowledge and experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.	• Potassium permanganate's chemical properties prevent it from becoming concentrated over 8% under normal condition. The low concentration range makes it physically impossible for potassium permanganate to build up heat due to a violent exothermic reaction. • Training on the potential hazards from utilizing concentrated sodium permanganate was not performed. The difference in neutralization process due to concentration potential was not thoroughly discussed. • The MSDS clearly states that a concentrated permanganate solution must be diluted to 6% or less prior to neutralization. The mechanism and necessity to determine actual concentration was not adequately communicated to all personnel on site.	JON 2 JON 3 JON 4 JON 5 JON 7
CC-17	UT-Battelle failed to ensure ISM was established and maintained by its subcontractors.	• IT and its subcontractors did not have any training on ISM. • IT did not implement the five core functions and eight guiding principles of ISM during execution of the project.	JON 1 JON 6

Table 3-4: Causal Factors

No.	Root Causes	Discussion	Related Judgment of Need
RC 1	UT-Battelle, BJC, and IT management failed to analyze the hazards for all field activities. This failure resulted in inadequate development and implementation of control measures for and knowledge of the potential hazards.	Available up-to-date information and literature for the chemical hazards (i.e., incompatibilities and controls necessary when working with concentrated permanganate and thiosulfate) were not used. There was too much reliance on the skill of the craft and knowledge of individuals to understand the chemical hazards involved.	JON 3 JON 4
RC 2	UT-Battelle, BJC, IT, and the two IT subcontractors on-site project personnel failed to implement the hazard controls and requirements stated in the project documents.	Many documented requirements were never implemented in the field. The requirements for double containment for all lines carrying permanganate and certification of equipment were never implemented. In addition, the logbooks at the site documenting all HS-related data were not maintained.	JON 5
RC 3	DOE ORO, UT-Battelle, BJC, and IT management did not establish clear roles and responsibilities for the planning, execution, and oversight of the project.	The lack of clear roles and responsibilities for the project led to inadequate performance of responsibilities and HS oversight.	JON 1 JON 7 JON 8 JON 9 JON 10 JON 11
RC 4	DOE ORO, UT-Battelle, BJC, and IT management did not establish or ensure a safety culture that implements ISM and encourages personnel to stop and re-enter the analysis phase when a change or unexpected condition arises.	There was an overall failure of the ISMS. The ISM core functions and guiding principles were not fully implemented, which led to hazards not being properly analyzed. There were many opportunities for management and workers to stop work and re-enter the hazard identification and analysis phases when changes and unexpected conditions were encountered. In addition, numerous fundamental SH deficiencies were observed at the project site.	JON 1 JON 2 JON 6 JON 9 JON 10

4.0 Judgments of Need

Judgments of need are the managerial controls and safety measures determined by the Board to be necessary to prevent and/or minimize the probability or severity of a recurrence. They flow from the causal factors, which are derived from the facts and analysis. Judgments of Need are directed at providing guidance for managers during the development of corrective action plans.

Table 4-1. Judgments of Need

No.	Judgments of Need	Related Causal Factors
JON 1	BJC and UT-Battelle management need to ensure that unambiguous roles and responsibilities are established for every project from conception through field implementation.	• The roles and responsibilities for BJC, UT-Battelle, and IT were not clearly understood or executed. • Work control processes were inadequate. • There was no document control instituted for the project. • Compliance with basic HS requirements was not enforced on site. • The HASP, HASP Addendum, and AHA were not in compliance with the MSDSs. • Turnovers for roles specified in the HASP and HASP Addendum were not effective, nor were they documented by changes to the documentation. • UT-Battelle failed to ensure ISM was established and maintained by its subcontractors. • Field implementation of documented controls and assumptions was inadequate.
JON 2	BJC, UT-Battelle, and IT management need to ensure line management understands their responsibility for safety, including a safe work environment with personnel always being aware of the potential hazards and the freedom to call a time out for evaluation of an activity or situation that raises questions especially questions as to whether the event/activity has been properly addressed in the project documentation.	• The roles and responsibilities for BJC, UT-Battelle, and IT were not clearly understood or executed. • Lessons from previous incidents and other chemical accidents within DOE were not learned.

