DOE/ID-10968

TYPE B ACCIDENT INVESTIGATION BOARD REPORT

GROUT INJECTION OPERATOR INJURY AT THE COLD TEST PIT SOUTH, IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, OCTOBER 15, 2001

IDAHO OPERATIONS OFFICE

November 2001

On October 16, 2001, I appointed a Type B Accident Investigation Board to investigate the October 15, 2001, Grout Injection Operator Injury at the Cold Test Pit South, Idaho National Engineering and Environmental Laboratory. The Board's responsibilities have been completed with respect to this investigation. The analysis, identification of contributing and root causes, and Judgments of Need reached during the investigation were performed in accordance with DOE Order 225.1A, *Accident Investigations.*

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

Mark W. Frei
Acting Manager
Idaho Operations Office

11/13/01
Date

This report is an independent product of the Type B Accident Investigation Board appointed by Mark W. Frei, Acting Manager, Idaho Operations Office, U. S. Department of Energy.

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

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

This report neither determines nor implies liability.

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TYPE B ACCIDENT INVESTIGATION BOARD REPORT: GROUT INJECTION OPERATOR INJURY AT THE COLD TEST PIT SOUTH, IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, OCTOBER 15, 2001.

EXECUTIVE SUMMARY

The Accident

On October 15, 2001, at approximately 10:32 a.m., a subcontractor operator of a grout injection rig received serious head injuries and required hospitalization when he was struck by flying debris from a failed fitting assembly. The board concluded that the direct cause of the accident was a failure of a 45° swivel elbow that was underrated for the system in which it was used. The rated working pressure for the 45° swivel elbow was 3,000 psi and the high-pressure grouting operation had a normal working pressure of 6,000 psi.

Background

The work being performed at the time of the accident was part of an in situ grouting treatability study being conducted at the Cold Test Pit South (CTPS) near the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL). CTPS is a simulated waste pit area used to demonstrate characterization, retrieval and treatment technologies that may prove useful for the remediation of buried hazardous and radioactive waste. The RWMC and CTPS operate under the programmatic direction of the DOE Office of Environmental Management and oversight by the DOE Idaho Operations Office. Bechtel BWXT, Idaho, LLC (BBWI) manages and operates the INEEL site for DOE.

The injured operator was an employee of a service subcontractor, Applied Geotechnical Engineering and Construction, Incorporated (AGEC) of Richland, Washington. AGEC's subcontract with BBWI included activities associated with high pressure in situ grouting operations at the CTPS. AGEC arrived at the site on October 8, 2001, and in situ grouting began on October 11. Holes were grouted in sequence on October 11 and 12, prior to stopping for the weekend. After some repairs and modifications to the high pressure grouting system were made on Monday morning, October 15, including the replacement of the 45° swivel elbow, drilling and grouting operations resumed on hole #14. A short time later, at approximately 10:32 a.m., the accident occurred.

Results and Analysis

There were a number of deficiencies in the work control process and management systems for this project that resulted in the accident. Table ES-1 summarizes the analysis performed by the Board by listing the contributing and root causes of the accident and the resultant judgments of need.

Conclusions

The Accident Investigation Board concluded that the accident was preventable. Significant weaknesses were identified in the implementation of integrated safety management for this subcontracted activity. Some of those weaknesses included failure by the subcontractor to follow the ESH&QA subcontract requirements, failure by BBWI to adequately enforce the subcontract requirements, and failure by DOE-Idaho to provide effective oversight of this

project. There have been several related events involving subcontractors at the INEEL over the past two years, and other events across the DOE complex that suggest an ineffective application of corrective actions and lessons learned from subcontractor events. BBWI and DOE-Idaho need to strengthen their efforts to ensure that the tenets of integrated safety management are understood, practiced, and enforced for subcontracts being performed at the INEEL to prevent an event like this from recurring.

Table ES-1
Judgments Of Need

Root and Contributing Causes	Judgments of Need
AGEC failed to follow and BBWI did not adequately enforce subcontract requirements. (Root Cause)	Prior to continued use of the AGEC High Pressure Grouting System at the INEEL, BBWI needs to develop acceptance criteria, perform an Engineering and Quality Assurance evaluation and develop and implement all corrective actions to ensure safe operation. BBWI needs to ensure that ESH&QA requirements of subcontracts are effectively implemented and enforced. AGEC needs to improve their feedback and quality improvement processes to correct operational deficiencies.
DOE did not develop implementation guidance regarding "Pressure Systems" requirements contained in DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*. (Contributing Cause)	DOE-EH needs to develop guidance for pressure safety programs beyond those for pressure vessels. DOE-ID needs to provide guidance to BBWI for the development of a comprehensive pressure safety program.
Interface among appropriate DOE-ID organizations (e.g., OSD, WMOD, and ERD) was inadequate to ensure effective oversight of ER activities. (Contributing Cause)	DOE-ID needs to formalize a process to integrate Operations, Programs, and Support Functions to improve planning, execution, and oversight of ER activities.
DOE-ID Oversight of this project was inadequate to ensure: • BBWI enforced terms and conditions of the sub-contract, and • BBWI ER work was planned and executed safely. (Contributing Cause)	DOE-ID needs to improve oversight of BBWI to ensure ER work is planned and executed in accordance with established ESH&QA requirements.
BBWI's process for ensuring implementation of ISM by subcontractors was inadequate to ensure worker safety. (Contributing Cause)	BBWI needs to improve VPP/ISMS Evaluation Criteria used during the Subcontractor Evaluation Process to ensure subcontractors have adequate VPP/ISMS program documentation. BBWI needs to improve subcontractor oversight processes to ensure ISMS implementation.
BBWI failed to follow and implement the ER QAP for the In Situ Grouting Treatability Study. (Contributing Cause)	BBWI needs to define Quality Acceptance Criteria in this subcontract. BBWI needs to fully implement the ER QAP.

Judgments Of Need

Root and Contributing Causes	Judgments of Need
BBWI's work control process failed to adequately identify hazards and controls for high pressure systems. (Contributing Cause)	BBWI needs to evaluate and modify company work control processes (STD-101, MCP-3562, and MCP-3571) to ensure high pressure systems are adequately analyzed for hazards and controls.
BBWI feedback and improvement mechanisms were ineffective in identifying deficiencies, precursor events and opportunities for improvement for incorporation into the work planning and execution processes. (Contributing Cause)	BBWI needs to integrate subcontractors into BBWI's Lessons Learned Management System and ensure lessons learned are used to plan work. BBWI senior management needs to ensure that corrective actions in response to DOE-identified ISMS and subcontractor safety deficiencies are effective to prevent recurrence.
The BBWI Management Assessment process was "expert-based" and did not identify QA and ISM deficiencies. (Contributing Cause)	BBWI needs to establish requirements for performing management assessments for operational readiness.

1. INTRODUCTION

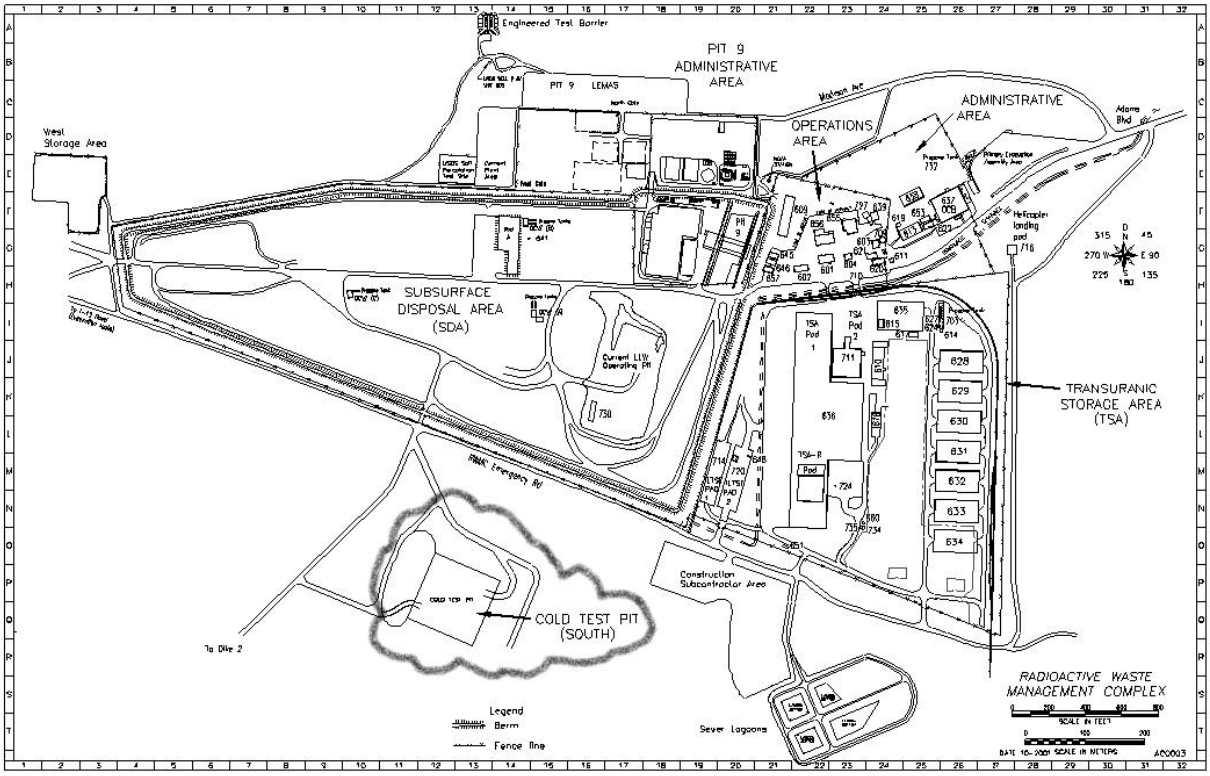
1.1. Background

On the morning of October 15, 2001, approximately 10:32 a.m., an operator of a grout injection rig received serious head injuries that required hospitalization when he was struck by flying debris from a fitting assembly that failed under pressure. Immediate first aid and assistance was provided by nearby workers. Emergency Medical Services (EMS) personnel were immediately summoned, and arrived on scene in about 18 minutes. EMS stabilized the patient and transported him to Eastern Idaho Regional Medical Center (EIRMC) where surgery was required to treat the head wound, which included injury to the right eye. A second surgery was required the following day. The operator was released from EIRMC on October 17, 2001.

On October 16, 2001, the Acting Manager, DOE-ID appointed a Type B Accident Investigation Board to investigate this accident in accordance with the requirements of DOE Order 225.1A, Accident Investigation (Appendix A).

1.2. Facility Description

The INEEL is located on 891 square miles of desert in a rural, sparsely populated area of southeastern Idaho. The INEEL is a multi-program laboratory whose mission is to integrate engineering and applied science to solve problems relating to environmental management, waste disposition, nuclear technology and application and national security.



RWMC with Cold Test Pit South

The CTPS was established in the mid-to late-1980's and has been used for many treatability studies. The area is located 200 yards south of the RWMC fenced boundary (see figure on previous page). Drums, waste boxes, and other containers of simulated waste are buried in the pit. Some containers from past studies remain buried there. A majority of the CTPS is open ground and covers approximately 10 acres. Support trailers, a wood storage shed and a soft-sided tent (yurt) are located at CTPS.

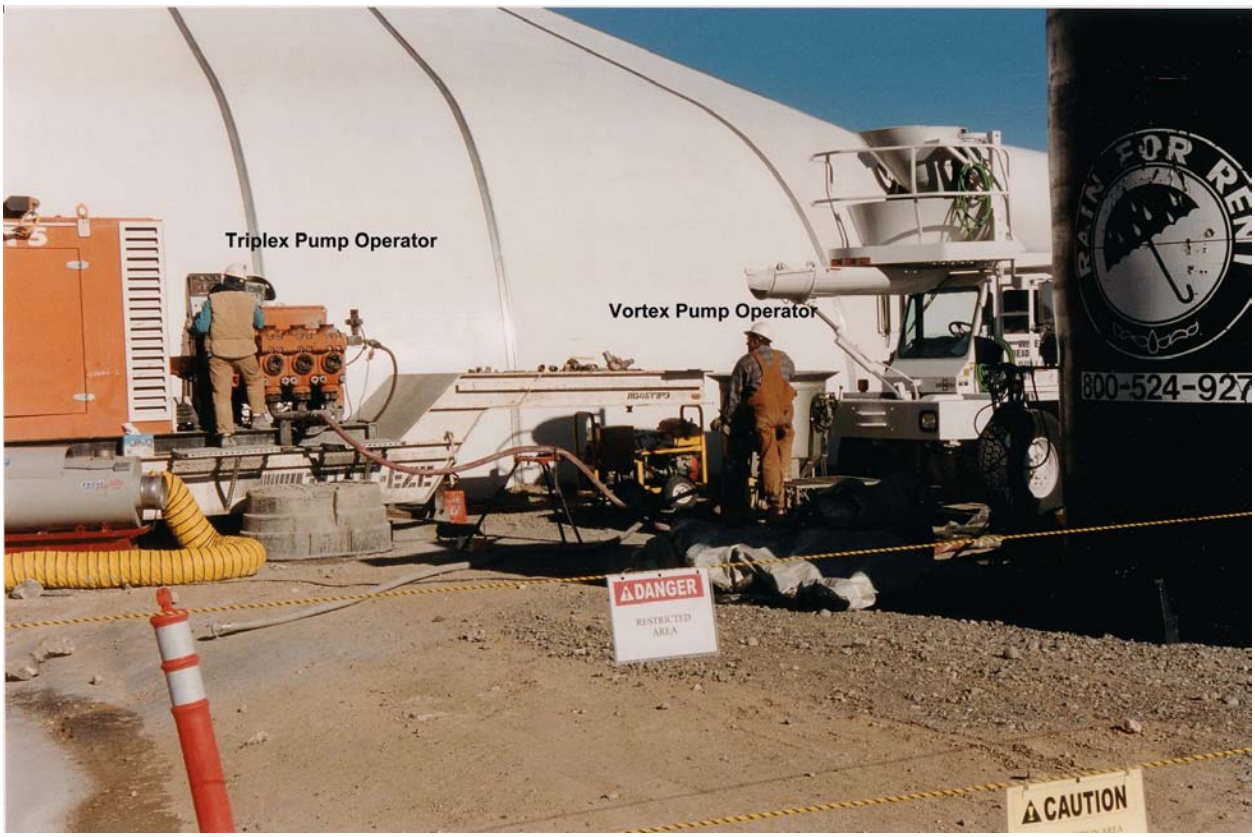
CTPS is used to demonstrate characterization, retrieval and treatment technologies that may prove useful for the remediation of buried waste. The simulated waste pit provides known targets and waste forms for accurate evaluation and calibration procedures, technologies, and equipment testing. The mission of the CTPS has been identified as a DOE-complex resource for verification and validation of geophysical and remediation technology equipment and systems.

1.3. Scope, Purpose and Methodology

This Type B Accident Investigation Board began its onsite investigation on October 17, 2001, and submitted its report to the Appointing Official (Acting Idaho Operations Office Manager) on November 13, 2001. The scope of the investigation was to identify all relevant facts; analyze the facts to determine the direct, contributing and root causes of the incident; develop conclusions; and determine judgments of need that, when implemented, should prevent the recurrence of this type of incident.

The Board conducted its investigation using the following methodology:

- Inspecting and photographing the accident scene and individual items of evidence.
- Performing an engineering and metallurgical evaluation of the failed components.
- Gathering facts through interviews, documentsand video reviews, and walk downs of the accident scene.
- Reviewing emergency and medical response.
- Validating facts through a factual accuracy review by DOE, contractor and subcontractor personnel.
- Analyzing facts and identifying causal factors through event and causal factors analysis, barrier analysis and change analysis.
- Developing judgments of need for corrective actions necessary to prevent recurrence based upon the analysis of the information gathered.



Scene Just Prior to The Accident

2. THE ACCIDENT

2.1. Background and Accident Description

2.1.1. Background

In September 1999, the Operable Unit (OU) 7-13/14 In-situ Grouting Treatability Study Work Plan was published. This treatability study work plan provided the strategy for conducting bench and field tests associated with in situ grouting of subsurface waste and contaminated soils. This was a remediation option for the Subsurface Disposal Area (SDA) of the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL). The purpose of the work plan was to describe the work to be conducted in support of the primary treatability study objective, which was a buried waste treatment alternative for the OU 7-13/14 Remedial Investigation/Feasibility Study (RI/FS). On June 29, 2000, BBWI issued a Request for Proposal (RFP) solicitation package to four potential sub-contractors for performance of the work described in the in situ grouting treatability study work plan. On July 19, 2000, AGEC submitted their proposal while the three other potential sub-contractors declined to submit proposals. On October 30, 2000, AGEC was issued a subcontract to provide all resources, (e.g., materials, labor, and equipment) necessary to fulfill the requirements for the implementability testing, contamination control equipment fabrication, drill rig modifications, and field testing.

Modification #1 was issued to the subcontract on March 1, 2001, to add additional scope and funding to accommodate the direct purchase of flow totalizer equipment. Nozzle testing was conducted on April 17, 2001 at AGEC's facility in Richland, WA. Implementability testing was completed on April 24, 2001, at AGEC's work site in Richland, WA. Modification #2 was issued to the subcontract on September 19, 2001, to add additional scope of work. A BBWI Management Self-Assessment (MSA), including the observation of a Systems Operability (SO) Test, was conducted to determine readiness of the equipment and project prior to subcontractor mobilization to the INEEL.

The grouting operations being employed during the treatability study involved the use of a modified drilling rig utilizing a specially constructed "drill shroud," designed by BBWI and constructed by Hiline Engineering & Fabrication Inc. (Hiline), a sub-tier contractor to AGEC. Hiline was also contracted by AGEC to construct a Thrust Block assembly that was used to align the drill rig over equally spaced access ports through which the grouting was conducted.

The physical arrangement of the grouting equipment was such that a grout (cement) truck poured grout into a hopper that fed a vortex (centrifugal) mixer pump. The vortex mixer pump was used to provide "low pressure" flow for down-hole drilling to provide some amount of lubrication for the drill bit. The vortex pump was also used to provide a positive suction head for the triplex (positive displacement) pump which was powered by a diesel engine through a gear box and clutch. The triplex pump was used to provide grout under "high pressure" to the drill rig (normal pressure for this job was about 6,000 psi). The drill rig was modified to accept the "drill shroud" specially designed for this project. The drill bit incorporated into the shroud was a hollow tapered point bit that had two tapped holes into which different size nozzles were threaded. The nozzles were 180° apart radially and separated vertically by several inches. The nozzle size required for this testing was 2.4 mm. The drill rig used rotary percussion to drive the bit down-hole.

A Thrust Block was placed over the simulated waste pit in an area that was covered by the yurt which provided weather protection. Below the Thrust Block was a shallow void above grade where a camera could be placed to remotely observe (and record) drill bit placement, grout flow from the nozzles while above grade, rotation and grout returns; that is, grout that was returned to the surface during the grouting operations. Grade level was gravel (approximately two feet deep) below which was about three feet of clay that covered the simulated waste. The simulated waste included a tracer element (Terbium) that was being used to evaluate the contamination control practices. Air flow was provided in the void area with HEPA filtered exhaust. HEPA filters were also provided on the drill shroud for contamination control evaluation.

