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 (100°C/212°F). 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.

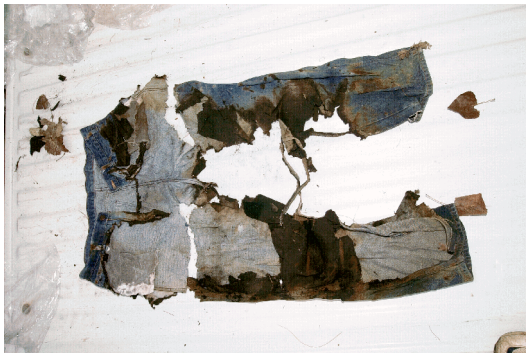

Exhibit 3-2. Cotton Pants Worn by IT Laborer

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 255-400°C/490-750°F. The normal ignition temperature for polyester is 450-560°C/840-1040°F. 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

Core Function 3
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

Guiding Principle 3

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.

Guiding Principle 4

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.

Guiding Principle 5

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

Guiding Principle 6

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.

Guiding Principle 7

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.

Guiding Principle 8

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