No.	Judgments of Need	Related Causal Factors
		• Management did not assure a safety culture where workers were willing to stop work and to re-enter the hazard identification and analysis phases when unexpected conditions were encountered. • Personnel knowledge and experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.
JON 3	BJC, UT-Battelle, and IT management need to ensure that all activities to be performed are identified and the appropriate SMEs perform a hazard analysis to determine potential hazards, resulting in the development and implementation of controls.	• The hazards associated with the chemicals on site and appropriate PPE were not adequately identified and analyzed. Proper controls were not developed and implemented. • Field implementation of documented controls and assumptions was inadequate. • The work planning and readiness review processes were inadequate. • The roles and responsibilities for BJC, UT-Battelle, and IT were not clearly understood or executed. • Lessons from previous incidents and other chemical accidents within DOE were not learned. • The HASP, HASP Addendum, and AHA were not in compliance with the MSDSs. • Personnel knowledge and experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.

No.	Judgments of Need	Related Causal Factors
JON 4	BJC needs to evaluate the adequacy of its readiness review process to ensure technical correctness, complete hazard identification and analysis, development and implementation of controls, and readiness on the part of field personnel and equipment to actually execute the activity/project are reviewed prior to granting permission to proceed.	• The hazards associated with the chemicals on site and appropriate PPE were not adequately identified and analyzed. Proper controls were not developed and implemented. • The work planning and readiness review processes were inadequate. • Field implementation of documented controls and assumptions was inadequate. • Lessons from previous incidents and other chemical accidents within DOE were not learned. • There was no document control instituted for the project. • Compliance with basic HS requirements was not enforced on site. • The HASP, HASP Addendum, and AHA were not in compliance with the MSDSs. • Personnel knowledge and experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.
JON 5	BJC, UT-Battelle, IT, and IT's subcontractors field personnel need to ensure complete implementation of all controls and requirements contained in project documents and that only activities with appropriately documented and approved hazard analysis are performed.	• Field implementation of documented controls and assumptions was inadequate. • Training on the hazards of the chemicals on site was not effective. • Work control processes were inadequate. • No document control was instituted for the project. • Compliance with basic HS requirements was not enforced on site.

No.	Judgments of Need	Related Causal Factors
		• The HASP, HASP Addendum, and AHA were not in compliance with the MSDSs. • Turnovers for roles specified in the HASP and HASP Addendum were not effective, nor were they documented by changes to the documentation. • Personnel knowledge and experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.
JON 6	UT-Battelle management needs to ensure that expectations for implementation of requirements, especially HS requirements, set forth in subtier contracts are properly communicated to and executed by field personnel.	• The roles and responsibilities for UT-Battelle, and IT were not clearly understood or executed. • The contracting process did not adequately implement ISM requirements. • UT-Battelle failed to ensure ISM was established and maintained by its subcontractors.
JON 7	DOE ORO, BJC, and UT-Battelle management need to ensure oversight of operations is instituted from design and development through actual field performance and delivery of the desired product.	• The work planning and readiness review processes were inadequate. • Field implementation of documented controls and assumptions was inadequate. • DOE ORO and the PORTS Site Office failed to establish unambiguous lines of authority and responsibility for HS at all organizational levels. • The roles and responsibilities for BJC, UT-Battelle and IT were not clearly understood or executed. • UT-Battelle and IT management did not assure a

No.	Judgments of Need	Related Causal Factors
		safety culture where workers were willing to stop work and to re-enter the hazard identification and analysis phases when unexpected conditions were encountered. • Compliance with basic HS requirements was not enforced on site. • Turnovers for roles specified in the HASP and HASP Addendum were not effective, nor were they documented by changes to the documentation. • Personnel knowledge and experience were with using potassium permanganate in lieu of sodium permanganate. Training was not adequate to inform personnel of the difference.
JON 8	DOE ORO line managers need to ensure an unambiguous DOE line of authority is established for all projects. Once the line of authority is established, clear oversight roles and responsibilities need to be in place and implemented.	• DOE ORO and the PORTS Site Office failed to establish unambiguous lines of authority and responsibility for HS at all organizational levels. • Communication between the various DOE organizations was not adequately performed. • The work planning and readiness review processes were inadequate. • The contracting process did not adequately implement ISM requirements. • Compliance with basic HS requirements was not enforced on site.
JON 9	DOE ORO line management needs to evaluate the addition of FR(s) and/or additional HS SMEs to the DOE PORTS Site Office.	• DOE ORO and the PORTS Site Office failed to establish unambiguous lines of authority and responsibility for HS at all organizational

No.	Judgments of Need	Related Causal Factors
		levels. • Communication between the various DOE organizations was not adequately performed.
JON 10	DOE ORO needs to ensure personnel performing FR responsibilities are adequately qualified.	• Communication between the various DOE organizations was not adequately performed.