The process being used during the treatability study was to position the drill rig on the Thrust Block and align the drill shroud over a hole in the Thrust Block. The bottom of the drill shroud was then double bagged to the Thrust Block. The drill bit was then lowered into the void area while various observations were made. Down-hole operations were commenced utilizing combinations of drill rotation and roto-percussion with "low pressure" grout being delivered until the bottom of the waste stack was reached. Grout was then supplied under "high pressure" while the drill

bit was indexed upward while rotating, thereby mixing the waste, filling voids and building a column grout.

AGEC arrived at the CTPS on October 8, 2001, to begin the grouting activities associated with the in situ grouting treatability study. Grouting activities commenced on October 11, 2001, and grouting was completed on holes one through seven. During the grouting activities that day, suspected foreign material was found on the vortex mixer hopper screen. The following day, ice was noted in the vortex mixer. Sequential grouting activities resumed at hole number eight and stopped after several attempts to complete grouting of hole number 13 failed. Increasing instances of nozzle plugging occurred on holes 12 and 13.

Hole 13 was abandoned after the grouting system sustained a high pressure event of approximately 7,250 psi for about 56 minutes due to nozzle plugging. Difficulty was experienced in relieving the high pressure captured in the grouting system caused by the nozzle plugging event. AGEC eventually relieved the pressure through a manual relief system and disassembled and cleaned out the grouting system. AGEC completed the re-assembly of the grouting system and began grouting activities on hole number 14. Grouting on hole 14 was stopped at 4:20 p.m. to repair some fitting leaks in the grouting system that developed outside the yurt. Grouting activities recommenced with resumption of low pressure operation and grouting was again stopped at 4:40 p.m., because of a grouting leak inside the yurt. Nozzle plugging again occurred and actions were taken to clear the plugged nozzles. Low pressure grouting operation was attempted twice more before grouting activities were suspended for the day. AGEC began system break down and cleaning activities. Two high pressure fittings and a hose were removed from the grouting system for comparison when purchasing replacement parts during the weekend.

AGEC purchased replacement parts that were invoiced on October 12, 2001. A high pressure hose was repaired and invoiced parts were picked up in Idaho Falls, ID, on Saturday, October 13, 2001. Some of these parts would be installed in the grouting system on Monday morning.

Because of forecasted cold weather, the grouting equipment had been covered with cement (insulating) blankets for the weekend. At or about 4:30 a.m. on the morning of October 15, 2001, heaters were started by BBWI personnel to warm the high pressure pumping equipment that was previously covered. The heaters also warmed the yurt that was used to cover the test pit, drill rig and test trailer. The vortex mixer was not covered or heated. The lowest morning (7:00 a.m.) temperature recorded by an on-site National Oceanic Atmospheric Administration (NOAA) metrology tower was 18° F.

On the morning of October 15, 2001, AGEC personnel arrived on site about 6:50 a.m., and AGEC and BBWI crews continued high pressure grouting operations in accordance with the project plan. AGEC deployed that day with three operators instead of the contractually required four operators. An AGEC operator was positioned at the vortex mixer. The operator's position for this grouting job on previous days was inside the yurt next to the drill rig viewing a closed circuit monitor for under thrust block operations.

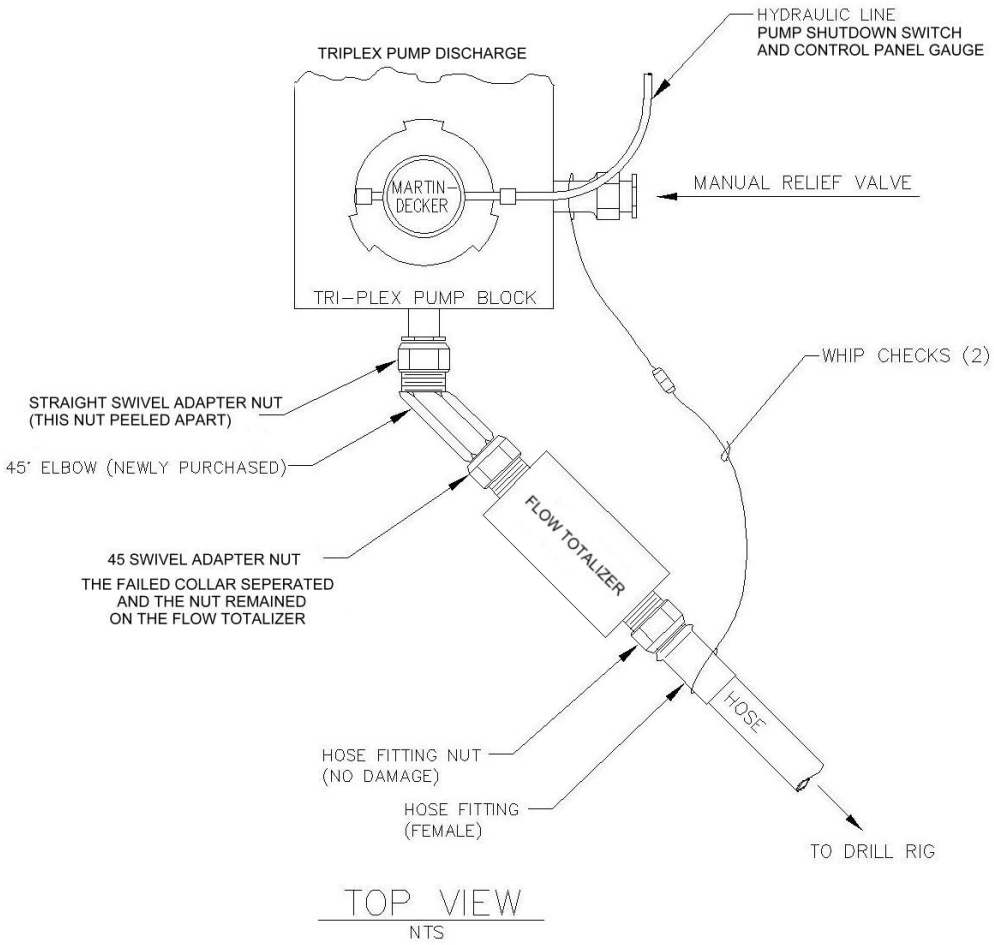
A Plan of the Day (POD) meeting was conducted about at 7:50 a.m. to review the days' planned activities. The Health and Safety Officer (HSO) was absent and the position was covered by the Field Team Leader (FTL) as allowed for in the Health and Safety Plan (HASP) for the OU 7-13/14 In Situ Grouting Treatability Study. From about 8:00 a.m., until about 10:00 a.m., the drill shroud assembly that was used previously was replaced with a new assembly. During this period of time, several other events took place. The first of three scheduled grout delivery trucks arrived at the CTPS (8:10 a.m.); AGEC personnel replaced a 45° swivel elbow with the newly purchased fitting on the discharge of the grouting pump; and AGEC personnel installed a tee connector and cap between the two hoses used to deliver grout to the drill rig. One of the hoses installed had both end connectors replaced over the weekend. The tracked drill rig was moved into position on the thrust block over hole number 14 and the drill shroud was prepared for grouting operations. The diesel motor powering the triplex pump was noted to be slow to come up to speed.

The cap was removed from the newly installed tee connector in order to fill the line between the grout pump and tee. The drill operator inside the yurt requested the triplex pump operator to "bump" the triplex pump a couple times. The drill operator informed the pump operator there was still no "mud" inside the yurt and asked if the triplex pump was in second gear. The triplex pump was "bumped" and approximately 40 liters of grout was flowed out of the newly installed tee connector. The cap was replaced on the tee connector.

Drilling operations commenced at 10:22 a.m., when the new drill bit entered hole #14 that had been abandoned on the previous Friday afternoon. Drilling ceased momentarily and grout pressure was stopped at 10:29 a.m. Drilling was resumed at 10:31 a.m. At approximately 10:32 a.m., the accident occurred as AGEC was attempting to start grout flow by increasing grout pressure.

2.1.2. Accident Overview

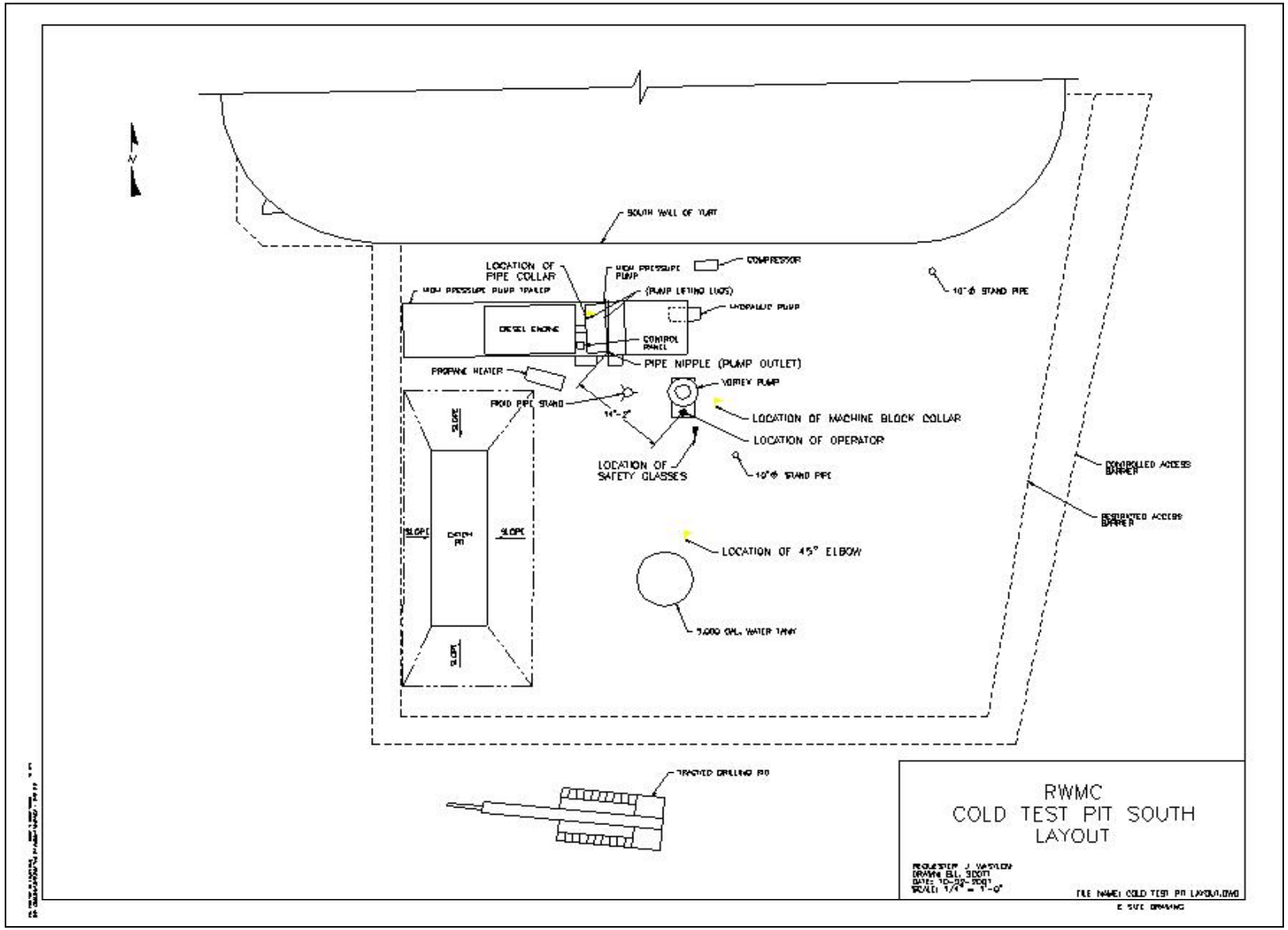
The accident occurred when a 45° swivel elbow with a rated working pressure of 3,000 psi (normal working pressure during high pressure grout injection was 6,000 psi) broke under pressure and set into course a chain of events that led to the injury of a subcontractor operator. The equipment involved in the accident, shown in the equipment drawing, included the straight swivel adapter on the triplex pump high pressure outlet, a 45° swivel elbow, a flow totalizer and two whip check restraining devices. (See Triplex Pump Discharge With Fittings, Flow Totalizer and Hose.)



Triplex Pump Discharge With Fittings, Flow Totalizer and Hose

The Board determined that the most likely chain of events for the accident started with the failure of the collar on the 45° swivel elbow nut by ductile rupture. This allowed the remainder of the 45° swivel elbow nut and flow totalizer to separate from the grout flow path. The flow totalizer was restrained to the block of the triplex pump by the use of two whip checks on its outlet connecting hose. The whip checks restrained the flow totalizer until the applied forces and momentum broke the whip checks.

While the flow totalizer was being thrown from the system, the applied force from the 45° swivel elbow was transmitted onto the straight swivel adapter nut on the high pressure outlet of the triplex pump. The straight swivel adapter nut then ruptured in a brittle cleavage fracture causing the 45° swivel elbow and the straight swivel adapter nut to be thrown from the grouting system. The straight swivel adapter nut struck the operator on his safety glasses on the right side of the head in the vicinity of the right eye socket causing the safety glasses to break and striking the operator.



Cold Test Pit South – Evidence Locations

2.2. Engineering Evaluation of the Failed Components

The Board commissioned BBWI's Project Engineering Department and Materials Department to select a mechanical engineer and a metallurgical engineer to perform a nondestructive evaluation of the failed fittings. The objectives of the examination were as follows:

- Determine the mode of failure.
- Look for possible material or manufacturing defects, metal fatigue, or corrosion, which may have contributed to the failure.
- Determine whether the method used to install the fittings could have contributed to the failure.
- If possible, determine the sequence of failure (i.e., which of the two fittings failed first).
- Advise whether the type of fittings and whip checks that failed were suitable for that particular application.

The mechanical and metallurgical engineers were given a tour of the accident scene. Photographs and sketches of the grout pumping system were reviewed. The recorded events prior to and after the accident were then provided. All five pieces of the two failed fittings and the failed whip checks were submitted for analysis. A summary of the results of the examination is as follows.

2.2.1. Fitting Mode of Failure

Both fittings failed at the swivel end nut connection to the body of the fitting. In manufacture, the nut is held captive to the body of the fitting, allowing the nut to be rotated to tighten the connection. The mode of failure for each fitting follows.

2.2.2. The 45° Swivel Elbow

The fitting nut collar was entirely separated from the main body of the nut by a circumferential fracture. The fracture surface was very uniform, with no sign of an initiation site. It was concluded that the nut failed by ductile rupture corresponding to a tensile overload (i.e. high pressure).

45° Swivel Adapter

Fitting Body

Fitting Nut

Nut Collar

2.2.3. Straight Swivel Adapter
The fitting nut failed by a brittle cleavage fracture process, not uncommon for low-carbon steels. Fracture by cleavage is promoted by low temperature, high loading rates, or a combination of both.

Straight Swivel Adapter

Fitting Nut

Fitting Body

2.2.4. Fitting Manufacturing Defects, Metal Fatigue or Corrosion
No gross material or manufacturing defects were observed in any of the failed fittings. There were no indications of metal fatigue or corrosion contributions to the failures.

2.2.5. Fitting Installation
There were no signs of significant, pre-fracture mechanical damage to the parts. There was no evidence of damage from gross over tightening.

2.2.6. Fitting Sequence of Failure
The damage patterns exhibited by the fittings and their post-accident resting places, suggest a failure sequence. The 45° swivel elbow nut failed by tensile over-load in a plane perpendicular to its centerline as noted by the uniform fracture surface. By comparison, the straight swivel adapter fitting exhibited a failure pattern that was dominated by a loading unsymmetrical to the fitting centerline. Such a failure pattern is consistent with a loading resulting from a blow down through the downstream end of the 45° swivel elbow fitting, since the exiting flow would be in a direction well off of the centerline of the straight swivel adapter. Failure of the whip checks that spanned the failed fittings indicates a dynamic unloading of the system fluid through the failure locations, confirming that a system blow down did occur.

Thus, it is most likely that the 45° swivel elbow nut preceded and contributed to the failure of the straight swivel adapter rather than a failure sequence in the opposite order.

2.2.7. Fitting Suitability for the Application
The straight swivel adapter had been in service for some time and was not replaced just prior to the accident on the morning of October 15, 2001. There were no manufacturing trademarks on the fitting and no information about the fitting was available. However, the 45° swivel elbow had been recently purchased from a local vendor and installed by the subcontractor on the morning of the accident. The manufacturer's catalog rated working pressure for this fitting was 3,000 psi. It should be noted that the vendor

invoiced a fitting rated at 4,000 psi, but supplied a fitting rated at 3,000 psi. The definition for the rated working pressure is the upper limit pressure the manufacturer expects the rated fitting to regularly see in a given application. A four-to-one burst pressure represents a safety factor of four times the rated working pressure to deal with pressure spikes. Occupational Safety and Health Administration (OSHA) and the DOE do have pressure safety requirements for some applications, but depend on industry consensus standards or engineering evaluation for other pressure system safety applications. No OSHA or DOE standards specifically cover high pressure grouting operations.

After a review of catalog data and discussions with a manufacturer's representative, the Board determined that the whip checks used were found not suitable for this application. In a 6,000 psi grout delivery system, it was unsuitable to use whip checks rated for a maximum working pressure of 200 psi air.

Based on pressure and flow traces generated by the flow totalizer on the days prior to this accident, the system was normally operated at a pressure of approximately 6,000 psi. Greater than 10,000 psi had been recorded on this project at one time previous to the accident. The pressure at the time of the accident event was not recorded and remains unknown. During this event, the failed 45° swivel elbow was not installed in the system, however the straight swivel adaptor was installed.

The Board concluded that after review of the mechanical and metallurgical engineers' evaluation, it was evident that the failure of both fittings was not due to a manufacturing or material defect, nor was the failure due to incorrect installation of the fittings. Rather, failure of the 45° swivel elbow was due to a tensile overload caused by the application of pressure beyond the rated capacity for the fitting. The 45° fitting that failed was underrated and not suitable for the pressures used in this grouting system. In addition, the whip checks used were not suitable in this application.

2.3. Emergency Response and Medical Treatment

The emergency response and medical treatment of the injured operator consisted of an initial response by BBWI and AGEC personnel that were at the site. Within 18 minutes, EMS personnel from the Central Facilities Area (CFA), about 6 miles away, were at the scene to treat the injured operator and transport him to EIRMC for further medical treatment.

When the operator was injured, the triplex pump operator announced "emergency" over the radios used for communications among the operators and personnel in the data-gathering trailer. This radio announcement put into motion the initial response. Several calls for EMS were made. These requests were made to the INEEL telephone operator, the Warning Communications Center (WCC), the Central Alarm Station and the shift desk at RWMC. The location of the accident scene was clearly announced as the CTPS near RWMC. EMS personnel from the Central Facilities Area (CFA) fire station responded to the accident site with an ambulance and EMT personnel, a fire truck, and a vehicle with a nurse from the CFA dispensary.

