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.

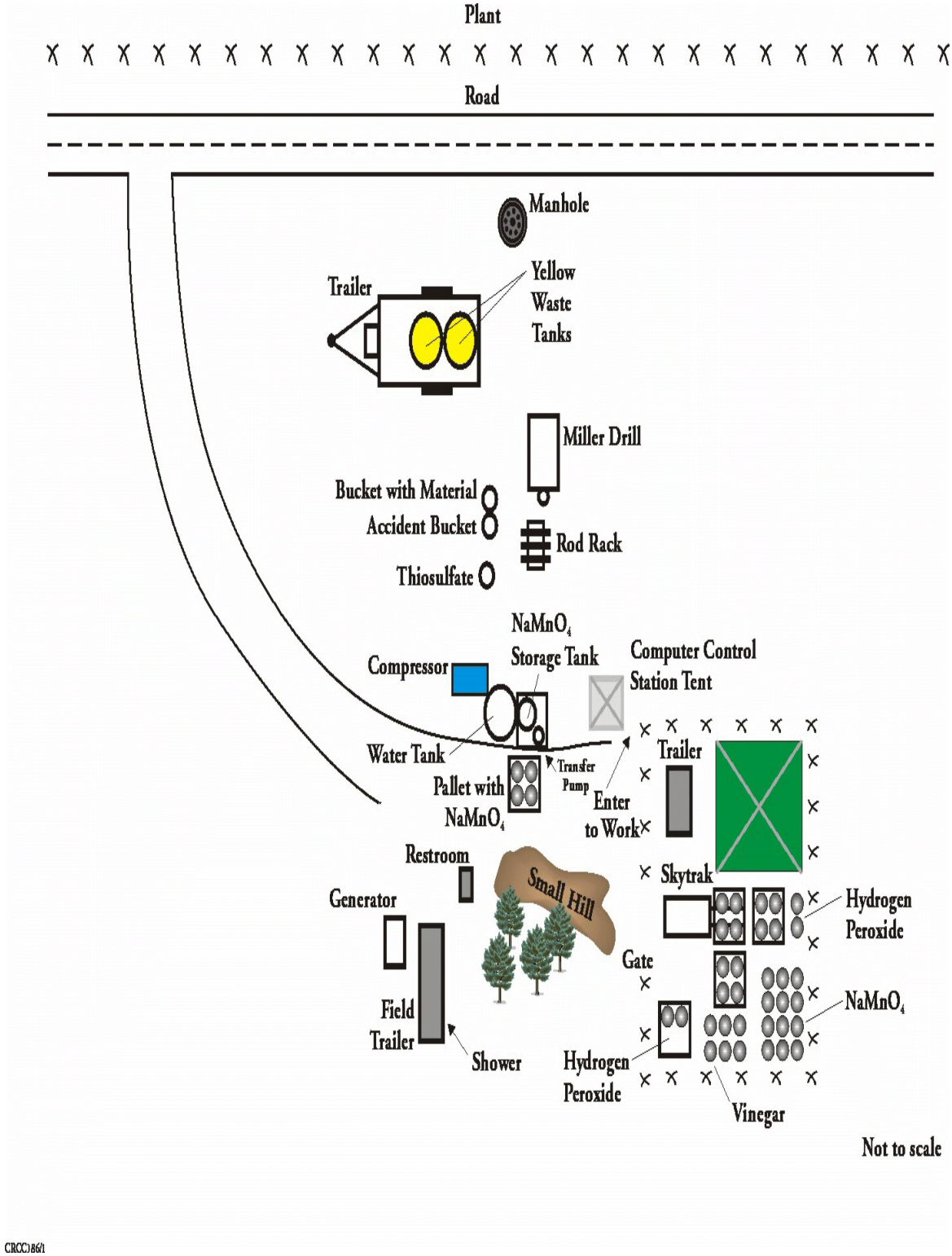
The DOE ORO EM Program Manager for this project did not coordinate the request for a UT-Battelle subcontract with the DOE UT-Battelle Contracting Officer's Representative (COR).

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.