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5.0 Board Signatures

Robert D. Dempsey
DOE Accident Investigation Board Chairperson
U.S. Department of Energy
Oak Ridge Operations

Date: 10/10/00

Jerry W. Robertson
DOE Accident Investigation Trained Board Member
U.S. Department of Energy
Oak Ridge Operations

Date: 10-10-00

Brenda Hawks
DOE Accident Investigation Board Member
U.S. Department of Energy
Oak Ridge Operations

Date: 10-10-00

Joe Enright
DOE Accident Investigation Board Member
U.S. Department of Energy
Oak Ridge Operations

Date: 10/10/00

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6.0 Board Members and Staff

Chairperson	Robert D. Dempsey, DOE ORO
Member	Brenda Hawks, DOE ORO
Member	Joe Enright, DOE WSSRAP
Member	Jerry Robertson, DOE ORO
Technical Editors	Patty Humphrey, DOE ORO Karen Brown, Informatics Corporation
Administrative Support	Melisa Hart, Critique, Inc. Patty Cates, Critique, Inc. Celeste Sharp, DOE ORO

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APPENDIX A
TYPE B INVESTIGATION BOARD APPOINTMENT MEMORANDUM

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DOE F 1325.8
(4/93)

United States Government — Department of Energy

Oak Ridge Operations Office

memorandum

DATE: August 23, 2000

REPLY TO ATTN OF: SE-32:Mullins

SUBJECT: **TYPE B INVESTIGATION - SUBCONTRACTOR EMPLOYEE CHEMICAL BURN INJURIES - PORTSMOUTH GASEOUS DIFFUSION PLANT, PORTSMOUTH, OHIO**

TO: Robert D. Dempsey, Deputy Assistant Manager, Office of the Assistant Manager for Environment, Safety, Health and Emergency Management (AMESH), SE-30

You are hereby appointed Chairman of the Investigation Board to investigate the August 22, 2000, chemical burn to an employee of IT Corporation, subcontractor to UT-Battelle, LLC, at the Portsmouth Gaseous Diffusion Plant. I have determined that the accident meets the requirements for a Type B Accident Investigation as required by DOE Order 225.1A, "Accident Investigations."

You are to perform a Type B investigation of this incident and to prepare an investigation report. The report shall conform to requirements detailed in DOE Order 225.1A and DOE G 225.1A-1, Implementation Guide for Use with DOE 225.1A, Accident Investigations. The Board will be comprised of the following members:

- Brenda Hawks, Nuclear Safety Programs Team Leader, Nuclear Safety Division, AMESH, ORO, Member
- Joseph R. Enright, Occupational Safety and Health Manager, Weldon Spring Site-Remedial Action Project, ORO, Member
- Jerry Robertson, Occupational Safety and Health Manager, Operations Division, AMESH, Trained Accident Investigator

The scope of the Board's investigation is to include, but is not limited to, identifying all relevant facts; analyzing the facts to determine the direct, contributing, and root causes 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, including oversight of subcontractors, 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 the Department.

If additional resources are required to assist you in completing this task, please let me know and it will be provided. Nancy Carnes has been appointed to serve as the Board's legal liaison. You and members of the Board are relieved of your other duties until this assignment is completed.

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

The final investigation report should be provided to me by September 25, 2000. Any delay to this date shall be justified and forwarded to this office. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report. If you have any questions, please contact me or Robert Poe at 576-0891.

G. Leah Dever
Manager

cc:
D. Michaels, EH-1, 7A-097, HQ/FORS
C. Huntoon, EM-1, 5A-014, HQ/FORS
R. Berube, EH-4, 7A-075, HQ/FORS
T. Rollo, EH-21, HQ/270CC
M. Johnson, SC-3, 7B-084, HQ/FORS
E. Cumesty, M-2, ORO
R. Folker, M-2, ORO
S. Wyatt, M-4, ORO
G. Benedict, UE-50, ORO
R. W. Poe, SE-30, ORO
M. McBride, SE-33, ORO
R. Nelson, EM-90, ORO
G. Malosh, LM-10, ORO
S. McCracken, EM-95, ORO
N. Carnes, CC-10, ORO
J. Fowler, CC-10, ORO
V. Adams, UE-54, PORTS