Immediately after the accident, the AGEC drill rig operator ran outside of the yurt and helped the injured employee to the ground. One of the BBWI personnel brought a first aid kit from the project trailer. First aid treatment was given to the injured employee. Approximately 10 minutes after the accident, one of the BBWI personnel went in a vehicle to locate the ambulance and other BBWI personnel went to locations along the RWMC perimeter road to direct the ambulance to the accident site. The BBWI personnel who left in the vehicle to locate the ambulance found the ambulance in front of a construction trailer at the BNFL site (near by). He directed the ambulance to follow him to the accident site.

Two distinct and separate actions slightly delayed EMS response to the CTPS location. The WCC shift personnel mis-communicated the location of the accident to EMS personnel as being at a white building outside of the BNFL construction site at RWMC instead of past BNFL at the CTPS location. The WCC shift personnel did not appear to be familiar with the CTPS location and asked the personnel calling for the emergency response where it was located. The caller then described the location as a white tent on the road past the BNFL construction site at RWMC. The shift desk at RWMC did not notify the BNFL construction site at RWMC of a fire department response to an RWMC facility as required in a Memorandum of Agreement between RWMC, BNFL and the DOE-ID office. If the BNFL location had been notified about the accident, they may have directed the EMS personnel to the CTPS location without delay. EMS personnel stated that they considered the delay to be less than one minute.

Total response time to the CTPS location by the EMS personnel was approximately 18 minutes from the time of the accident. After two minutes, the EMS personnel stabilized the injured operator and transported him to EIRMC for further treatment. The triplex pump operator from AGEC accompanied the injured operator in the ambulance to EIRMC.

The injury sustained required two surgeries at EIRMC to stabilize the injured operator prior to discharge on October 17, 2001. The injured operator was struck on the right side of the head by the straight swivel adapter nut. This nut broke his safety glasses and caused injury to the right side of the head in the vicinity above the right eye socket.

The emergency room physician and the treating ophthalmologic surgeon described the injury as a fracture of the lateral (outside) orbital rim (eye socket), fracture of the medial (next to the nose) wall of the orbit, as well as the posterior wall of the orbit. All fractures comminuted (many distinct pieces). There was a hemorrhage in the posterior orbit (behind the eyeball). The orbital nerve, and retinal artery were placed on traction, and entrapped by fracture fragments. Surgically, the tension was removed from the orbital nerve and retinal artery, the lateral orbital fragments were elevated, and plated. The medial wall was not touched, to allow room for subsequent swelling. The injured operator had light perception, and ability to ascertain finger movement in the affected eye the following day. The prognosis for further improvement was questionable at that time. The injured operator required further medical treatment on returning home. The injured operator had no other injuries. It is of special note that there was no loss of consciousness, and no damage to any structures inside the calvareum (i.e., no evidence of brain injury).

The Board concluded that, overall, the initial emergency and medical responses were timely and appropriate with only a minor delay in arrival of EMS personnel due to miscommunication of the location of the accident.

2.4. Investigation Readiness and Accident Scene Preservation

The accident scene was turned over from EMS personnel to the In Situ Grouting (ISG) Project Team after transporting the injured operator from the CTPS location. An INEEL photographer took photographs and an INEEL videographer shot film of the accident location just prior to and after the accident. The photographer and videographer were on location to take pictures and films of the ISG operations and captured the initial response to the accident, arrival of EMS personnel as well as the post accident locations of evidence. No photographs or videos were taken inside the yurt just prior to the accident or after the accident prior to removal of equipment. After the scene was turned over to the ISG Project Team, the FTL and Project Manager (PM) controlled the accident scene. The area where the accident occurred had a barrier rope up prior to the accident to keep unauthorized personnel away from the high pressure grout operations. This barrier rope was used as the accident scene controlled area after the EMS personnel turned over the scene to the ISG project team.

The FTL and PM made the decision after having photographs and film of the accident scene to allow the cleaning of the grouting system and drill rig so that the grout would not harden in the equipment. The AGEC drill rig operator required the assistance of BBWI personnel to clean out the equipment. During the cleaning out process, several BBWI and DOE personnel arrived and toured the accident scene. Clean-out processes, relocation of equipment and removal of evidence from the scene altered the physical evidence that may have been useful to the Board.

The safety glasses worn by the injured operator were located, picked up, photographed and then placed back in the approximate location where found. The straight swivel adapter nut from the triplex pump outlet was also found, picked up and then placed approximately back where it was found. Both the safety glasses and swivel nut were collected for inspection at the critique following the accident. It was noted that although no blood was observed on the safety glasses and swivel nut, personnel handled both items without protective gloves to protect them from potential blood born pathogens.

The PM started a critique of the event at the project trailer while clean out operations of the grouting system were taking place. The FTL controlled the accident scene and directed all arriving individuals to check in at the project trailer. The PM collected witness statements from individuals at the critique that were present at the accident scene. During the critique, the safety glasses and straight swivel adapter nut were inspected and held by several individuals who did not have protective gloves on to protect themselves from potential blood born pathogens. A BBWI equipment operator found the 45° swivel elbow during the clean out process and brought it to the critique.

Evidence collection continued and flags placed into the ground at approximate locations where the items were found. The accident scene was then ribboned off for access

control at the existing rope barrier. The evidence was bagged with custody seals and placed on a laboratory sample chain of custody form. All evidence collected at that time was placed into INEEL Protective Forces' custody. This evidence was turned over to the DOE Accident Investigation Board on October 17, 2001. The accident scene during night hours was in the INEEL Protective Forces' custody with the instructions that access could only be granted to the accident scene by the FTL and PM.

On October 18, 2001, a DOE Accident Investigation Board member found the separated collar of the 45° swivel elbow nut and placed the item into evidence. This 45° swivel nut collar was found on top of the triplex pump, which had been covered for weather protection since the clean out process after the accident.

The accident scene became the custody of the DOE Accident Investigation Board on October 18, 2001, with permission for access granted only by the Board Chairman or a designated member of the Board. Custody of the accident scene was returned to BBWI on November 5, 2001. Throughout this time period either a security guard or project personnel maintained continuous access control using the written guidelines provided by the Board chairman.

The Board concluded that decisions made by project personnel to clean out equipment, move equipment and remove evidence from the scene altered some of the physical evidence that may have been useful to the Board.

3. ACCIDENT FACTS AND ANALYSIS

3.1. Physical Hazards, Controls and Related Events

3.1.1. Define the Scope of Work

Effective work execution begins with the preparation of a well-defined scope of work that translates the mission and requirements into terms that those who are to accomplish the work can clearly understand. The scope of work must provide sufficient detail to support hazard analysis and implementation of controls at the task level. To fulfill its responsibilities, line management must determine the work to be performed and be accountable for understanding it through every phase of the work cycle.

The INEEL developed a Program Description Document, *PDD-1004, INEEL Integrated Safety Management System*, to describe how BBWI integrates ESH & QA into their work activities. Section 2, Business, Budgets, and Contracts Process, explains how ES&H activities are integrated into the business process. A fundamental objective within Section 2 is to establish a well-defined scope of work and establish in depth hazard analysis and hazard identification.

The INEEL was placed on the Environmental Protection Agency 's (EPA) National Priorities List (NPL) of Superfund sites in November 1989. On December 9, 1991, a Federal Facility Agreement and Consent Order (FFA/CO) was signed and enforceable deadlines established. An action plan for implementation of the FFA/CO was developed and established numerous operable units (OU) within Waste Area Group (WAG) 7 that encompasses RWMC.

In May of 1996, a *Work Plan for Operable Unit 7-13/14 Waste Area Group 7 Comprehensive Remedial Investigation/Feasibility Study (RI/FS)* was published. The Work Plan discussed the use of engineering and treatability studies as part of the feasibility study to provide a basis to recommend a preferred alternative for a remedial action to reduce risks for OU 7-13/14. In March of 1998, an *Addendum to the Work Plan for OU 7-13/14 WAG 7 Comprehensive RI/FS* was published.

The scope of work for in situ grouting operations at the CTPS was defined in *Operable Unit 7-13/14 In Situ Grouting Treatability Study Work Plan* and refined in the *Implementation Test and Field Test Plan for the Operable Unit 7-13/14 In Situ Grouting Treatability Study,* which were developed as part of the Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA) process. The scope of work formed the basis for BBWI's subcontract with AGEC. The statement of work in the subcontract presented a detailed description of all activities and requirements for AGEC to perform the implementability and field testing for the in situ grouting treatability study for BBWI. It also contains a breakdown of the activity responsibilities shared by BBWI and the subcontractor. Prior to AGEC's field test activities at CTPS, the subcontract was modified twice. These modifications together increased the ceiling price of the contract, extended the completion time, added additional vendor data requirements and required AGEC to ensure flow meter calibration before it was used for data collection.

Environmental Restoration (ER) activities were to be conducted in accordance with the general quality assurance requirements in the DOE/ID-10587 (*Quality Assurance Project Plan For Waste Area Groups 1, 2, 3, 4, 5, 6, 7, 10, and Inactive Sites*) and PLN-694, *Environmental Restoration Program Project Management Plan* (ER PMP).

Criterion 7, Procurement, of the ER PMP Quality Assurance Plan (QAP) states, "The procurement process ensures that purchased items and services meet established requirements and perform as expected. That process begins with applicable requirements being defined in the procurement documentation and includes acceptance criteria. Procurement documents include all requirements imposed on subcontractors, including training and oversight responsibility. Inspection criteria are established for all items and services requiring inspection."

When a PM determines that the procurement quality organization will perform the inspection, inspection planning is developed. If the procurement quality organization is not employed, the deliverables are to be inspected by the receiving organization. These quality assurance requirements were not followed or implemented when developing the procurement documents.

The Board concluded that the subcontract did not fully define all of the quality acceptance or inspection criteria necessary to ensure that the services being provided would meet established requirements and perform as expected.

The Statement of Work included in the subcontract required AGEC to perform work safely and in a manner that ensured adequate protection for employees, the public, and the environment, and required them to be accountable for the safe performance of work. The subcontractor was required to manage and perform work in accordance with BBWI's

Integrated Safety Management System (ISMS) or develop its own documented system that fulfilled all of the eight guiding principles and five core functions for Integrated Safety Management.

AGEC indicated on their VPP/ISMS pre-qualification questionaire that they did not have a program compliant with ASME NQA-1, *Quality Assurance Requirements for Nuclear Facility Operations* (NQA-1). The BBWI Procurement Quality Division performed a "table top" review of AGEC's QA/QC Plan and, after requesting a few minor changes, deemed AGEC an NQA-1 supplier qualified for this procurement only. A list of the NQA-1 quality requirements applicable were included in the subcontract and required specific items to be flowed down to AGEC's lower tier subcontracts.

BBWI's subcontract with AGEC stipulated that all vendor data listed on form 414.12A "Vendor Data Requirements" was to be submitted to BBWI Procurement Document Control. BBWI Procurement Document Control never received any of the vendor data. The purpose submitting vendor data to BBWI's Procurement Document Control was to make sure that vendor data goes through all of the required BBWI review and approvals as stipulated on the form. The vendor data that was supposed to be submitted to procurement document control included: AGEC's Quality Assurance Plan, the Pump and Drill Rig Operating Procedures, the flow totalizer calibration data, the Contamination Control Equipment Visual Examination Procedure, the Weld Procedure Qualification, the Welder Performance Personal Certification, the Inspection Test Procedures, the Inspector Certification, and the Training and/or Practical Experience Records for Grouting /Drilling Personnel.

The Board reviewed the ER Program Quality Assurance Plan, The ER Program QA Project Plan, the In Situ Grouting Work Plans, the In Situ Grouting Treatability Study Test Plans, the Request for Proposal, and the Subcontract (including all modifications), and concluded that BBWI failed to follow and implement the Environmental Restoration Quality Assurance Plan for the In Situ Grouting Treatability Study.

3.1.2. Hazards Analysis

3.1.2.1. Integrated Safety Management Flow Down:

The objective of a hazard analysis is to develop an understanding of task-specific hazards that may affect the worker, the public, and the environment. Hazard controls should be established based on this understanding and other factors related to the work. The requirement for performing a hazard analysis is defined in BBWI's Integrated Safety Management System (ISMS) Core Function 2, "Identify and Analyze the Hazards."

To ensure an effective process is in place for identifying and analyzing hazards, requirements must flow down to subcontractors and be implemented successfully. The following describes the various requirements for identifying and analyzing hazards and how these requirements affected BBWI and AGEC.

The BBWI subcontract with AGEC stated that "The Subcontractor shall manage and perform work in accordance with BBWI's ISM or may develop its own documented System. If elect [sic] to develop its own System the System shall describe how the Subcontractor will: define the scope of work; identify and analyze hazards; develop and implement hazard controls; perform work in accordance with the hazard controls; and provide feedback on adequacy of controls and continue to improve safety management."

BBWI required AGEC to be pre-qualified as having implemented all 14 elements of VPP and ISMS as identified in the pre-qualification application. The AGEC VPP/ISMS pre-qualification application was reviewed and accepted by the BBWI Industrial Safety/VPP organization on July 19, 2000, stating that they had a program in place equivalent to the BBWI ISM program.

The INEEL VPP/ISM pre-qualification application required the use of one of several methods for documenting hazard identification and analysis. The application submitted by AGEC identified that this requirement was met through the following mechanisms:

- The equipment and support equipment are operated per the manufacturer's recommendations;
- Project job safety analysis will be completed prior to initiation of field work and reviewed by all cognizant individuals;
- Hazard identification and mitigation are to be completed as part of or as an attachment to the job hazard analysis or equivalent or noted on occurrence in daily log.

The Board concluded that the response provided by AGEC lacked the definition and description necessary to adequately define an ISM program. The AGEC Health and Safety Program was not requested by the BBWI Industrial Safety/VPP organization as part of the ISM/VPP pre-qualification application and was not evaluated for its adequacy in implementing an ISM process. BBWI's acceptance was premature and lacked rigor in evaluating the subcontractor's health and safety program for ISM implementation.

3.1.2.2. Identification of Hazards:

The hazards associated with the in situ grouting activities were initially identified in the hazard classification, *Hazard Classification for the Operable Unit 7-13/14 In Situ Grouting Cold Test*, (Hazard Classification) September 2001. The high pressure hazard resulted in a categorization of the activity as low hazard and required the development of an Auditable Safety Analysis, otherwise known as the HASP (*The Health and Safety Plan For Operable Unit 7-13/14 in Situ Grouting Treatability Study*, September 2001.)

The HASP was applicable to both BBWI and AGEC personnel. The HASP required the subcontractor to provide hazard and mitigation information regarding the nature of the grouting tasks and participate in job-site hazard walk-downs. The HASP included a task and hazard analysis. The hazards identified in the HASP did not include nozzle plugging, effects on equipment due to cold environmental conditions, and hoisting and rigging for movement of the shroud.

Nozzle plugging was a condition deemed acceptable during grouting operations. Nozzle plugging was not determined to be a hazard and was therefore not evaluated in the HASP. Nozzle plugging conditions were known to result in an increased pressure situation, but this was never recognized to present increased risk and, therefore, never evaluated.

Environmental conditions were not evaluated with respect to the hazards presented to the operation and maintenance of the AGEC equipment. The temperature on October 15, 2001, reached a low of 18 degrees Fahrenheit at 7:00 a.m. On the morning of October 12, 2001, testimony indicated that ice was found in the vortex mixer.

The BBWI subcontract with AGEC required the implementation of DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*, Attachment 2, which required AGEC to: "Identify existing and potential workplace hazards and evaluate the risk of associated worker injury or illness. Analyze or review operations and procedures; and equipment, product, and service needs."

The BBWI subcontract identified the following requirements associated with performing hazard analysis:

- "The subcontractor shall perform work safely, i.e., in a manner that ensures adequate protection for employees, the public, and the environment and shall be accountable for the safety performance of work. The contractor shall exercise a degree of care commensurate with the work and the associate hazards. The Subcontractor shall ensure that management of ES&H functions and activities becomes an integral but visible part of the work planning and execution processes"
- "Before work is performed, the associated hazards are evaluated and an agreed upon set of ES&H standards and requirements are established, which, if properly implemented, provide adequate assurance that employees, the public, and the environment are protected from adverse consequences."
- "The subcontractor shall be required to contribute to a "job hazard analysis" from which additional hazard mitigation training requirements may be identified."

The subcontract required AGEC to implement BBWI's Subcontractor Requirements Program, PDD-1001, and Work Coordination and Hazard Control, PRD-1007.

PDD-1001, The Subcontractor Requirements Program, was established to ensure a consistent and controlled method of providing requirements for subcontractors as they performed work at the INEEL facilities controlled by BBWI. This program applied to individual BBWI suppliers or subcontractors that provide services in accordance with and as specified by BBWI subcontract, purchase order, or other procurement documents.

The program was developed to prevent workplace injuries, ensure a safe workplace, and to promote a "ZERO Injury" commitment and zero work quality deficiencies amongst subcontractors hired at the INEEL. The following requirements are established in the Subcontractor Requirements Program:

- "Hazard prevention and control is addressed through both preventative and corrective measures; first being worksite analysis, the second being accident and incident investigations."
- "Identifying hazards associated with activities and controlling or eliminating those hazards when planning and executing work is the responsibility of the Subcontractor Field Supervision."
- "Identifying and evaluating potential hazards and potential process or program deficiencies associated with each aspect of a project is the responsibility of the Subcontractor Field Supervision."

PRD-1007 provides requirements for coordinating work and controlling the hazards associated with work performed by subcontractor personnel. It requires subcontractor line management to safely control subcontract work activities by identifying and documenting existing and predictable hazards, and by informing workers about these hazards and their mitigation. PRD-1007 provides the following requirements:

"The hazards associated with the work, and the applicable hazards identified in the Hazard Control Set shall be documented in a hazard evaluation (JSA, CWA, SWP, HASP, RWP.) Hazard evaluation shall address:

- applicable activities to be performed
- involved or affected personnel, by name or job function
- potential and credible hazards
- magnitude/significance of identified risks"

"The completed JSA (including the subcontractor's review and approval signatures) shall be submitted to BBWI for review/acceptance."

It was clear, based on the requirements flow-down process from the ISM/VPP pre-qualification application to the Subcontractor Requirements Program, that AGEC was required to perform a task level hazard analysis, i.e. job safety analysis, for the drilling and grouting operations performed, but this analysis was not completed for this activity. The AGEC Health and Safety Program did not include requirements for hoisting and rigging, pressure safety, or performing a job safety analysis. AGEC had a form for analyzing hazards, the AGEC Activity Hazard Analysis Form, but it was not completed for drilling and grouting activities, nor was it requested by BBWI, thus BBWI did not review or accept it. The AGEC form was deficient in that it was not equivalent to a JSA, as it did not require a task level hazard analysis and did not include a high pressure hazard associated with grouting operations.

3.1.2.3. Work Control Document:

The BBWI hazard identification and analysis process is implemented through any of three work control processes:

- MCP-3562, Hazard Identification, Analysis and Control of Operational Activities, for operations and environmental remediation;
- STD-101, Integrated Work Control Process for maintenance, modifications, construction, D&D, and environmental remediation project activities; and

- MCP-3571, Independent Hazard Review, for research and laboratory activities.