CRCC)86/1

Figure 2-1. Project Site Layout

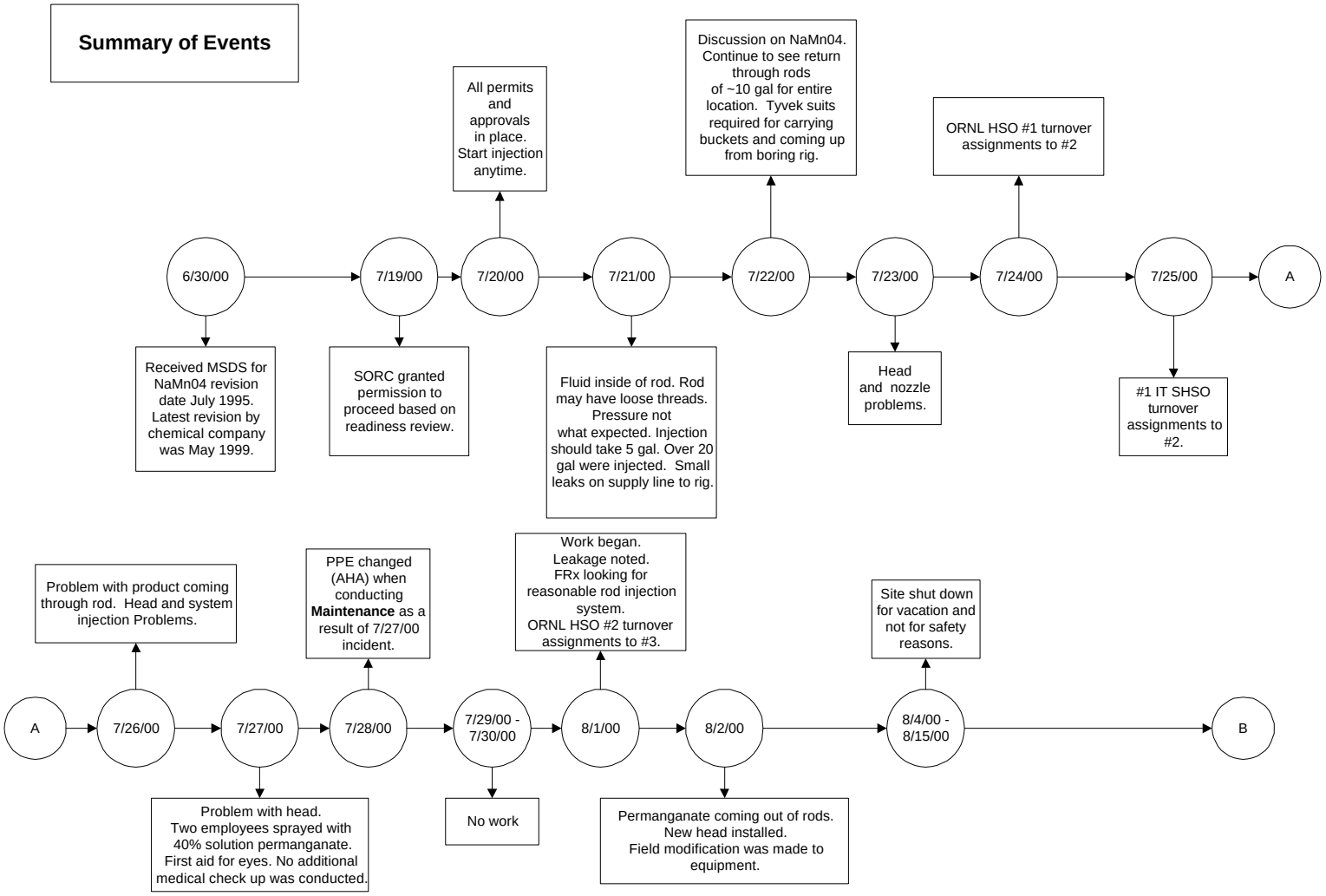
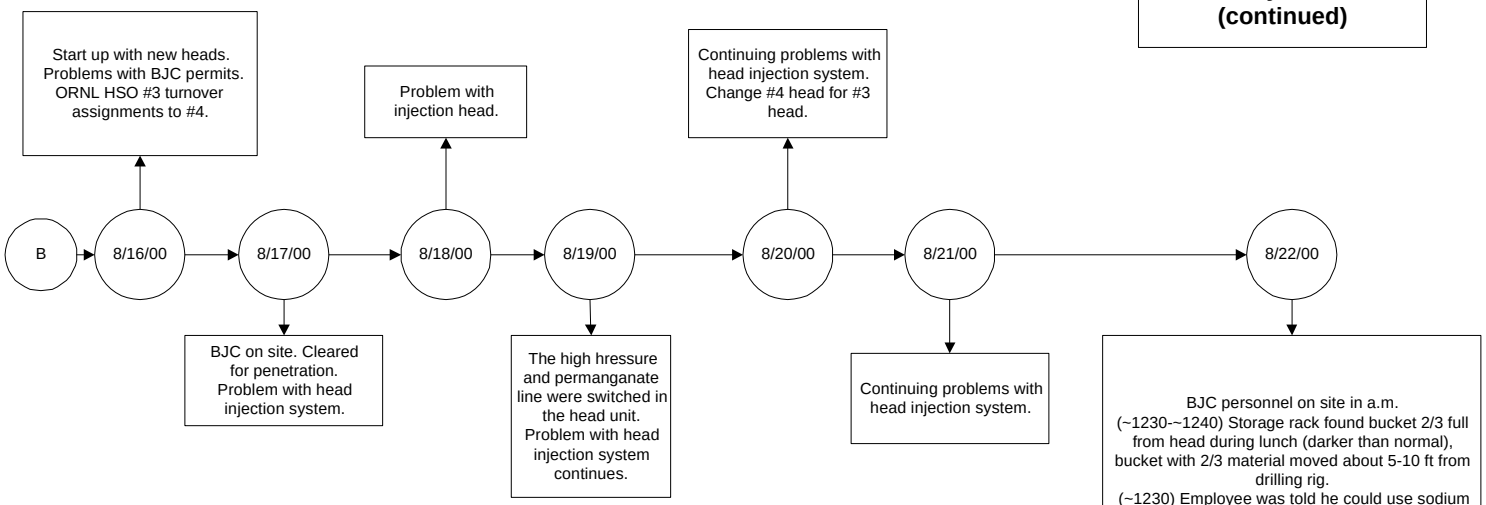


Figure 2-2. Time Line

Summary of Events (continued)



BJC personnel on site in a.m.
(~1230-~1240) Storage rack found bucket 2/3 full from head during lunch (darker than normal), bucket with 2/3 material moved about 5-10 ft from drilling rig.
(~1230) Employee was told he could use sodium thiosulfate.
to put in next tank in place of bisulfate for neutralization.
(~1245) Board concluded the employee placed sodium thiosulfate into bucket of concentrated permanganate.
(~1245) Accident occurs.
(~1246) Injured employee sprayed with water.
(1252) Call 911 from personal cellular phone
(1300) BJC Safety Advocate notified.
(1310) PORTS IC on scene.
(1315) First EMS vehicle arrived.
(1317) PORTS IC requested helicopter.
(1339) Helicopter Life Flight on scene.
(1346) Medflight in air to OSU.
(1403) PORTS IC grants all clear.

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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