APPENDIX B
ANALYSIS

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Table B-1: Barrier Analysis

Barrier	Purpose	Analysis/Effect on Accident
PPE (Apron)	An apron covers the front of a person from the chest to below the knees and provides protection against splatters of hazardous substances.	The barrier failed because the proper PPE was not utilized. The apron would have reduced the severity or prevented the burns received by the victim.
PPE (Goggles and/or full face shield)	Goggles protect the eyes from splashing of chemical solutions. A face shield protects the face from splashing of chemical solutions.	The barrier failed because proper PPE was not utilized. Regular safety glasses with side shields were utilized, which protected the eyes. The use of goggles and full face shield would have prevented further burns on the face.
Hazard Analysis	A forward-looking identification and control of hazards throughout the life cycle of a project.	The barrier failed due to deficiencies in the USQD, HASP, and HASP Addendum, which did not properly analyze all of the hazards. Some of the controls identified in the MSDS, AHA, HASP, HASP Addendum, and USQD were not implemented. An adequate and fully implemented hazard analysis would have identified the necessary controls to prevent or mitigate the seriousness of the accident.
Procedures/Work Control Documents	Document control.	The barrier failed because documents were not formally approved and controlled. An adequate configuration control program would ensure documents were approved, maintained up to date, and controlled throughout the life of the project. This control would have increased the likelihood the documents would be updated to reflect actual field activities and potential hazards.
Training	To learn about the hazards related to their job, the means for protecting themselves, and how to perform particular tasks.	The barrier failed because the hazards and properties of the various chemicals were not understood. Personnel were not trained on the hazards associated with the tasks being performed. The lack of adequate training reduced personnel awareness to potential hazards, resulting in unsafe activities.
Oversight	To ensure worker protection by compliance with DOE directives and National Consensus Standards.	The barrier failed because DOE and contractor surveillance failed to identify problems at the work site. Adequate oversight would have identified HS deficiencies on the site.

Table B-1: Barrier Analysis

Barrier	Purpose	Analysis/Effect on Accident
Certified Engineered Equipment	Credibility of equipment to operate as designed.	The barrier failed because all equipment supplied did not include certification for the activity. The HASP states that all custom modification to equipment is strictly prohibited unless authorized in writing by the original equipment manufacturer or certified as safe by a registered professional engineer. This was not completed. The numerous leaks in and around the rods, resulting in modification of the equipment, contributed to unnecessary exposure to permanganate.
Readiness Review	Ensure objectives are well established, procedures and personnel are ready to implement the scope of work, and programmatic objectives are accomplished prior to initiation of field activities.	The barrier failed because the BJC SORC readiness review team failed to ensure HS and programmatic objectives were implemented prior to initiation of field activities. An adequate readiness review would have ensured the controls to safely perform the work were fully implemented.
Roles and Responsibilities	Provide clear roles and responsibilities.	The barrier failed because no one took overall responsibility for HS. Clear roles and responsibilities provide for adequate accountability, assuring that proper assessments and oversight are performed.
Effective Equipment	Identify the hazards and appropriate engineered controls.	The barrier failed because modifications in the field to the equipment were not communicated, and they prevented engineering controls from being implemented. Proper engineering controls would have reduced the collection of permanganate solution.
Daily Tailgate Safety Meeting	To discuss significant changes in the scope of work on the site, potential hazards, and activities to be performed that day and to provide specific job assignments.	The barrier failed because daily tailgate meetings did not address specific job assignments for the day or adequately address the potential hazards of permanganate neutralization and appropriate PPE for work activities. Proper communication during tailgate sessions provides needed information to control work and implement protective measures for work activities.
Secondary containment for containers, hoses, and pipes containing or transporting permanganate	To prevent sprays, spills, and leaks.	The barrier failed because secondary containment was not provided. Secondary containment provides containment of spray, spills, and leaks, thereby reducing the potential for exposure.