BBWI project operations personnel, CFA Planning, and RWMC determined that STD-101 was the appropriate work control process for this in situ grouting activity. The work order (WO) was prepared by a Central Facility Area qualified planner, and was approved on October 8, 2001. The type of work order was determined to be a standard planned work order (Work Order number 46762-01). The STD-101 hazard analysis process for a standard planned work order consists of the following activities:

1. Develop work scope definition
2. Complete draft hazard profile screening checklist (HPSC)
3. Perform planning walkdown
4. Finalize HPSC
5. Develop controls from Hazard Mitigation Guide
6. Develop Job Safety Analysis (not required for Standard Work Orders)
7. Incorporate lessons learned and feedback from identified error-likely situations

The STD-101 Hazard Profile Screening Checklist (HPSC) is a standards based hazard identification questionnaire. The questionnaire does not screen for hazards related to high pressure systems such as high pressure grouting pumps used in this activity and environmental effects on equipment operation and maintenance. The questionnaire focuses on coded (ASME) pressure vessels, systems, or relief devices, e.g., boilers and pressure vessels.

A planning walkdown for grouting and drilling operations was not performed prior to or after mobilization of the equipment to the INEEL. The STD-101 process allows planned work orders to be performed without the completion of a JSA, therefore a JSA was not developed. Lessons Learned from previous failures with this equipment were not identified or incorporated into the WO, e.g., failures that occurred during the Nozzle Test (unknown to BBWI until after the accident) and past occurrence reports.

The completed WO did not include tasks associated with the contamination control bagging process. The WO did not address the steps necessary to complete this activity or evaluate the hazards associated with the task. The hazard associated with high pressure systems was identified in the Hazard Classification and HASP, but did not flow down into the work control document for the activity. The WO did not identify the hazards associated with high pressure, environmental conditions, nozzle plugging, and energy pathways. Environmental conditions and pressure increases due to plugging are hazards discussed previously that were not recognized. Energy pathways from the discharge of the triplex pump were neither evaluated nor used to identify the hazards associated with high pressure in the instance of failed parts.

3.1.2.4. Operating Procedures:

AGEC developed work instructions that were used to define INEEL and AGEC responsibilities during the grouting and drilling activities. The work instructions were similar to an interface agreement rather than a procedure. The work instructions were not procedures, were not developed using a job safety analysis, and only

defined roles when performing grouting and drilling activities. AGEC did not have operating procedures to control operations during grouting and drilling activities.

The Board concluded that AGEC did not have a Health and Safety Program that adequately implemented the ISM hazard analysis concept. The work planning by both AGEC and BBWI did not ensure this work was performed in a safe manner by using a task specific hazard analysis. Additionally, the BBWI STD-101 work control process did not provide for a standards-based mitigation of hazards related to all high pressure systems in use.

3.1.3. Develop and Implement Controls

The objective of developing and implementing controls is to identify and provide the full range of controls (i.e., engineering, administrative, and personal protective equipment) consistent with the level and nature of hazards to be encountered during task performance. The development and implementation of work controls assumes that the contractor has adequately and completely identified the hazards with the defined scope of work. The requirements for performing a hazard analysis are defined in BBWI's Integrated Safety Management System (ISMS) Core Function 3, "Develop and Implement Controls."

The BBWI subcontract with AGEC required the implementation of an equivalent ISM program. The INEEL VPP/ISM pre-qualification application required controls to be implemented to mitigate hazards. The controls should include process and/or material substitution, engineering, administrative, and personal protective equipment. The application submitted by AGEC identified that the requirements were met through the following mechanisms:

- "The corporation has a written health and safety plan that stipulates levels and job title equivalents and their responsibilities."
- "Controls are implemented to mitigate hazards: The corporation may mitigate hazards primarily by engineering and/or operational controls. Control requirements will be primarily derived from evaluation of project job hazards analysis and on the job experience."

The BBWI subcontract with AGEC states:

- "Before work is performed, the associated hazards are evaluated and an agreed upon set of ES&H standards and requirements are established, which, if properly implemented, provide adequate assurance that employees, the public, and the environment are protected from adverse consequences."
- "Administrative and engineering controls to prevent and mitigate hazards are tailored to the work being performed and its associated hazards. Emphasis should be on designing the work and/or controls to reduce or eliminate the hazards and to prevent accidents and unplanned releases and exposures."

The subcontract also required AGEC to implement the BBWI Subcontractor Requirements Program, which defines the following requirements associated with developing and implementing controls:

- "The hierarchy for developing and implementing controls is 1) engineering controls, (2) administrative controls, and (3) the use of PPE. Hazard

prevention and control is addressed through both preventative and corrective measures; first being worksite analysis, the second being accident and incident investigations."

- "Identify hazards associated with activities and control or eliminate those hazards when planning and executing work."

The HASP and the work control document identify the established hazards and controls for the activity. The work control process used for this activity was STD-101, and a planned standard work order was developed. The established controls for HPSC hazards are documented in the BBWI Hazard Mitigation Guide (HMG). The controls placed in the WO were based on the hazards identified from the completion of the HPSC, and were incorporated from the HMG. The work order did not identify high pressure as a hazard and the HMG did not include controls for high pressure systems, with the exception of boilers and pressure vessels.

3.1.3.1. Engineered Controls:

Engineered controls are the first in the hierarchy of controls to prevent injury to the workers. Engineered safety features associated with the triplex pump included the automatic pressure safety shutdown and a manual pressure relief mechanism. No overpressure prevention device was provided downstream of the triplex pump discharge. Engineered controls for the high pressure pump operations were not identified as mitigative controls in either the HASP or WO, with the exception of whip checks and LO/TO. Although nozzle plugging was accepted, and the resulting overpressure conditions were recognized, this was not identified as an increased risk requiring additional mitigative actions.

The manual pressure relief on the pump discharge operates by backing off a large bolt allowing internal pressure from the grout system to relieve through a weep hole. The grout delivery system downstream of the triplex pump outlet did not have an overpressure prevention device installed. AGEC could not provide documented evidence of proper operation of the automatic safety shutdown of the triplex pump. According to the triplex pump manufacturer representative, the automatic safety shutdown trip point is set at 8700 psi. The manufacturer's operating manual recommends setting this trip point at 290-435 psi above the operating pressure in use. Interviews with AGEC established that the automatic safety shutdown trip point had not been reset. The pressure recorded on October 11, 2001, by the flow totalizer indicated operation above 10,150 psi. The automatic shutdown mechanism did not shutdown the pump during this excursion. AGEC indicated they were unaware of ever having had an automatic safety shutdown on the triplex pump.

No evaluation was conducted to ensure that the installed whip checks were properly rated for this application. The manufacturer's rating for the whip checks that failed was 200 psi air, per whip check, and provided no hydraulic service rating. The manufacturer did not recommend that these whip checks be used for this application due to the high operating pressures. Both whip checks failed during the accident.

Although not identified as a hazard in the HASP or WO, nozzle plugging was considered an anticipated event during this type of grouting operation and was an identified lessons learned in the January 1995, Innovative Grout Retrieval Demonstration Final Report. Two 2.4 mm diameter nozzles were the only grout

discharge path during this operation. Controls associated with plugging were not established in the hazard/control set of the HASP or WO. Nozzle clean-out procedures included the use of percussion, and triplex pump pulsing as methods resolve nozzle plugging problems, but none were evaluated to determine the hazards associated with these activities or the controls needed to prevent an incident. The effects of the grout set time were not evaluated with respect to nozzle plugging. Specified time limits were not established in the work order to ensure the grout set time was not exceeded, which could lead to plugging of the nozzles. Additionally, the contamination control bagging process was not evaluated in the work order to determine hazards and controls, nor the increased time required to go from hole to hole, which would affect the grout cure time. The thrust block camera was not identified as a control, although at times it was used to verify grout flow.

Other engineering controls such as equipment guarding were not used. Guarding installed at the outlet of the high pressure pump may have been an effective control for containing an over-pressurization event.

The Board concluded that engineering controls in place (whip checks and automatic pressure safety shutdown) were not well understood and were not effective to preclude over-pressurization and the resulting events. Additionally, it was not recognized that an automatic pressure relief mechanism downstream of the pump was needed.

3.1.3.2. Administrative Controls:

The subcontract required that the subcontractor be trained or have documented experience on high pressure systems per OSHA requirements and PRDs required by the subcontract. Research of OSHA standards and national consensus standards indicate that there is minimal guidance or requirements associated with high pressure systems. Neither the triplex pump operator nor the injured operator had documented manufacturer's training on high pressure systems, but did have documented experience. The injured operator had 30 years experience in concrete and grouting heavy equipment construction. The triplex pump operator had 6 years experience with jet grout systems and related equipment. The drill operator and the other vortex mixer operator had training from the triplex pump manufacturer representative. There was no manufacturer's trained triplex pump operator in the vicinity of the triplex pump on the day of the accident. When questioned, AGEC personnel did not demonstrate adequate understanding of the automatic safety shutdown mechanism on the triplex pump. Additionally, no documentation existed that showed AGEC personnel had obtained training on the PRDs required by the subcontract.

The BBWI subcontract with AGEC required the implementation of DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees,* (DOE 440.1A) Attachment 2, which included the following requirements related to the development and implementation of controls:

DOE Order 440.1A Attachment 2 Section 20, Pressure Safety

a. "Establish safety policies and procedures to ensure pressure systems are designed, fabricated, tested, inspected, maintained, repaired, and operated by

trained and qualified personnel in accordance with applicable and sound engineering principles."

b. "When national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials, etc.), implement measures to provide equivalent protection and ensures safety equal to or superior to the intent of the ASME code. Measures shall include:

(1) design drawings, sketches, and calculations shall be reviewed and approved by an independent design professional;

(2) qualified personnel shall be used to perform examinations and inspections of materials, in-process fabrications, non-destructive tests, and acceptance tests;

(3) documentation, traceability, and accountability shall be maintained for each unique pressure vessel or system, including descriptions of design, pressure, testing, operation, repair, and maintenance."

DOE-EH has not issued a guidance document to adequately define the requirements of DOE Order 440.1A, Attachment 2, Section 20, items a and c, for pressure safety. Draft guidance documents have been developed, but not approved. BBWI is required by contract to implement DOE Order 440.1A, but a review of programs and procedures indicated that BBWI does not have a comprehensive pressure safety program in place at the INEEL to meet the requirements of DOE O 440.1A. Both DOE-ID and BBWI have fully implemented a portion of the pressure safety order with respect to programs for pressure vessels and boilers, but not other high pressure systems. AGEC had no documentation to support implementation of DOE O 440.1A as required by the subcontract. The AGEC Health and Safety Program did not address high pressure safety.

The Board concluded that DOE Order 440.1A had not been fully defined or implemented, which resulted in a less than adequate evaluation of administrative controls.

3.1.3.3. Personal Protective Equipment

The personal protective equipment requirements for the activity were established in both the HASP and the work order. Personal protective equipment consisted of safety shoes, leather gloves, safety glasses, and hard hats. AGEC personnel complied with the PPE requirements of the HASP and work order.

The Board could not conclude whether the PPE prescribed by the work order would have been adequate to protect the injured operator from injury, had proper engineered safety barriers been in place. The safety glasses failed to provide adequate protection to prevent injury to the injured operator.

The Board concluded that AGEC's Health and Safety Program was inadequate. The work planning by both AGEC and BBWI did not ensure that this work was performed in a safe manner by identifying and implementing adequate engineering, administrative, and PPE controls. Additionally, the BBWI STD-101 work control process did not provide for a standards-based determination to mitigate hazards related to all high pressure systems.

3.1.4. Perform Work Within Controls

The objective of performing work within controls is to ensure that hazards identified are mitigated as described and engineered into work documents used by personnel performing work at the INEEL, including subcontractor personnel. The requirement for performing work within controls is defined in BBWI's Integrated Safety Management System (ISMS), PDD-1004. The BBWI ISMS Core Function 4 is "Perform Work Within Controls." Controls are identified and implemented before starting work and workers must comply with written work documents.

The subcontract required AGEC to implement an INEEL VPP/ISMS equivalent program. Criteria 9 of the INEEL VPP/ISMS pre-qualification application required work to be performed within the controls described. During the conduct of the investigation, the Board identified the following examples where work was not performed within established controls:

- AGEC was contractually obligated to perform work in accordance with an Integrated Safety Management Program. However, as discussed in section 3.1.6, ISM was not fully implemented.
- Grout truck drivers were allowed inside the restricted work area without receiving a site briefing, as required by the HASP.
- The subcontract required a Job Hazard Analysis be completed, but none was prepared.
- High pressure training was identified in the HASP, but was neither developed nor given to all appropriate workers.
- Hoisting and rigging practices were observed that were not in accordance with the requirements of the DOE Hoisting and Rigging Standard. Specifically, workers were under a suspended load, pulling on loaded lifting slings, and not centering the load on the fork truck tines. The Board informed the DOE-ID Waste Management Operations Division (WMOD) and ERD who in turn notified the RWMC Facility Manager of these hoisting and rigging concerns via a letter dated November 1, 2001.
- BBWI workers were observed using bare hands while performing contamination control bagging operations, contrary to PPE requirements found in the work order.

Prior to mobilization at the INEEL, BBWI performed a Management Self Assessment (MSA). The scope of the MSA was defined in the MSA Plan for the Operable Unit 7-3/14 In Situ Grouting Treatablility Study Field Test. BBWI does not have a procedure for performing MSAs, however, MCP-2783, *Startup and Restart of Nuclear Facilities,* provides limited guidance for a Line Management Assessment or MSA. The process defined in MCP-2783 may be used as the framework for conducting an MSA. One portion of the MSA included the observation of an SO test. The SO test only included

the operation of the AGEC drill rig to ensure proper alignment with the thrust block and to verify implementation of the bagging process. Several deficiencies were identified with respect to the implementation of this MSA including:

- The MSA did not recognize that the SO test was not proceduralized in accordance with MCP-3056, Test Control.
- The MSA failed to recognize that the SO test did not include observed operation of the entire grouting and drilling operation. Only an inspection of the grouting pumps and associated equipment was made.
- The MSA checklists were not completed by all team members.
- All MSA pre-start and post-start findings were not tracked in accordance with MCP-598, Corrective Action System.
- The MSA team failed to recognize the deficiencies in the AGEC quality control program with respect to replacement parts and their specified ratings.
- The MSA failed to determine that AGEC did not perform any type of job hazard analysis (AGEC's Activity Hazard Analysis) for grouting and drilling operations
- RWMC personnel did not participate in the MSA.

Pre-job briefings were performed daily by BBWI and AGEC. The AGEC briefings lacked rigor in identifying hazards and mitigative measures for AGEC grouting and drilling operations. The AGEC Daily Field Project Sheet included sections for hazards and controls, but personnel performing the briefing did not adequately complete the form prior to the briefing.

A critical spares list, required by the subcontract, was neither generated, reviewed nor approved. No critical parts list was available at the job site and not all spare parts were available at the job site.

AGEC did not effectively implement their own Quality Assurance Program to ensure all equipment and parts for the activity had specifications with working pressure ratings appropriate for the triplex pump normal working pressure of 6,000 psi. The 45° swivel elbow had a working pressure rating of 3000 psi. It remains unclear if the straight swivel adapter, hoses and repaired hose fittings had the appropriate working pressure ratings.

The periodic maintenance requirements for the triplex pump manufacturer's operating and maintenance manual were not documented. No documented evidence of periodic maintenance of the automatic shutdown device was provided to the Board.

The Board concluded that AGEC and BBWI did not fully implement ISM for this high pressure grouting operation. Hazards were not completely identified, their controls could not be developed and consequently work was conducted in an unstructured manner. The Board also concluded that BBWI does not have a proceduralized method to perform an effective Management Self-Assessment. This is discussed further in Section 3.1.6.

3.1.5. Feedback and Improvement

Feedback and improvement processes at INEEL consisted of the following mechanisms: assessment and corrective action, analysis of performance information, and lessons-learned processes.

DOE-ID completed an Integrated Safety Management System Phase II Verification in June 2000. The report identified that one of the most significant weaknesses needing both BBWI and DOE-ID attention was ensuring the flowdown of safety requirements to subcontractors, particularly vendor subcontractors. The report further stated that both DOE-ID and BBWI management needed to ensure subcontractors managed and performed work in accordance with a documented ISM system, interfaces between facility operations and other programs were defined and understood, and problems associated with the implementation of an issues management program were effectively corrected.

An independent assessment team from DOE-ID Performance Assurance Division (PAD) performed a validation review of both DOE-ID and contractor actions taken to address the Judgments of Need from the July 1998 CO_2 accident in September 2000. The assessment report noted that improvements were made in many areas of ISM, however, problems still existed in conformance to procedures and conduct of operations in performing work. PAD recommended that measures be taken by both DOE-ID and BBWI to ensure effective corrective actions were implemented to preclude the recurrence of unstructured work, which was a root cause of the July 1998 CO_2 accident.

A Focused Safety Management Evaluation (FSME) was conducted in December 2000, and identified the need to strengthen work planning processes including the flow down of ISM hazard analysis and controls to subcontractors. Areas of concern noted in the FSME report included defining the scope of work, analyzing the hazards and developing and implementing the controls. A corrective action plan was developed in March 2001 that addressed the results of the Focused Safety Management Evaluation. In September 2001 corrective actions were completed for subcontractor issues identified in the FSME.

During the conduct of the investigation, the Board identified that the requirement for AGEC to develop and implement ISMS was contained in the subcontract between BBWI and AGEC. Although the requirement was included in the subcontract, AGEC was unable to effectively implement the requirement which resulted in deficiencies in all elements of ISM. Further, BBWI accepted unstructured work to proceed without effective hazard controls to protect workers.

The Board concluded that corrective actions implemented by BBWI in response to deficiencies identified by DOE in implementing ISM and subcontractor safety were not effective in preventing recurrence.

Self-assessments were performed by the DOE-ID Environmental Restoration Division (ERD) during each quarter of the fiscal year. A self-assessment, conducted in September 2001, evaluated the interaction of ERD WAG managers, who have line management responsibility for projects and activities conducted at WAGs and the Facility Representatives who perform oversight of work. The self-assessment report discussed the lack of communication between Facility Representatives and ER WAG managers.

The Board interviewed DOE-ID ERD, Operational Safety (OSD), and WMOD managers and staff to understand the interaction among these organizations during the planning and execution of the high pressure grouting operations. DOE-ID ERD line management, who was responsible for the safety of the grouting activities, did not involve OSD SME's

in the planning and execution of grouting activities. DOE-ID ERD line management interaction with WMOD management and staff was inadequate to assure RWMC Facility Representatives were aware of the field tests. As a result, the Facility Representatives did not conduct oversight of AGEC's high pressure grouting operation.

Inadequate attention on the part of DOE-ID to effectively correct this organizational deficiency contributed to inadequate definition of interfaces among DOE-ID ERD programs and both OSD and WMOD management and staff during the planning and execution of high pressure grouting operations.

The Board concluded that corrective actions implemented by DOE-ID to address organizational interface problems identified in June 2000 were not effective to prevent recurrence.

The Board reviewed BBWI's process used to pre-qualify subcontractors to VPP\ISMS and QA requirements. BBWI's process for pre-qualification of subcontractors was described in Form 540.12, Hazard Level I, "Qualification Application Construction, Maintenance or Services," and required AGEC to demonstrate that its safety program was compliant with INEEL's VPP/ISMS. AGEC submitted an outline of their VPP/ISMS program to BBWI, but detailed VPP/ISMS program implementation documentation was not required to be submitted. BBWI approved AGEC's VPP/ISMS program outline on July 19, 2000, and included AGEC on the INEEL Pre-Qualification List for Construction Contractors. The Board identified numerous deficiencies in AGEC's implementation of its VPP/ISMS program as outlined in its pre-qualification submittal to BBWI. (See section 3.1.6)

The Board concluded that these deficiencies were mainly caused by a lack of program documentation to implement AGEC's VPP/ISMS program. Further, BBWI accountability mechanisms were inadequate to ensure ESH & QA contractual requirements were implemented.

Analysis of Performance Information

In evaluating how DOE-ID and BBWI had analyzed performance information, the Board reviewed recent ORPS and CAIRS reports to determine whether precursors existed before the accident. Since August 16, 1999, INEEL experienced six incidents involving personal injuries while subcontractors were performing drilling activities. Two incidents involved injuries sustained by subcontractors when pressurized systems failed. In one case, a subcontractor injury resulted in 10 restricted workdays when the worker was injured while clearing an obstruction from a high-pressure hose. (See Other INEEL Subcontractor Drilling Events Table)

Other INEEL Subcontractor Drilling Events

Event Date/Location	Report #	Event Summary	Actions Taken
08/16/1999 O.M.R.E. Drilling and Sampling Site	CAIRS # 1999156	Operator rotated drill head while helper's hand was between wrench and stop. Helper's middle finger was smashed and lacerated - 3 Restricted Workdays.	Construction Management (CM) curtailed operations, conducted an investigation, and conducted additional training on HASP, HPSC, stop work authority, and JSA requirements.
10/21/1999 RWMC Subsurface Disposal Area	ORPS # ID—BBWI-RWMC-1999-0001	While using a drill rig fitted with a drilling solids/air separator, the main hose connection came loose and sprayed the driller and helper with pressurized rock particles.	Work was stopped, area secured, and injured personnel were taken to Site Medical Facility. Manufacturer of separator assembly was notified.
12/15/1999 Outside RWMC Perimeter Fence	CAIRS # 1999244	Employee was placing rod plate under tool joint on drill rig. Employee's middle finger slipped under the plate causing his fingertip to break and lacerate the finger, requiring 10 sutures.	Handles on plate to be modified to eliminate possibility of recurrence.
01/27/2000 Between Gun Range and TRA	CAIRS # 2000021	While adding a drill rod to the drill head, the rod dropped, pinching the drill helper's finger resulting in a laceration to his left index finger, requiring 26 sutures - 26 Restricted Workdays.	Work was stopped and the injured employee treated. The CM conducted a critique, the JSA was modified, and the subcontractor will pursue a design modification with the manufacturer.

01/28/2000 INTEC New Percolation Pond	CAIRS # 2000022	Employee was attempting to clear an obstruction from high-pressure air hose. The obstruction cleared and the hose whipped back striking the employee in the hand. Employee's left thumb was broken, and the rest of his fingers on that hand were bruised - 10 Restricted workdays.	Accident was reviewed to identify lessons learned. A special tool was built to properly secure the hose in the future, and the tool was added to the JSA. All employees were retrained.
05/05/2000 INTEC Potable Water Pumps	ORPS # ID--BBWI-LANDLORD-2000-0015	Subcontractor set up well drilling rig over one of two potable well pumps to pull and replace the pump. The pump was partially pulled then secured and left for the day. Later it was determined this was the wrong pump and the electrical leads had been lifted and were still energized.	Electrical energy to the exposed leads was isolated. INTEC SAD mandated that all work on INTEC should be performed under an INTEC work order, including work outside INTEC fence within sight of INTEC.

The Board concluded that a series of subcontractor drilling events occurred at INEEL prior to the accident. Corrective actions developed and implemented in response to these events were not effective to prevent recurrence.

The Board reviewed mechanisms for communication, dissemination and use of lessons learned involving subcontractors. The Board reviewed *INEEL Program Description Document INEEL Integrated Safety Management System* (PDD-1004) to understand BBWI's process for integrating subcontractors into feedback and improvement processes at INEEL. PDD-1004 established the use of MCP-192, *Lessons Learned System,* to generate, analyze, and disseminate lessons learned information. Although MCP-192 addressed the lessons learned process for BBWI employees, it lacked guidance and direction regarding the mechanism used to ensure lessons learned available to BBWI employees were communicated and used by subcontractors to plan work activities.

The Board searched the Lesson Learned Management System and found many lessons learned applicable to subcontractor drilling operations. Of note were three lessons learned dated January 25, 2000, July 31, 2000, and August 29, 2001, that identified deficiencies in drilling operations and discussed recommended actions to address the root causes of the deficiencies. Use of these lessons learned during work planning would have assisted in ensuring operating procedures were established, task specific

hazards were identified and understood, controls were established to protect workers and subcontractor VPP/ISM processes were established and fully implemented.

As part of the subcontractor pre-qualification process, AGEC provided BBWI with an outline of the process used by AGEC to implement feedback and improvement for its company. This process relied on tailgate meetings to promote improvements in AGEC's operations. AGEC did not make system improvements to the grouting system, after a series of grout leaks, high operating pressures and fitting failures occurred prior to mobilization to the INEEL.

The Board concluded the following:

BBWI's lessons learned system lacks implementation guidance and direction to ensure subcontractors have access to INEEL lessons learned during work planning and execution.

AGEC's feedback and improvement process was inadequate to ensure high-pressure grouting system deficiencies were corrected after a series of system failures occurred.

3.1.6. Management Systems

The integration of DOE-ID ER programs with both facility and support functions has been a recurring problem at the INEEL. This problem was recently identified during the Phase II ISMS Verification in June 2000. Attempts by DOE-ID management and staff to correct the problem informally were not effective. Prior to the day of the accident, DOE-ID OSD had not been involved in the planning and execution of the In Situ Grouting Feasibility Study and oversight of the field activities were not performed by WMOD staff assigned to RWMC.

During the conduct of the investigation, the Board evaluated the implementation of safety requirements for AGEC work being conducted on the day of the accident. As part of this evaluation the implementation of requirements for safe operation of high pressure grouting equipment were reviewed to determine compliance with DOE Order 440. 1A. The Board identified that a set of requirements or standards were not established to protect workers from the hazards associated with high pressure grouting. This was caused, in part, because DOE-EH had not developed implementation guidance for DOE Order 440.1A, in the area of pressure safety and existing requirements of the Order were unclear. Lacking guidance and clear Order requirements, the INEEL's pressure safety requirements as applied to high pressure grouting operations were not established and, therefore, could not be incorporated into STD-101 Integrated Work Control Process.

The Board also reviewed the BBWI programs used to pre-qualify subcontractors to VPP/ISMS and QA requirements and noted several weaknesses. BBWI had not established a rigorous pre-qualification process to ensure that VPP/ISMS requirements were implemented by subcontractors. BBWI's accountability mechanisms were also not effective in ensuring that contractually identified ESH&QA requirements were

implemented by subcontractors or that subcontract requirements were met. Examples include:

- BBWI Quality Procurement allowed AGEC to become an NQA-1 supplier for this subcontract with deficiencies in its QA/QC plan,
- BBWI failed to ensure that AGEC vendor data submittals including calibration data for the flow totalizer were received by procurement document control,
- BBWI allowed AGEC to perform work without the required staffing as stipulated in the subcontract, and,
- BBWI failed to ensure AGEC implemented its ISM System or followed its QA Plan.

The Board concluded that AGEC failed to follow and BBWI did not adequately enforce the provisions or requirements of the subcontract.

The INEEL's ISMS program was recently changed to incorporate the results of a DOE-EH FSME. The FSME noted that flow down and implementation of the five core functions of ISM to control work performed by subcontractors was problematic and needed attention by BBWI. These weaknesses were also identified by DOE-ID during the conduct of various assessments and by Type A Accident Investigation Boards prior to the FSME. The impact of not implementing the five core functions of ISM program for all INEEL activities, including work performed by all subcontractors, was not only highlighted by serious accidents, but also numerous near miss events and worker injuries prior to this accident.

Weaknesses existed in all elements of the INEEL ISM program as it applied to service contracting mechanisms for the In Situ Grouting Treatability Study. As an example, a task-level hazard analysis was not performed to identify hazards associated with operating the high pressure grouting system. Since a hazard analysis was not performed, effective controls were not established to protect workers operating high pressure grouting system.

Corrective actions implemented by BBWI to address ISM weaknesses, identified by numerous DOE-ID assessments, Type A investigations and the FSME, were not effective to correct these weaknesses prior to the accident. The Board determined senior level BBWI management had not stressed the need to ensure issues management was effective to prevent recurrence of long standing systemic ISM deficiencies.

The Board also determined that numerous grout pumping system deficiencies were identified during testing in January 1995. Both AGEC and BBWI failed to recognize their significance so that high pressure grouting systems improvements could be implemented.

The Board interviewed DOE-ID ERD, OSD, PAD, WMOD and Quality Assurance Division management and staff to determine the extent of their interaction with BBWI line management for the In Situ Grouting Feasibility Study. These interviews substantiated that DOE-ID oversight was not effectively performed for BBWI ER planning and execution of the In Situ Grouting Feasibility Study. For example:

- DOE-ID did not ensure BBWI enforced the implementation of ESH&QA requirements stipulated in the AGEC subcontract. As a result AGEC was not held accountable for fully implementing their quality assurance plan or ISM.
- DOE-ID oversight of the planning and execution of the In Situ Grouting Feasibility Study was inadequate to ensure BBWI organizations fulfilled their ESH & QA responsibilities.

The Board concluded that deficiencies in the subcontractor safety management systems at INEEL indicated a need for line management to ensure effective implementation of ISM. BBWI senior management needs to develop and implement processes to ensure effective corrective actions are implemented to prevent recurrence of DOE-identified ISMS and subcontractor safety deficiencies.

BBWI's ER organization was based on a foundation of project teams supported by ER and other INEEL functional staff. Imperative to the success of a project team is the leadership of the PM and the skills and abilities of its members. The PM has the responsibility to assemble a project team with appropriate skills and qualifications and to make sure their roles and responsibilities are clearly understood. Interviews with BBWI ESH & QA, Environmental Management (EM), and Site Operations management and staff were conducted by the Board to determine an understanding of their roles and responsibilities as they applied to the in situ grouting activities. The Board determined that several members of the project team did not have a clear understanding of their roles and responsibilities. For example, the ER PMP describes the roles and responsibilities of each position within an ER project, but prior to the accident, only the WAG 7 Manager and PM were aware the document existed. Also, the subcontract with AGEC required the BBWI project quality engineer to inspect AGEC's equipment and to document approval for delivery to the INEEL. However, the BBWI Project Quality Engineer was not aware of this requirement.

The ER QAP describes the quality assurance systems used to manage, perform, and assess work of the BBWI ER Directorate. Section A-5 of the ER QAP implements the requirements of DOE-Order 414.1A, and describes how the quality assurance program is implemented on ER projects. The Board noted several areas were BBWI failed to follow the requirements of the ER QAP. Examples include:

- BBWI did not fully define the QA acceptance or inspection criteria during the procurement process,
- BBWI did not ensure that an effective MSA was performed or that issues discovered were placed into the INEEL issues tracking system, and,
- BBWI did not ensure that personnel performing work had the required skills or abilities to perform their work safely.

The Board concluded that BBWI failed to follow and implement the ER QAP for the ISG treatability study.

Readiness reviews and readiness assessments are performed as determined by the project manager in accordance with direction given in MCP-2783, "Startup and Restart of Nuclear Facilities." Because of the low risk nature of some activities, some projects are determined to be ready by using an MSA, which are less prescriptive than a readiness review or readiness assessment. The RWMC Operations Safety Board and

the situ grouting PM determined that an MSA would be appropriate for the in situ grouting treatability study. MCP-2783 does not give criteria for performing a MSA, but allowed the use of the readiness assessment criteria or the development of checklists using a graded approach. As part of the investigation, the Board interviewed the members of the MSA team and reviewed the checklists used for the MSA. The Board determined that an expert-based process had been used to develop checklists that had vague completion criteria. The checklists failed to incorporate requirements from the subcontract, and when used, failed to identify QA and ISMS deficiencies. The Board also noted that the RWMC Site Area Director Self Assessment Program failed to include assessments of BBWI ER projects being performed at the CTPS.

Guiding Principles of Integrated Safety Management

Examples of Implementation Deficiencies

Guiding Principle 1: Line Management Is Directly Responsible for the Protection of the Public, Workers, and the Environment.

- DOE-ID ERD, DOE-ID WMOD, BBWI and AGEC line management did not ensure that ISMS was implemented for high pressure grouting operations.
- BBWI line management did not ensure that AGEC met contractual requirements stipulated in the Statement of Work.
- DOE-ID and BBWI were not effective in implementing corrective actions for precursor events.
- BBWI line management, on-site the day of the accident, permitted AGEC to conduct ISG operations without the required number of AGEC personnel.

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.

- Responsibilities and authorities for DOE-ID line management were not established in the Health and Safety Plan.
- DOE-ID and BBWI have not established and implemented effective mechanisms to ensure implementation of VPP/ISM requirements by subcontractors.
- AGEC's Health and Safety Program did not identify safety and health responsibilities.

Guiding Principle 3: Personnel Shall Possess the Experience, Knowledge, Skills, and Abilities That Are Necessary to Discharge Their Responsibilities.

- AGEC's operator training was inadequate to ensure the operator of the triplex pump achieved the level of knowledge and skill to safely operate and maintain the grout pumping and injection system.
- AGEC operators were not fully aware of the safety features of the equipment.

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 Operations Are Planned and Performed.

- AGEC conducted ISG operations the day of the accident with three personnel and not four personnel as required by the subcontract.
- The lack of oversight of grouting activities was influenced by other program priorities.

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.

- Requirements associated with the high pressure grouting system were not identified as required by DOE Order 440.1A, Chapter 6, *Pressure Safety* prior to initiating ISG operations at the Cold Test Pit South
- AGEC did not use controlled procedures for the operation of ISG equipment

Guiding Principle 6: Administrative and Engineering Controls To Prevent and Mitigate Hazards Shall Be Tailored to the Work Being Performed and Associated Hazards.

- The implementation of the BBWI hazard identification and analysis process was inadequate to identify and mitigate the hazards associated with high pressure grouting and drilling equipment.
- Adequate engineering controls were not established to ensure worker safety while operating the triplex pump.

Guiding Principle 7: The Conditions and Requirements To Be Satisfied for Operations To Be Initiated and Conducted Shall Be Clearly Established and Agreed Upon.

- BBWI did not establish controls to ensure AGEC had developed procedures for the operation on the high pressure ISG system
- A job safety analysis for the high pressure grouting operation was not developed by AGEC.
- BBWI allowed the high pressure grouting activities to continue without ensuring a job safety analysis was developed and approved.

Core Functions of Integrated Safety Management

Examples of Implementation Deficiencies
Core Function 1: Define the Scope of Work
• Statement of Work did not fully define quality acceptance criteria.
• Scope of work did not incorporate lessons learned.
Core Function 2: Analyze the Hazards
• Standard 101 does not adequately identify and mitigate the hazard for high pressure grouting operations.
• AGEC failed to analyze all the hazards associated with nozzle plugging events.
Core Function 3: Develop and Implement Controls
• No operating procedures were developed by AGEC
• BBWI failed to analyze, identify and control all work hazards.
Core Function 4: Perform Work Safely
• Unstructured work was accepted by BBWI
• AGEC did not maintain the equipment according to manufacturer's recommendations.
Core Function 5: Feedback and Improvement
• AGEC's feedback and improvement mechanism contained in VPP/ISMS program failed to identify previous equipment deficiencies and correct them prior to field testing at INEEL.
• Weakness in control of work performed by subcontractors has been a long standing issue at INEEL.

3.2. Barrier Analysis

Barrier Analysis is a tool that examines barriers that are placed between a hazard and a target. The hazard analyzed under this Barrier Analysis was the high pressure used in the injection grouting system. The barriers analyzed included administrative barriers and physical barriers that were either in place or should have been in place to prevent the target (the injured Operator) from being injured. The results of the Barrier Analysis, shown in Appendix C, were incorporated into the Events and Causal Factors Analysis, shown in Appendix B.

3.3. Change Analysis

Change Analysis is a process that examines intended and unintended changes to the system and its consequence. It examines the accident situation compared to an accident free situation and determines the differences. These differences are then analyzed for their effect on the accident and the results are then incorporated into the Events and Causal Factors Analysis as shown in Appendix B. The results of the Change Analysis is a tool that reinforces the results of the Barrier Analysis.

3.4. Causal Factors Analyzed

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

Direct Cause – the immediate events or conditions that caused the accident

The direct cause of the accident was a failure of a 45° swivel elbow that was underrated for the system in which it was used. The rated working pressure for the 45° swivel elbow was 3000 psi and the high-pressure grouting operation had a normal working pressure of 6000 psi.