Table B-2: Change Analysis

Normal "Ideal"	Actual	Analysis
Workers are adequately trained to the hazards of the chemicals and OSHA hazard communication requirements.	Not all workers understood the hazards associated with the various chemicals on site and their reactions, and they allowed many OSHA noncompliant conditions to exist on site.	OSHA hazard communication requires employees be trained and understand the hazards of workplace chemicals and basic safety requirements. This training would have heightened personnel awareness to potential hazards and reduced acceptance of noncompliant conditions.
ES&H reviews are performed by DOE and contractor oversight groups to ensure HS of workers.	An adequate ES&H review was not conducted on site.	Adequate reviews would have identified HS deficiencies and the lack of hazard analysis for all activities. Proper oversight would have identified HS problems and achieved resolution.
Hazard analysis is performed on all work using up-to-date technical information.	Hazard analysis did not evaluate the different properties of the various chemicals located at the site with up-to-date technical information.	Understanding the neutralization reaction and chemical concentrations was necessary to safely perform the work.
Adequate turnover between changing staff to communicate changes in design, operations, and procedures.	Inadequate communication between changing staff occurred.	Hazards were introduced when changes in design, operations, and procedures were not effectively communicated.
The BJC HS Advocate assigned to project performed duties in accordance with EH-5614, *Safety Advocate Program*.	Procedure were not followed, and HS deficiencies remained.	Adherence to the procedure might have identified HS deficiencies.
Employees are encouraged to approach all work with a high degree of inquisitiveness (i.e., Stop Work Authority/Time Out for Evaluation).	Work continued after numerous problems with the equipment and leaks of permanganate. Employees became desensitized to the hazards that were present.	Failure to analyze and control hazards due to changing work conditions.
BJC STR assigned to project executed duties in accordance with BJC-FS-01, *STR Requirements for Subcontract Execution.*	The procedure for subcontract execution was not followed.	The STR did not follow requirements required by the procedure. Adherence to the procedure would have increased the formality and rigor of oversight.

Table B-2: Change Analysis

Normal "Ideal"	Actual	Analysis
Documenting all HS-related data in the logbooks per the HASP.	The documentation on deficiencies and hazards was not documented in the logbook.	Personnel were not aware of all safety deficiencies, and decisions on control were not communicated to everyone on site. Making personnel aware of safety deficiencies reduces the likelihood of accidents.
Conduct effective daily tailgate safety meetings discussing significant changes in the scope of work, specific job assignments, and potential hazards on site.	Tailgate safety meetings were conducted, but they were not effective.	Discussions on the changes to the scope of work, changes to specific work assignments, and implementation of appropriate PPE related to the hazards were not effective. Proper daily tailgate meetings would have reduced the likelihood of personnel performing work outside that assigned and without proper PPE protection.
Neutralize sodium permanganate safely.	Bisulfite and thiosulfate were used interchangeably to neutralize permanganate.	Concentrated permanganate reacts violently with thiosulfate. Knowledge of neutralization reaction would have decreased the likelihood of the accident.
Always assume the permanganate solution is concentrated until actual measurements are performed to verify the dilution.	Assumed permanganate solution was dilute without taking measurements to verify concentration.	If a measurement to determine permanganate concentration was performed, neutralization of concentrated permanganate utilizing the dilute process would not have occurred.

APPENDIX C
HEALTH AND SAFETY PLAN

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Table C-1: HASP - Key Project Personnel and Responsibilities

- BJC PM - responsible for the day-to-day operation and activities for the project.
- BJC STR - coordinates all field activities with the UT-Battelle PM and BJC PM. Ensures that all work is done in compliance with BJC requirements.
- BJC Health Physics Manager - responsible for the day-to-day health physics operations and activities at PORTS. The BJC Health Physics Manager will coordinate and assign Radiation Control Technicians and related project support as needed.
- BJC HS Manager - is responsible for the day-to-day HS operations and activities at PORTS. The BJC HS Manager coordinates and assigns related project support as needed.
- BJC HS Advocate - with the STR, coordinates all HS needs between the BJC HS organization and project personnel.
- UT-Battelle PM - coordinates field activities with the UT-Battelle field team and subcontractors and is responsible for all operations and activities pertaining to the project.
- UT-Battelle Project HSO - reports all activities to the UT-Battelle PM. The HASP states that an experienced HSO, who is acceptable as qualified by UT-Battelle and BJC, will be present at an active job site at all times. The specific responsibilities include the following:
  (1) implementing the HASP on the work site, ensuring that each person at the site understands and signs off on the HASP prior to working, and noting any deviations to the BJC HS Advocate;
  (2) conducting project safety meetings, pre-entry briefings, and daily tailgate safety meetings, documenting all subjects and personnel attendance prior to initiation of work each day and when there are significant changes in the scope of work on the site; and documenting all HS-related data in the HS logbook;
  (3) conducting any required monitoring as designated by the HASP and performing periodic inspections to evaluate the HASP's effectiveness;
  (4) conducting audits to ensure compliance with all HS procedures and providing documentation in the HSO's logbook;
  (5) performing a functional check at least once per day (more often if ambient weather conditions change or other conditions necessitate the need as perceived by the HSO) of any monitoring equipment and recording the results on the daily instrument calibration log;
  (6) ensuring that all nonradiological monitoring equipment is calibrated and operating correctly according to the UT-Battelle HS procedures manual (ORNL 1992) and/or the manufacturer's instructions;
  (7) assisting personnel with completion of action-level incident response or accident forms if needed;
  (8) ensuring that an HS work permit has been issued by BJC through the STR prior to the start of on-site activities;
  (9) ensuring that no equipment will be operated any closer than 20 feet from electrical transmission lines;
  (10) notifying the STR of personnel at the work site at the beginning of the day and the location of work activities; and
  (11) ensuring that sanitation requirements of OSHA 1926.51 are adhered to on the project.

  The HASP goes on to state the HSO will have first aid and cardiopulmonary resuscitation certification and will take all necessary measures required by law when providing medical assistance to injured personnel. A physician-approved and portable first aid kit will be kept immediately available and regularly inspected. A UT-Battelle HSO will be provided for the lance permeation and ISCOR deployment.

Table C-2: HASP Addendum - IT Personnel Responsibilities

- Technical Advisor **-** provides technical input into design and implementation; advises on potential for worker exposure to project hazards along with appropriate methods and/or controls to eliminate site hazards; facilitates reporting of injuries, reviews injury reports, and provides the appropriate level of guidance in accident prevention.
- PM **-** reports to upper-level management and has overall responsibility for safety in preventing and protecting against all hazards during site activities. Ten specific responsibilities of the IT PM, in conjunction with the UT-Battelle and BJC PMs, are stated.
- SSHS or Designee **-** has the ultimate responsibility to stop operations when a hazard exists that may threaten the safety and health of the field team or surrounding population or that causes adverse impact to the environment. Thirteen specific responsibilities are stated, which include maintaining effective site-specific HASP procedures for the project; implementing all safety procedures and operations on site; upgrading or downgrading the levels of PPE based upon site observations; having responsibility for HS monitoring equipment on site; and maintaining a daily safety log of all site activities.
- Field Team Leader **-** is the subcontractor site supervisor. Nine specific responsibilities are stated, which include assuring and enforcing compliance with the site-specific HASP and enforcing the "buddy system" on site.
- SHSO **-** assigned on a full-time basis to each site during site activities. Assists and represents the HS Representative. The SHSO has the responsibility and authority to implement and enforce the approved site-specific HASP, including modifying/halting work and removing personnel from the site if work conditions change and impact on-site/off-site HS matters. The SHSO serves as the main contact for any on-site emergency situation. The SHSO advises the PM on all aspects of HS on the site.

Table C-3: HASP Requirement Compliance

A HASP is required by EPA and OSHA, 29 CFR 1926.65, for all hazardous waste operations. The Lance Permeation Project at X-701B is characterized as a hazardous waste operation. On July 19, 2000, the BJC SORC Chairperson gave permission to proceed for the X-701B Lance Permeation Phase of the UT-Battelle project based on the readiness review performed on June 29, 2000.

29 CFR 1926.65 Requirement	Project Compliance
Organization Structure (Must establish the specific chain of command and specify the overall responsibilities of supervisors and employees. The organizational structure shall be reviewed and updated as necessary to reflect the current status of waste site operations.)	• The July 1999 HASP does not contain an organizational structure; however, Section 2 provides a list of key project personnel and responsibilities. The information provided is satisfactory to meet the requirements for oversight on the stated project. However, the Board determined that BJC personnel did not execute the responsibilities assigned in accordance with site procedures. The UT-Battelle Project HSO on site at the time of the accident did not execute his responsibilities as stated in this HASP. Changes to key personnel were not documented in the HASP to ensure that the current status was reflected. The key personnel list was not even correct at the start of the project. This is a noncompliance with requirements. • The June 2000 HASP Addendum provides IT's project personnel and responsibilities. In general, the text meets the requirement for a documented organization structure. However, the "Site Health and Safety Organization Chart" was not completed with the actual names of the individuals assigned to the stated responsibilities. Additionally, the HASP Addendum was not updated to reflect changes in assignments during the project. This is a noncompliance with requirements.