Contributing Causes – events or conditions that collectively with other causes increased the likelihood of an accident but that individually did not cause the accident

Root Causes – causal factors that, if corrected, would prevent recurrence of the same or similar accidents Barrier Analysis

ROOT CAUSES AND CAUSAL FACTORS SUMMARY

ROOT CAUSE	CAUSAL FACTORS
AGEC failed to follow and BBWI did not adequately enforce subcontract requirements	• AGEC deployed with 3 personnel instead of the contractually required 4 personnel on the day of the accident • AGEC Vendor Data was not received by the BBWI Procurement Document Control personnel specified in the contract • AGEC's Quality Assurance Program was not followed and was not enforced by BBWI • AGEC used BBWI supplied personnel and fork lift to remove and replace AGEC owned shroud equipment • AGEC failed to recognize significance of hose and fitting failures and failed to take corrective actions that would prevent recurrence • BBWI Quality Procurement allowed AGEC to become NQA-1 supplier with deficiencies in Company QA Plan • AGEC failed to submit Vendor Data to BBWI Procurement Quality Document Control • BBWI did not oversee the process to assure AGEC QA Plan and vendor data met contract requirements • AGEC failed to implement the Company QA Plan to ensure equipment used was adequate for work performed • BBWI failed to ensure AGEC Company QA Plan was implemented • **DIRECT CAUSE** - AGEC used an under rated (3,000 psi) 45° swivel elbow in grout system (working pressure 6,000 psi)

CONTRIBUTING CAUSES AND CAUSAL FACTORS SUMMARY

CONTRIBUTING CAUSES	CAUSAL FACTORS
DOE did not develop implementation guidance regarding "Pressure Systems" requirements contained in DOE Order 440.1A. (Contributing Cause)	• BBWI did not establish a comprehensive pressure safety program in accordance with DOE O 440.1A • DOE-ID did not ensure development and implementation of a comprehensive pressure safety program in accordance with DOE O 440.1A • DOE-EH did not provide guidance on pressure safety from DOE O 440.1A
Interface among appropriate DOE-ID organizations (e.g., OSD, WMOD, and ERD) was inadequate to ensure effective oversight of ER activities	• DOE-ID ERD interface with Operations and OSD was inadequate due to lack of communication on activities

CONTRIBUTING CAUSES AND CAUSAL FACTORS SUMMARY

CONTRIBUTING CAUSES	CAUSAL FACTORS
DOE-ID oversight of this project was inadequate to ensure BBWI enforced terms and conditions of the subcontract and BBWI ER work was planned and executed safely	• DOE-ID did not provide effective oversight of the development of Statement of Work to ensure quality acceptance criteria was well defined and Lessons Learned from previous events incorporated • Inadequate DOE-ID oversight of AGEC operations
BBWI's process for ensuring implementation of ISM by subcontractors was inadequate to ensure worker safety	• BBWI review of HASP did not identify or define hazard identification and did not identify any mitigating controls • HASP did not identify all hazards associated with work to be performed • Equipment layout was not addressed in HASP • AGEC did not perform a task level hazard analysis for the work being performed • AGEC's safety program had inadequate task level hazard analysis • INEEL VPP/ISMS Pre-Qualification Questionnaire was inadequate to evaluate AGEC VPP/ISMS program • Training was not adequate to ensure safe operations of the high pressure grouting system • No operating procedures were developed to control grouting systems safely
BBWI failed to follow and implement the ER QAP for the ISG Treatability Study	• No well defined Quality Acceptance criteria or Lessons Learned established in the Statement of Work • Project QA Engineer did not follow the ER QAP and did not inspect and accept AGEC equipment for delivery • Nine of 18 NQA-1 quality criteria requirements in AGEC's QAP were not contractual requirements
BBWI's work control process failed to adequately identify hazards and controls for high pressure systems	• Hazard Profile Screening Checklist was incomplete and lacks hazard identification for all high pressure systems • Hazard Mitigation Guide was incomplete and lacks controls for all high pressure systems • Plugging of injection nozzles was not identified as a hazard • AGEC and BBWI failed to analyze and mitigate hazard associated with nozzle plugging
BBWI feedback and improvement mechanisms were ineffective in identifying deficiencies, precursor events and opportunities for improvement for incorporation into the work planning and execution processes	• Several precursor events were noted • Statement of Work did not include Lessons Learned • BBWI failed to track issues from a MSA in company issue management system to track identified issues to closure • BBWI management did not stress the need to use the issue management system to track identified issues to closure

CONTRIBUTING CAUSES AND CAUSAL FACTORS SUMMARY

CONTRIBUTING CAUSES	CAUSAL FACTORS
MSA process was “expert-based” and did not identify QA and ISM deficiencies	• BBWI does not have a proceduralized method to perform an effective Management Self Assessment • MSA lacked rigor and discipline • All MSA checklists did not have acceptance criteria • Did not evaluate or inspect entire high pressure grouting process

4. JUDGEMENTS OF NEED

Judgments of Need are managerial controls and safety measures necessary to prevent or minimize the probability or severity of a recurrence. They should be used in the development of corrective actions. The following table summarizes the root and contributing causes, and judgments of need.

Judgments Of Need

Root and Contributing Causes	Judgments of Need
AGEC failed to follow and BBWI did not adequately enforce subcontract requirements. (Root Cause)	Prior to continued use of the AGEC High Pressure Grouting System at the INEEL, BBWI needs to develop acceptance criteria, perform an Engineering and Quality Assurance evaluation and develop and implement all corrective actions to ensure safe operation. BBWI needs to ensure that ESH&QA requirements of subcontracts are effectively implemented and enforced. AGEC needs to improve their feedback and quality improvement processes to correct operational deficiencies.
DOE did not develop implementation guidance regarding "Pressure Systems" requirements contained in DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*. (Contributing Cause)	DOE-EH needs to develop guidance for pressure safety programs beyond those for pressure vessels. DOE-ID needs to provide guidance to BBWI for the development of a comprehensive pressure safety program.
Interface among appropriate DOE-ID organizations (e.g., OSD, WMOD, and ERD) was inadequate to ensure effective oversight of ER activities. (Contributing Cause)	DOE-ID needs to formalize a process to integrate Operations, Programs, and Support Functions to improve planning, execution, and oversight of ER activities.
DOE-ID Oversight of this project was inadequate to ensure: • BBWI enforced terms and conditions of the sub-contract, and • BBWI ER work was planned and executed safely. (Contributing Cause)	DOE-ID needs to improve oversight of BBWI to ensure ER work is planned and executed in accordance with established ESH&QA requirements.
BBWI's process for ensuring implementation of ISM by subcontractors was inadequate to ensure worker safety. (Contributing Cause)	BBWI needs to improve VPP/ISMS Evaluation Criteria used during the Subcontractor Evaluation Process to ensure subcontractors have adequate VPP/ISMS program documentation. BBWI needs to improve subcontractor oversight processes to ensure ISMS implementation.
BBWI failed to follow and implement the ER QAP for the In Situ Grouting Treatability Study. (Contributing Cause)	BBWI needs to define Quality Acceptance Criteria in this subcontract. BBWI needs to fully implement the ER QAP.

Judgments Of Need

Root and Contributing Causes	Judgments of Need
BBWI's work control process failed to adequately identify hazards and controls for high pressure systems. (Contributing Cause)	BBWI needs to evaluate and modify company work control processes (STD-101, MCP-3562, and MCP-3571) to ensure high pressure systems are adequately analyzed for hazards and controls.
BBWI feedback and improvement mechanisms were ineffective in identifying deficiencies, precursor events and opportunities for improvement for incorporation into the work planning and execution processes. (Contributing Cause)	BBWI needs to integrate subcontractors into BBWI's Lessons Learned Management System and ensure lessons learned are used to plan work. BBWI senior management needs to ensure that corrective actions in response to DOE-identified ISMS and subcontractor safety deficiencies are effective to prevent recurrence.
The BBWI Management Assessment process was "expert-based" and did not identify QA and ISM deficiencies. (Contributing Cause)	BBWI needs to establish requirements for performing management assessments for operational readiness.

5. Board Signatures

11-13-01
Raymond Furstenau, Director, TRA & SMC Division
Chairperson

11/13/01
Ronald Gill, Facility Engineer, SMC
Team Member, Trained Investigator

11-13-01
Nicole Hernandez, Facility Representative, RWMC/WROC
Team Member

11-13-01
Julie Finup, Facility Representative, RWMC/WROC
Team Member

11-13-01
Richard Caummisar, Industrial Safety Branch
Team Member

11/13/01
Robert Crowley, DOE-EH
Team Member, Trained Investigator

6. BOARD MEMBERS, ADVISORS AND STAFF

Raymond Furstenau, Director, TRA & SMC Division
Chairperson

Ronald Gill, Facility Engineer, SMC
Team Member, Trained Investigator

Nicole Hernandez, Facility Representative, RWMC/WROC
Team Member

Julie Finup, Facility Representative, RWMC/WROC
Team Member

Richard Caummisar, Industrial Safety Branch
Team Member

Robert Crowley, DOE-EH
Team Member, Trained Investigator

William Harker, Infrastructure Management Division, General Engineer
Board Advisor

William C. McQuiston, ESH&QA Management Systems Analyst
Board Advisor, Trained Investigator

Nancy Makey, ES&H Staff, BBWI
Administrative

Julie Hand, Senior Scientist/Engineer, BBWI
Administrative

Denise Glore, Attorney
Legal Counsel

Terry Krietz, DOE-EM
Observer

APPENDIX A
APPOINTMENT LETTERS

United States Government RECEIVED **Department of Energy**

memorandum

Idaho Operations Office

Reactor Programs/
TRA Facility

Date: October 16, 2001

Subject: Type B Accident Investigation – Personal Injury During Environmental Restoration Grouting Demonstration at RWMC Cold Test Pit South (TS-PAD-01-048)

To: Raymond V. Furstenau, Director
TRA & SMC Division, MS 7135

You are hereby appointed Chairperson of the Investigation Board to investigate the October 15, 2001, personal injury to an employee of Applied Geotechnical Engineering and Construction, a subcontractor of BWXT-Idaho, Inc., at the Idaho National Engineering and Environmental Laboratory. I have determined, based upon preliminary findings, that a Type B Accident Investigation as described in DOE Order 225.1A, *Accident Investigation* is warranted.

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

Richard Caummisar, Industrial Safety Branch, Team Member
Ronald Gill, TRA &SMC Division, Accident Investigator
Nicole Hernandez, Facility Representative, RWMC, Team Member
Julie Finup, Facility Representative, RWMC, Team Member

The scope of the Boards' investigation is to include, but is not limited to, identifying all relevant facts; analyzing the facts to determine the direct, contributing and root causes of the incident; developing conclusions; and determining judgments of need that, when implemented, should prevent the recurrence of the incident. The Board will focus on and specifically address the role of DOE and contractor organizations and Integrated Safety Management Systems, including oversight of subcontractors, as they may have contributed to the overall accident. The scope will also include an analysis of the application of lessons learned from similar accidents within the Department.

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

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

The final investigation report should be provided to me by November 16, 2001. Any delay to this date shall be justified and forwarded to this office. Discussions of the investigation and copies of the draft report will be controlled until I authorize release of the final report. If you have any questions, please contact me.

Mark W. Frei
Acting Manager

cc: S. L. Johnson, DOE-HQ, EM-1
R. S. Scott, DOE-HQ, EM-40
P. M. Golan, DOE-ID, EM-5
C. D. Stadler, DOE-HQ, EH-2
B. D. Shipp, BBWI, MS 3898
R. C. Nugent, BBWI, MS 3890
S. Phillips, AGEC
E. L. Watkins, BBWI, MS 3890

United States Government RECEIVED **Department of Energy**

memorandum

Idaho Operations Office

Reactor Programs/
TRA Facility

Date: October 17, 2001

Subject: Amended Team Charter for Type B Accident Investigation - Personal Injury During Environmental Restoration Grouting Demonstration at RWMC Cold Test Pit South (TS-PAD-01-049)

To: Raymond V. Furstenau, Director
TRA & SMC Division, MS 7135

Reference: Memorandum, Mark W. Frei to Raymond V. Furstenau, Subject: Type B Investigation – Personal Injury During Environmental Restoration Grouting Demonstration at RWMC Cold Test Pit South, dated October 16, 2001

In addition to the Investigative Team membership chartered by the referenced memorandum, I would like to add Bob Crowley of EH-2. Bob will bring extensive accident investigation experience including work on the recent Fermi Lab Accident. Please welcome Bob to the team and make full use of his expertise.

Mark W. Frei
Acting Manager

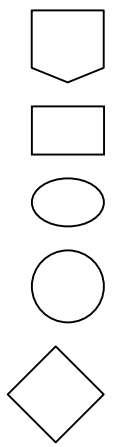
cc: S. L. Johnson, DOE-HQ, EM-1
P. M. Golan, DOE-ID, EM-1
R. S. Scott, DOE-ID, EM-40
C. D. Stadler, DOE-HQ, EH-2
B. D. Shipp, BBWI, MS 3898
R. C. Nugent, BBWI, MS 3890
E. L. Watkins, BBWI, MS 3890
S. Phillips, AGEC

APPENDIX B

EVENTS AND CAUSAL FACTORS CHART

KEY

	CONTRIBUTING CAUSES AND ROOT CAUSES
A	BBWI failed to follow and implement the ER QAP (PLN-694 Appendix A of the ER Project Management Plan) for the ISG Treatability Study
B	BBWI's process for ensuring implementation of ISM by subcontractors was inadequate to ensure worker safety
C	BBWI's work control process failed to adequately identify hazards and controls for high pressure systems
D	BBWI Feedback and Improvement mechanisms were ineffective in identifying deficiencies, precursor events and opportunities for improvement for incorporation into the work planning and execution processes
E	MSA process was "expert-based" and did not identify QA and ISM deficiencies
F	Interface among appropriate DOE-ID organizations (e.g., OSD, WMOD, and ERD) was inadequate to ensure effective oversight of ER activities
G	DOE-ID oversight of this project was inadequate to ensure BBWI enforced terms and conditions of the subcontract and BBWI ER work was planned and executed safely
H	AGEC failed to follow and BBWI did not adequately enforce subcontract requirements
I	DOE did not develop implementation guidance regarding "Pressure Systems" requirements contained in DOE Order 440.1A. (Contributing Cause)



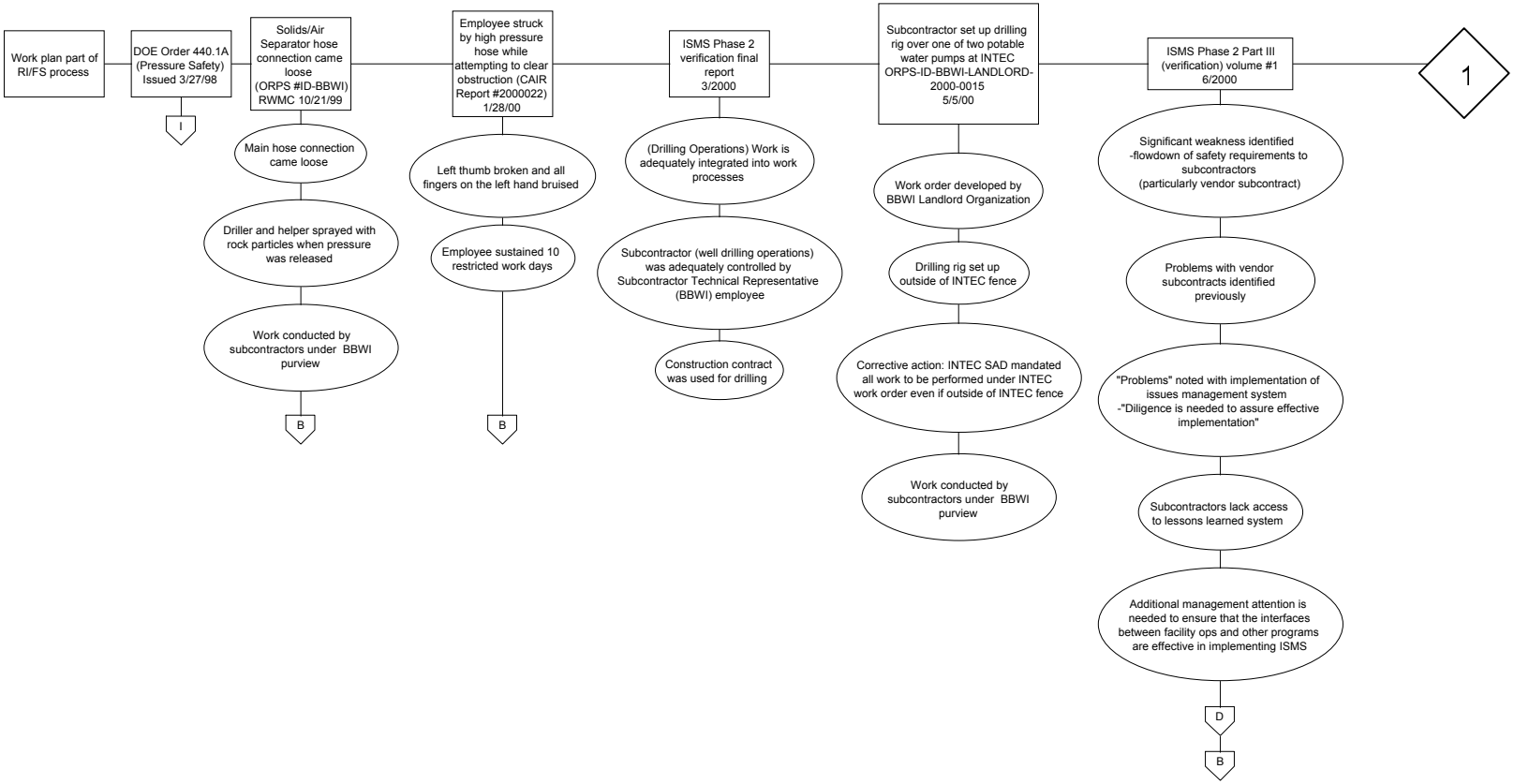
Root Causes
Contributing Causes

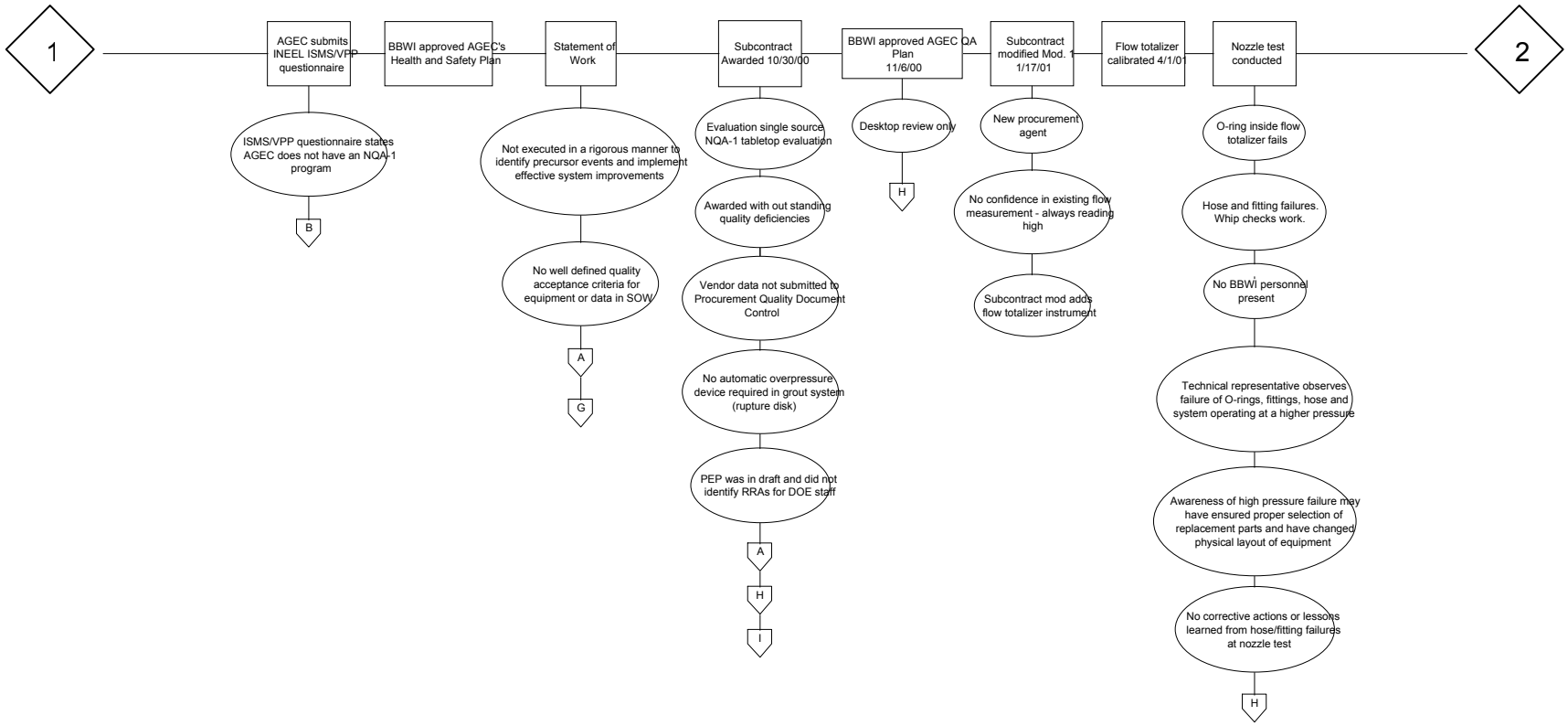
Events

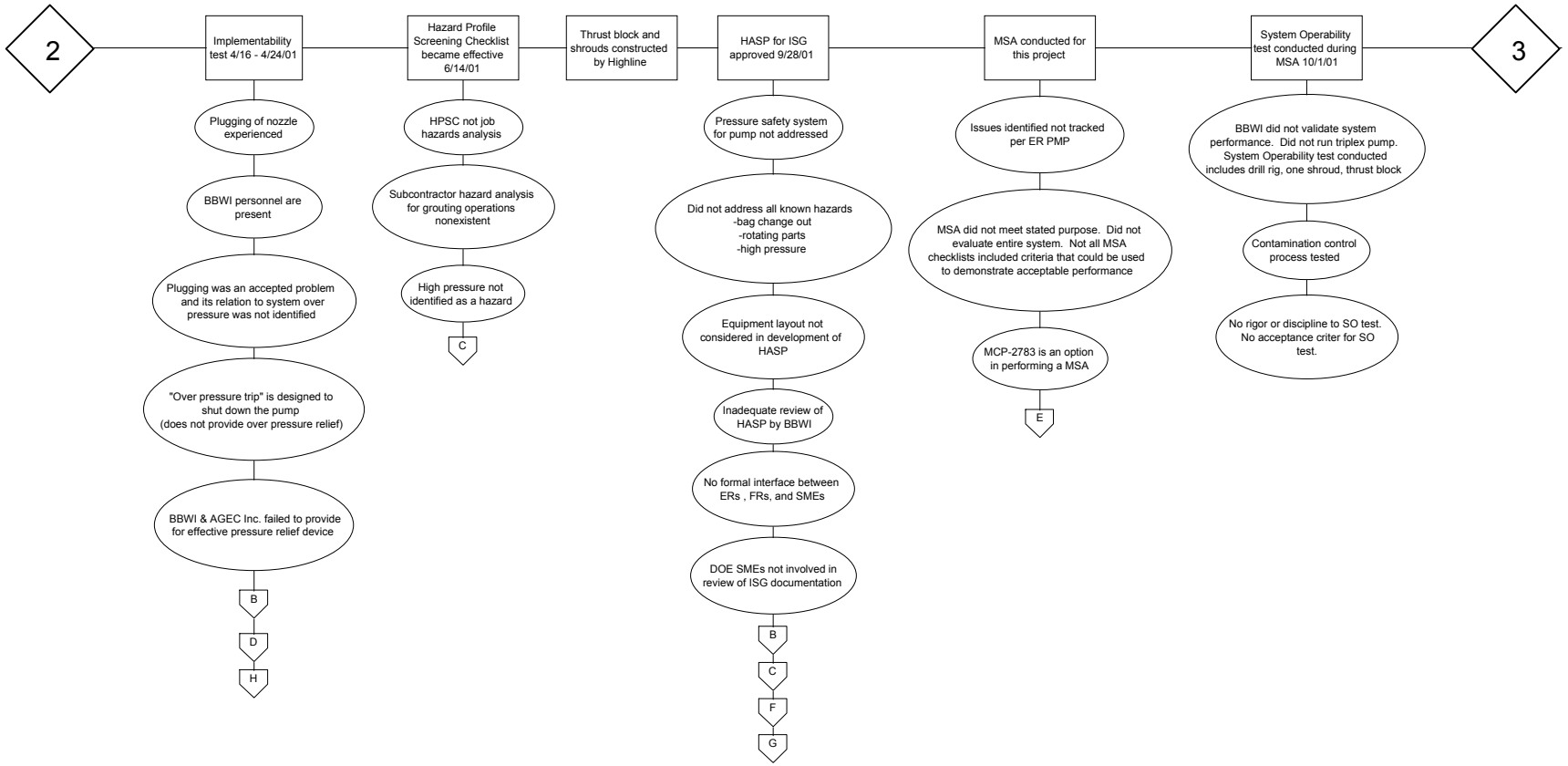
Conditions

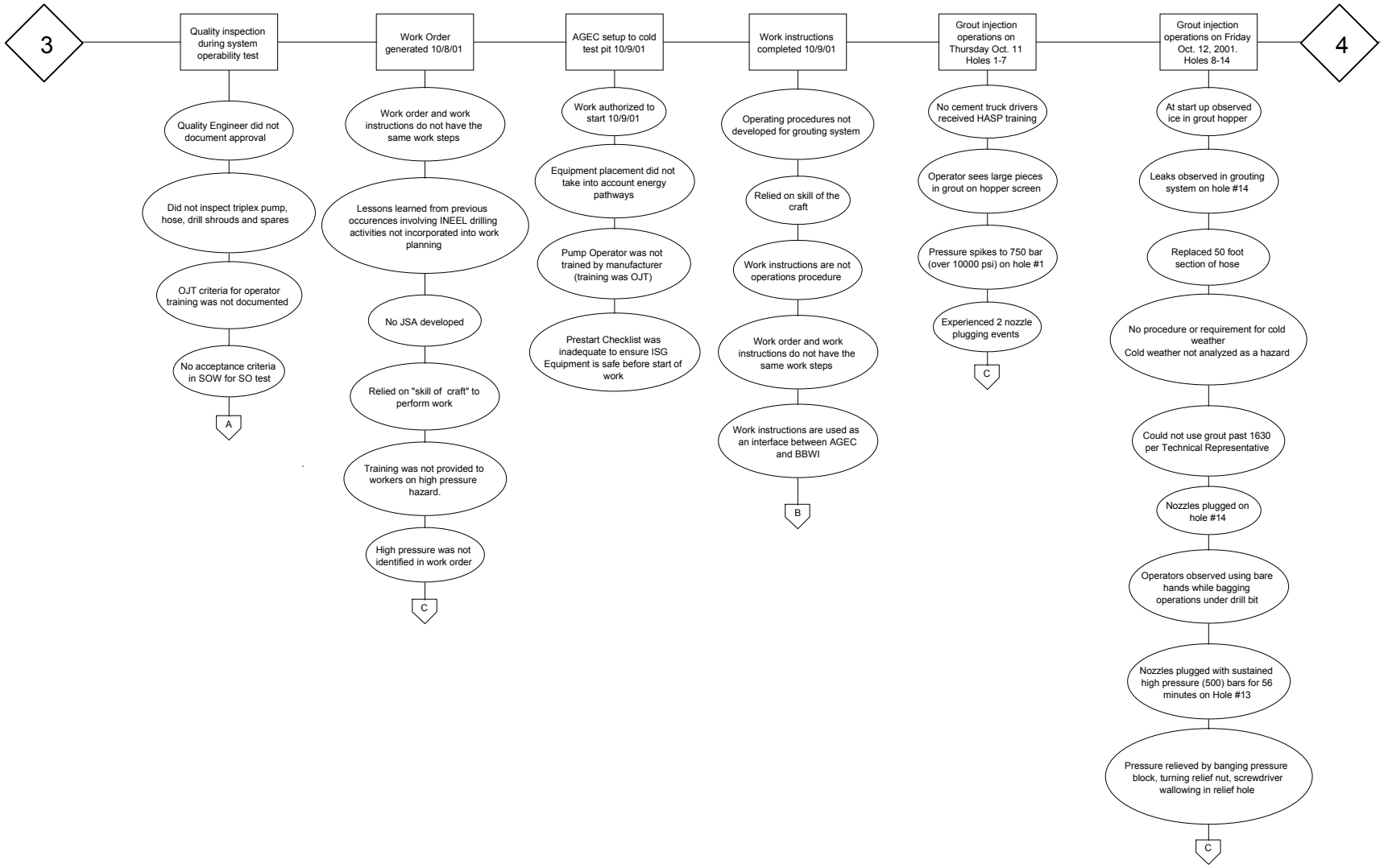
Accident and
Direct Cause

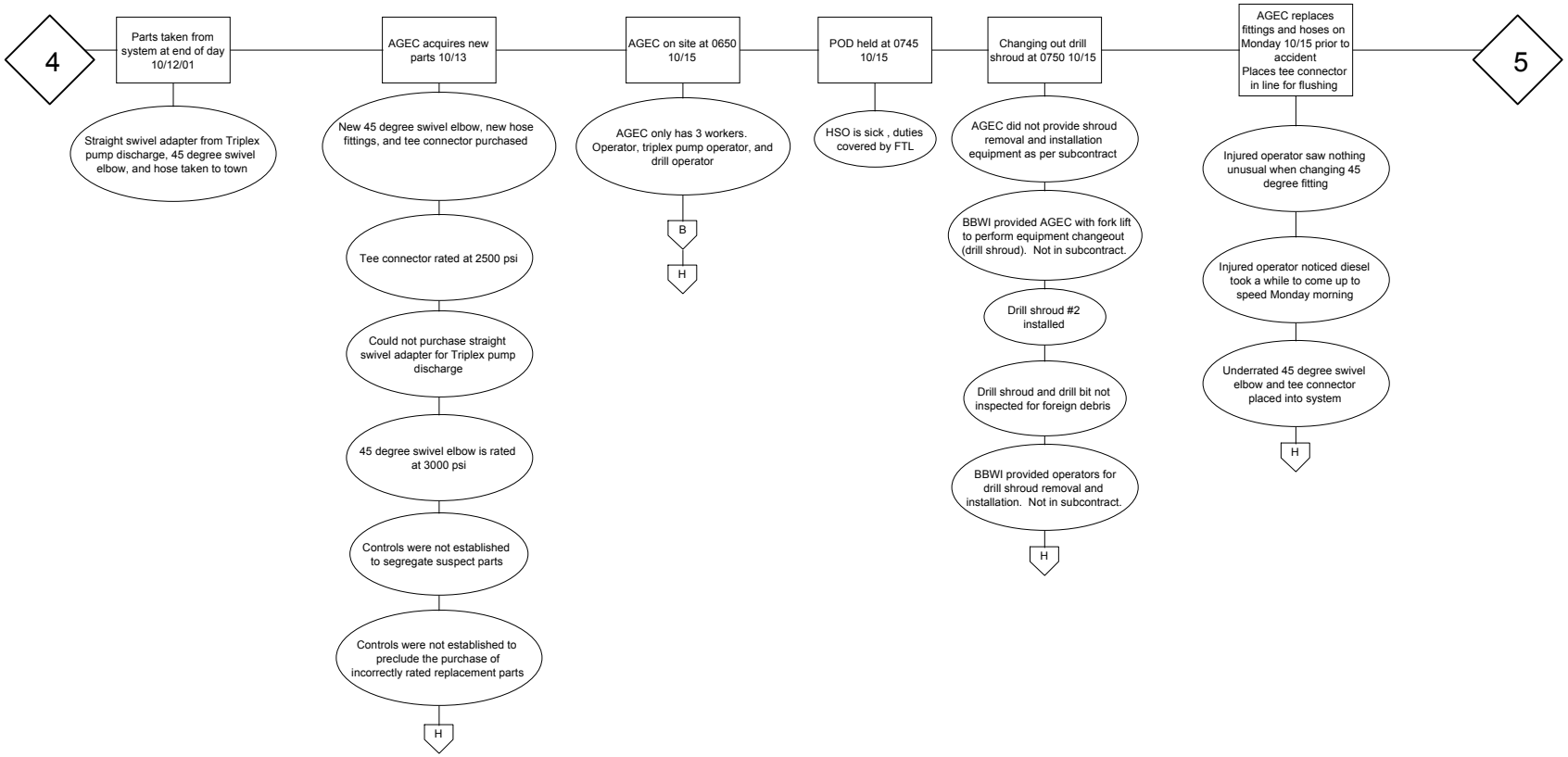
Chart Page Links

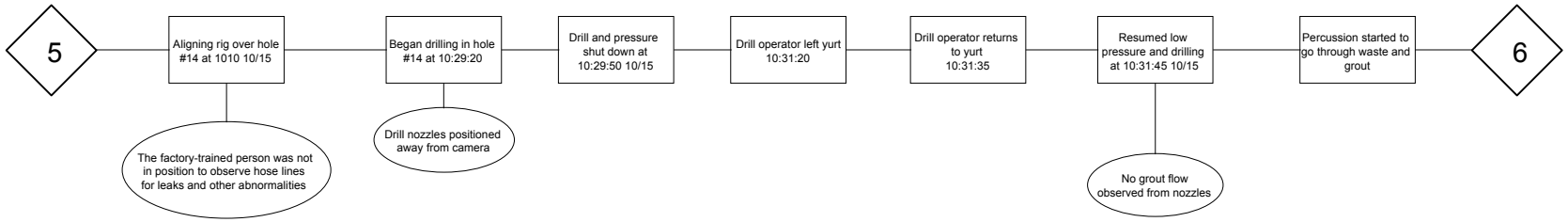

Work plan part of RI/FS process
DOE Order 440.1A (Pressure Safety) Issued 3/27/98
I
Solids/Air Separator hose connection came loose (ORPS #ID-BBWI) RWMC 10/21/99
Main hose connection came loose
Driller and helper sprayed with rock particles when pressure was released
Work conducted by subcontractors under BBWI purview
B
Employee struck by high pressure hose while attempting to clear obstruction (CAIR Report #2000022) 1/28/00
Left thumb broken and all fingers on the left hand bruised
Employee sustained 10 restricted work days
B
ISMS Phase 2 verification final report 3/2000
(Drilling Operations) Work is adequately integrated into work processes
Subcontractor (well drilling operations) was adequately controlled by Subcontractor Technical Representative (BBWI) employee
Construction contract was used for drilling
Subcontractor set up drilling rig over one of two potable water pumps at INTEC ORPS-ID-BBWI-LANDLORD-2000-0015 5/5/00
Work order developed by BBWI Landlord Organization
Drilling rig set up outside of INTEC fence
Corrective action: INTEC SAD mandated all work to be performed under INTEC work order even if outside of INTEC fence
Work conducted by subcontractors under BBWI purview
ISMS Phase 2 Part III (verification) volume #1 6/2000
Significant weakness identified -flowdown of safety requirements to subcontractors (particularly vendor subcontract)
Problems with vendor subcontracts identified previously
"Problems" noted with implementation of issues management system -"Diligence is needed to assure effective implementation"
Subcontractors lack access to lessons learned system
Additional management attention is needed to ensure that the interfaces between facility ops and other programs are effective in implementing ISMS
D
B
1

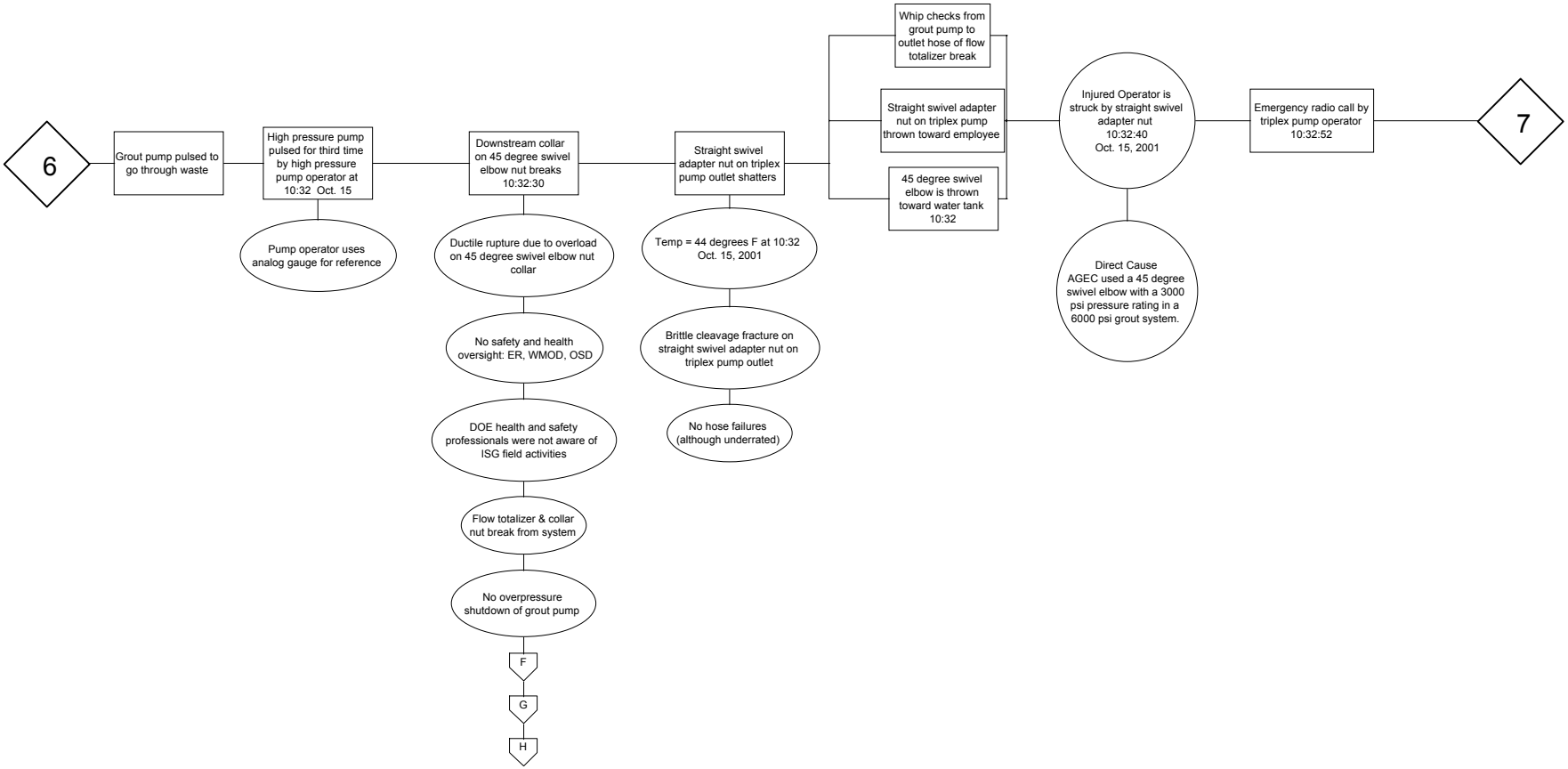

1
AGEC submits INEEL ISMS/VPP questionnaire
BBWI approved AGEC's Health and Safety Plan
Statement of Work
Subcontract Awarded 10/30/00
BBWI approved AGEC QA Plan 11/6/00
Subcontract modified Mod. 1 1/17/01
Flow totalizer calibrated 4/1/01
Nozzle test conducted
2
ISMS/VPP questionnaire states AGEC does not have an NQA-1 program
B
Not executed in a rigorous manner to identify precursor events and implement effective system improvements
No well defined quality acceptance criteria for equipment or data in SOW
A
G
Evaluation single source NQA-1 tabletop evaluation
Awarded with out standing quality deficiencies
Vendor data not submitted to Procurement Quality Document Control
No automatic overpressure device required in grout system (rupture disk)
PEP was in draft and did not identify RRAs for DOE staff
A
H
I
Desktop review only
H
New procurement agent
No confidence in existing flow measurement - always reading high
Subcontract mod adds flow totalizer instrument
O-ring inside flow totalizer fails
Hose and fitting failures. Whip checks work.
No BBWI personnel present
Technical representative observes failure of O-rings, fittings, hose and system operating at a higher pressure
Awareness of high pressure failure may have ensured proper selection of replacement parts and have changed physical layout of equipment
No corrective actions or lessons learned from hose/fitting failures at nozzle test
H