Table C-3: HASP Requirement Compliance

29 CFR 1926.65 Requirement	Project Compliance
Comprehensive Work Plan (Shall address the tasks and objectives of the site operations and the logistics and resources required to reach those tasks and objectives.)	• The HASP, combined with the HASP Addendum, contains satisfactory information regarding the objectives of the project. The HASP and HASP Addendum do NOT contain satisfactory information concerning the objectives and methods for accomplishing those tasks. The task of handling the permanganate returning up the drill rig is not identified; therefore, no method for handling is stated. The only process described for neutralization of permanganate is in Section 11.3, "Spill Response." The documents did not address permanganate neutralization from either ground fissures during injection process or permanganate solution collected from rod return and/or previous bore holes. • The AHA was prepared to address the potential hazards for the operation. This document was attached to the HASP Addendum as required information. The AHA did not identify all the potential hazards present at the job site, nor were all the tasks identified. The only neutralization process stated in documentation is for a concentrated spill. • The above statements demonstrate inadequate Comprehensive Work Plan requirements in the areas of specific task definition and methods for accomplishment. Satisfactory compliance with project objectives is not demonstrated in these documents.
Site-Specific HASP (The site HASP must be kept on site. The plan shall address the each phase of site operation and include the requirements and procedures for employee protection.)	• The HASP, HASP Addendum, and AHA were on site. However, the HASP Addendum on site was dated May 2000, whereas the HASP Addendum reviewed by the BJC SORC readiness review team for permission to proceed was dated June 2000. It was noted by the Board that pages 8 and 11 were dated "Final June 15, 2000," and all other pages were dated "May 2000." • General personnel HS hazards are addressed in these documents. • As stated above, all phases of site operations are not contained in the documents.
HS Training Program (All personnel on site shall receive training prior to engaging in hazardous waste operations. Personnel must be trained to the level required by their job function and responsibility.)	• Based on a cursory review of training records and interviews, the Board did not find any deficiencies in formal training requirements for personnel on site. • Daily tailgate meetings were conducted and discussed general HS requirements. • The Board concludes the specific hazards associated with ability of sodium permanganate to be concentrated above 10% was not adequately understood and communicated to personnel on site. Personnel on site were familiar with potassium

Table C-3: HASP Requirement Compliance

29 CFR 1926.65 Requirement	Project Compliance
	permanganate, which at ambient temperature does not exist in solution form at or above 8%. The Board concludes that adequate training/knowledge of the potential hazards associated with concentrated sodium permanganate was not provided. • BJC HS Advocate performed a safety briefing to all individuals on site July 18, 2000. The briefing was satisfactory to provide basic safety requirements and emergency response for the site. However, personnel reporting to the site for changeover of personnel did not receive this safety briefing. The Board concludes the lack of a safety briefing for later reporting personnel demonstrates a weakness in ISM core function 5, Feedback and Continuous Improvement.
Medical Surveillance Program (A medical surveillance program is required by the employer.)	• All employers reviewed have a medical monitoring program. Based on the cursory review of medical monitoring records and interviews, the Board concludes that a medical surveillance program(s) was in place for personnel performing operations.
Standard Operating Procedures for Safety and Health.	• The HASP and HASP Addendum state that safety precautions to be followed are outlined in the *ORNL Health and Safety Procedures Manual*, Sections 8.6 and Section 13 (ORNL 1992). The *ORNL Health and Safety Procedures Manual* was not on site. • No training or instruction on the *ORNL Health and Safety Procedures Manual* was provided to the subcontractors for the project. • The Board concludes the requirement for standard operating procedures for HS was not satisfactory implemented on site.
Any Necessary Interface Between General Program and Site-Specific Activities	• General program personnel include the UT-Battelle PM; BJC HS Manager; BJC PM; UT-Battelle Technical Director; BJC STR; IT Technical Advisor; IT PM; and IT HS Representative. The necessary interfaces between these organizations was not clearly defined in either the HASP or the HASP Addendum. • The HASP Addendum provides an organizational chart; however, the chart neither contains all the needed positions nor provides names for all of the identified positions. • Neither the HASP nor the HASP Addendum adequately discusses the interface between organizations. Roles and responsibilities were not clearly defined.

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APPENDIX D
SODIUM PERMANGANATE, SODIUM THIOSULFATE, AND SODIUM METABISULFITE PROPERTIES, HAZARDS, AND HANDLING

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Table D-1: Sodium Permanganate (Permanganate), Sodium Thiosulfate (Thiosulfate), and Sodium Metabisulfite (Bisulfite) Properties, Hazards, and Handling

Forty percent sodium permanganate ($NaMnO_4$), referred to as permanganate, is a powerful oxidizing material used to oxidize hallogenated organic compounds (i.e., TCE). Under normal conditions, the material is stable. However, it may decompose spontaneously if exposed to intense heat (135^0C/275^0F) and may be explosive in contact with certain incompatible chemicals. It may react violently with divided and readily oxidizable substances. As an oxidant, permanganate is noncombustible, but it will accelerate the burning of combustible materials (including but not limited to wood, cloth, organic chemicals, and charcoal). Therefore, contact with all combustible materials and/or chemicals must be avoided. The product should be stored in a cool, dry area in closed containers, and storing on wooden decks should be avoided. Permanganate is incompatible with acids, peroxides, and all combustible organic or readily oxidizable materials, including inorganic oxidizable materials and metal powders. Mixture with hydrochloric acid liberates chlorine gas. Also, in a fire situation, permanganate may form corrosive fumes. Acute overexposure can be irritating to body tissue if contact occurs. Permanganate solution will cause further irritation of tissue, open wounds, burns, or mucous membranes.

Spills of permanganate should be collected and diluted to approximately 6% with water. After dilution, reduce with sodium thiosulfate, bisulfite, or ferrous salt. The bisulfite or ferrous salt may require some dilute sulfuric acid (10 wt percent) to promote reduction. If an acid is utilized, the solution should be neutralized with sodium bicarbonate to neutral pH. Sludge should be decanted/filtered and disposed of at an approved landfill. Where permitted, the solution may be drained into a sewer with large quantities of water. The PPE recommended in the manufacturer's chemical fact sheet during handling includes face shields and/or goggles, rubber or plastic gloves, and a rubber or plastic apron. An eyewash station should be provided in the work area, and engineering or administrative controls should be implemented to control mist. If clothing becomes contaminated, it should be washed off immediately. In addition, spontaneous ignition may occur in contact with cloth or paper.

Sodium thiosulfate ($Na_2S_2O_3$), referred to as thiosulfate, is used to neutralize permanganate. Under normal conditions, the material is stable. This material is to be stored in a tightly closed container in a cool, dry, ventilated area. Burning may produce sulfur oxides. Thiosulfate is incompatible with metal nitrates, sodium nitrates, iodine, acids, lead, mercury, and silver salts. If this material is swallowed or inhaled, it may cause irritation to skin, eyes, and the respiratory tract. Low level of toxicity is possible with ingestion. In addition, irritation may occur from skin contact and contact with the eyes. The manufacturer's MSDS recommendations for PPE are protective gloves , body-covering clothing, and safety glasses. It is also recommended that an eyewash fountain and quick-drench facilities be maintained in the work area. In case of a spill, the material should be swept up and containerized for reclamation or disposal. Vacuuming or wet sweeping may be used to avoid dust dispersal.

Sodium metabisulfite anhydrous 97% ($Na_2S_2O_5$), referred to as bisulfite, is used to neutralize permanganate. Under normal conditions the material is stable, but it may decompose if heated.

This material is to be stored in a tightly closed container in a cool, dry, well-ventilated area away from incompatible substances. Incompatible materials include strong oxidizers and acids. This material may produce sulfur dioxide gas when in contact with acids and/or water (ice). Conditions to avoid are dust generation, moisture, exposure to air, excess heat, and oxidizers. Hazardous decomposition products include oxides of sulfur and toxic fumes of sodium oxide. Potential health effects are as follows: (1) eye - irritation; (2) skin - irritation, may cause skin sensitization, an allergic reaction, which becomes evident upon re-exposure; (3) ingestion - gastrointestinal irritation, exposure may cause central nervous system depression, gastrointestinal and cardiac abnormalities, and violent colic; and (4) chronic exposure - prolonged or repeated skin contact may cause dermatitis, reproductive effects have been reported in animals, and repeated and prolonged exposure may cause allergic reactions in sensitive individuals. The manufacturer's MSDS recommendations for PPE are protective eyeglasses or chemical safety goggles, appropriate protective gloves to prevent skin exposure, and protective clothing to prevent skin exposure. The MSDS states storage facilities should be equipped with an eyewash facility and a safety shower. The manufacturer's MSDS states to flush eyes with plenty of water for at least 15 minutes and to immediately flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. It further goes on to state to get medical aid immediately. In the case of a spill, sweep up the material and place it in a suitable container for disposal, avoiding dust generation and ensuring that proper ventilation is provided. There is a caution to make sure that no water gets inside the container.