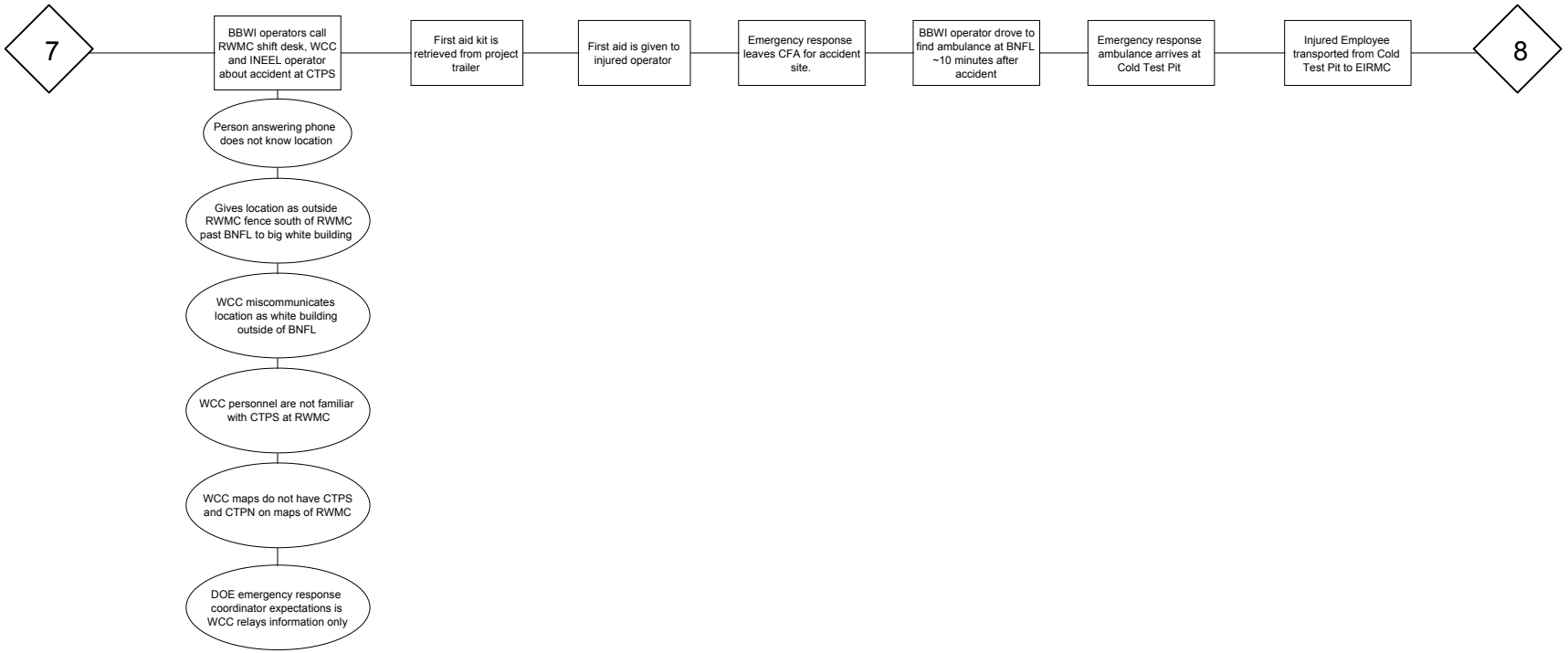

2
Implementability test 4/16 - 4/24/01
Plugging of nozzle experienced
BBWI personnel are present
Plugging was an accepted problem and its relation to system over pressure was not identified
"Over pressure trip" is designed to shut down the pump (does not provide over pressure relief)
BBWI & AGEC Inc. failed to provide for effective pressure relief device
B
D
H
Hazard Profile Screening Checklist became effective 6/14/01
HPSC not job hazards analysis
Subcontractor hazard analysis for grouting operations nonexistent
High pressure not identified as a hazard
C
Thrust block and shrouds constructed by Highline
HASP for ISG approved 9/28/01
Pressure safety system for pump not addressed
Did not address all known hazards
-bag change out
-rotating parts
-high pressure
Equipment layout not considered in development of HASP
Inadequate review of HASP by BBWI
No formal interface between ERs , FRs, and SMEs
DOE SMEs not involved in review of ISG documentation
B
C
F
G
MSA conducted for this project
Issues identified not tracked per ER PMP
MSA did not meet stated purpose. Did not evaluate entire system. Not all MSA checklists included criteria that could be used to demonstrate acceptable performance
MCP-2783 is an option in performing a MSA
E
System Operability test conducted during MSA 10/1/01
BBWI did not validate system performance. Did not run triplex pump. System Operability test conducted includes drill rig, one shroud, thrust block
Contamination control process tested
No rigor or discipline to SO test. No acceptance criter for SO test.
3

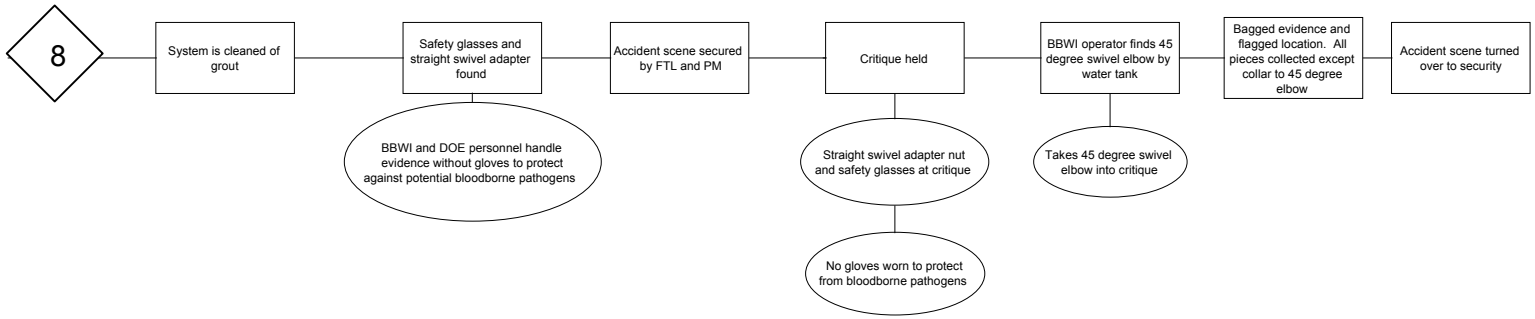

3
Quality inspection during system operability test
Quality Engineer did not document approval
Did not inspect triplex pump, hose, drill shrouds and spares
OJT criteria for operator training was not documented
No acceptance criteria in SOW for SO test
A
Work Order generated 10/8/01
Work order and work instructions do not have the same work steps
Lessons learned from previous occurences involving INEEL drilling activities not incorporated into work planning
No JSA developed
Relied on "skill of craft" to perform work
Training was not provided to workers on high pressure hazard.
High pressure was not identified in work order
C
AGEC setup to cold test pit 10/9/01
Work authorized to start 10/9/01
Equipment placement did not take into account energy pathways
Pump Operator was not trained by manufacturer (training was OJT)
Prestart Checklist was inadequate to ensure ISG Equipment is safe before start of work
Work instructions completed 10/9/01
Operating procedures not developed for grouting system
Relied on skill of the craft
Work instructions are not operations procedure
Work order and work instructions do not have the same work steps
Work instructions are used as an interface between AGEC and BBWI
B
Grout injection operations on Thursday Oct. 11 Holes 1-7
No cement truck drivers received HASP training
Operator sees large pieces in grout on hopper screen
Pressure spikes to 750 bar (over 10000 psi) on hole #1
Experienced 2 nozzle plugging events
C
Grout injection operations on Friday Oct. 12, 2001. Holes 8-14
At start up observed ice in grout hopper
Leaks observed in grouting system on hole #14
Replaced 50 foot section of hose
No procedure or requirement for cold weather
Cold weather not analyzed as a hazard
Could not use grout past 1630 per Technical Representative
Nozzles plugged on hole #14
Operators observed using bare hands while bagging operations under drill bit
Nozzles plugged with sustained high pressure (500) bars for 56 minutes on Hole #13
Pressure relieved by banging pressure block, turning relief nut, screwdriver wallowing in relief hole
C
4


4
Parts taken from system at end of day 10/12/01
Straight swivel adapter from Triplex pump discharge, 45 degree swivel elbow, and hose taken to town
AGEC acquires new parts 10/13
New 45 degree swivel elbow, new hose fittings, and tee connector purchased
Tee connector rated at 2500 psi
Could not purchase straight swivel adapter for Triplex pump discharge
45 degree swivel elbow is rated at 3000 psi
Controls were not established to segregate suspect parts
Controls were not established to preclude the purchase of incorrectly rated replacement parts
H
AGEC on site at 0650 10/15
AGEC only has 3 workers. Operator, triplex pump operator, and drill operator
B
H
POD held at 0745 10/15
HSO is sick , duties covered by FTL
Changing out drill shroud at 0750 10/15
AGEC did not provide shroud removal and installation equipment as per subcontract
BBWI provided AGEC with fork lift to perform equipment changeout (drill shroud). Not in subcontract.
Drill shroud #2 installed
Drill shroud and drill bit not inspected for foreign debris
BBWI provided operators for drill shroud removal and installation. Not in subcontract.
H
AGEC replaces fittings and hoses on Monday 10/15 prior to accident
Places tee connector in line for flushing
Injured operator saw nothing unusual when changing 45 degree fitting
Injured operator noticed diesel took a while to come up to speed Monday morning
Underrated 45 degree swivel elbow and tee connector placed into system
H
5


5
Aligning rig over hole #14 at 1010 10/15
The factory-trained person was not in position to observe hose lines for leaks and other abnormalities
Began drilling in hole #14 at 10:29:20
Drill nozzles positioned away from camera
Drill and pressure shut down at 10:29:50 10/15
Drill operator left yurt 10:31:20
Drill operator returns to yurt 10:31:35
Resumed low pressure and drilling at 10:31:45 10/15
No grout flow observed from nozzles
Percussion started to go through waste and grout
6


6
Grout pump pulsed to go through waste
High pressure pump pulsed for third time by high pressure pump operator at 10:32 Oct. 15
Pump operator uses analog gauge for reference
Downstream collar on 45 degree swivel elbow nut breaks 10:32:30
Ductile rupture due to overload on 45 degree swivel elbow nut collar
No safety and health oversight: ER, WMOD, OSD
DOE health and safety professionals were not aware of ISG field activities
Flow totalizer & collar nut break from system
No overpressure shutdown of grout pump
F
G
H
Straight swivel adapter nut on triplex pump outlet shatters
Temp = 44 degrees F at 10:32 Oct. 15, 2001
Brittle cleavage fracture on straight swivel adapter nut on triplex pump outlet
No hose failures (although underrated)
Whip checks from grout pump to outlet hose of flow totalizer break
Straight swivel adapter nut on triplex pump thrown toward employee
45 degree swivel elbow is thrown toward water tank 10:32
Injured Operator is struck by straight swivel adapter nut 10:32:40 Oct. 15, 2001
Direct Cause AGEC used a 45 degree swivel elbow with a 3000 psi pressure rating in a 6000 psi grout system.
Emergency radio call by triplex pump operator 10:32:52
7


7
BBWI operators call RWMC shift desk, WCC and INEEL operator about accident at CTPS
First aid kit is retrieved from project trailer
First aid is given to injured operator
Emergency response leaves CFA for accident site.
BBWI operator drove to find ambulance at BNFL ~10 minutes after accident
Emergency response ambulance arrives at Cold Test Pit
Injured Employee transported from Cold Test Pit to EIRMC
8
Person answering phone does not know location
Gives location as outside RWMC fence south of RWMC past BNFL to big white building
WCC miscommunicates location as white building outside of BNFL
WCC personnel are not familiar with CTPS at RWMC
WCC maps do not have CTPS and CTPN on maps of RWMC
DOE emergency response coordinator expectations is WCC relays information only


8
System is cleaned of grout
Safety glasses and straight swivel adapter found
BBWI and DOE personnel handle evidence without gloves to protect against potential bloodborne pathogens
Accident scene secured by FTL and PM
Critique held
Straight swivel adapter nut and safety glasses at critique
No gloves worn to protect from bloodborne pathogens
BBWI operator finds 45 degree swivel elbow by water tank
Takes 45 degree swivel elbow into critique
Bagged evidence and flagged location. All pieces collected except collar to 45 degree elbow
Accident scene turned over to security

APPENDIX C

BARRIER ANALYSIS

Hazard : High Pressure from Grouting		Target : Operator	
What were the barriers?	How did each barrier perform?	Why did the barrier fail?	How did the barrier affect the accident?
Administrative Barriers			
Operating Procedures	FAILED	No Operating Procedures developed to perform work. Relied on “Work Instructions” for coordination and interface between BBWI and AGEC to perform work.	Relied on skill of the craft to perform work.
Statement of Work	FAILED	Incorporated the core functions and guiding principles of ISMS; however, it was not rigorously implemented. No lessons learned from precursor events incorporated. Lack of Rigor and Discipline to follow Statement of Work requirements for Quality Assurance, Hazard Analysis and work performance.	Lost opportunity to identify precursor events and provide quality assurance acceptance criteria.
Job Hazard Analysis	FAILED	No Job Hazard Analysis was performed as required in the Statement of Work.	AGEC was allowed to participated in a Hazard Profile Screening Checklist instead of a Job Hazard Analysis that did not identify all hazards.
WAG-7 Program Execution Plan	FAILED .	The WAG-7 Project Execution Plan was a draft document. The PEP is used to identify both DOE and BBWI roles and responsibilities.	Roles and Responsibilities were neither communicated nor understood.
AGEC Quality Assurance Plan	FAILED	BBWI approved the AGEC QA Plan through a “desk top” review only. AGEC submitted with the INEEL ISMS VPP pre-qualification application that it did not have a NQA-1 Quality Program. BBWI did not verify implementation of AGEC QA Plan in the field.	Implementation of the plan did not preclude the purchase of incorrectly rated replacement parts and failed to segregate previously failed parts from service. Missed opportunity to prevent use of underrated part.

Hazard : High Pressure from Grouting		Target : Operator	
What were the barriers?	How did each barrier perform?	Why did the barrier fail?	How did the barrier affect the accident?
Training	FAILED	Training and knowledge of high pressure systems and applications would have made operators aware of hazards exposed to when working on the injection grouting system. A Job Hazard Analysis (which was not performed) would have identified high pressure as a hazard to which the workers should be trained. Received "exception" for training to INEEL Subcontractor Requirements Manual. No comprehensive high pressure training in INEEL Subcontractor Requirements Manual. On the Job Training criteria for which triplex pump operator was trained to was not documented.	Awareness of the consequences of failure could have changed the physical layout of the pumping equipment and ensured proper selection of replacement parts or the need for engineered barriers. No training requirements were generated from a Job Hazard Analysis. AGEC received no training to the Subcontractors Requirement Manual at the INEEL except Site Access. The INEEL does not have a comprehensive high pressure training requirement. Triplex pump operator did not have formal training.
MOA between RWMC, BNFL and DOE-ID	FAILED	RWMC Shift Desk was notified of the accident and emergency response by the INEEL Fire Department and failed to notify BNFL of the emergency response.	Emergency response vehicles were mistakenly told to respond to a white building at BNFL site. Minimum delay in emergency response to the accident site.
BBWI Health and Safety Plan (HASP)	FAILED	Pressure safety shutdown system for the pump was not addressed in the HASP. Written for all personnel involved in the project (BBWI, AGEC, and others). Did not address training on the equipment by either BBWI or AGEC. Did not address all known hazards (bag change-out procedure, nozzle plugging). Relied on knowledge of AGEC for protection. Inadequate review of the HASP by BBWI and DOE-ID.	Did not protect the injured AGEC operator.
BBWI ER Project Management Plan	FAILED	The PMP did not flow down roles and responsibilities to the BBWI personnel in the field. The ER Quality Assurance Plan, an addendum to the PMP was not followed for quality acceptance criteria in SOW, inspection of procured services and inspection of the subcontractor's quality program.	Not following the QAP allowed uncertain quality acceptance criteria for the systems operability test and acceptance of equipment to the INEEL without a thorough quality inspection and identification of subcontractor quality deficiencies. The lack of quality inspection of the contractor led to underrated components being used in the injection grouting system and injury of the operator.
System Operability Test	FAILED	The Statement of Work only specified the inspection and fit test of the drill rig, drill shroud and thrust block assembly and an inspection only of the high pressure grout system. Did not require the operation of the overall grout injection system as a combined pump, injection grouting and contamination control system. Lacked acceptance criteria.	Lost opportunity to identify and understand system operations, systems failures and lost opportunity to review corrective actions from previous failures identified during the nozzle tests.

Hazard : High Pressure from Grouting		Target : Operator	
What were the barriers?	How did each barrier perform?	Why did the barrier fail?	How did the barrier affect the accident?
Implementability Test	FAILED	Information of previous line failures was not utilized in this test. Plugging was an "accepted problem" and its relation to system over pressurization was not identified. Didn't recognize the need for an effective automatic pressure relief device. "Overpressure trip" is designed to shutdown the pump. Does not provide relief of an over pressure condition.	Hazard of nozzle plugging not analyzed. None of the methods employed as "pressure protection" provided a means for preventing an over pressure condition that could result in component failure. The team could not determine that the manufacture's recommendation to set the "Overpressure trip" shutdown at 290 to 435 psi over the maximum pressure of the job to be carried out.
Management Self Assessment	FAILED .	The MSA was intended to provide a process to assure that the activities supporting the field test of the in-situ grouting treatability study have addressed all applicable requirements and can be conducted safely. The MSA did not evaluate the entire grouting process. Issues identified in the MSA were not tracked per MCP-598. The MSA checklists did not include acceptance criteria that could be used to demonstrate acceptable performance.	The MSA, as performed, did not meet the stated purpose. It did not identify the requirements for safe performance of high pressure work.
DOE-ID Oversight	FAILED	DOE-ID H&S professionals were not aware the project was in operation, therefore, no oversight was conducted on the project. No formal interface was established between the FR's, SME's and ER counterparts.	Missed opportunity to ensure rigorous implementation of requirements. Lost opportunity for an "up front" review for implementation of H&S requirements.
BBWI Oversight	FAILED	Ineffective in evaluating the safety aspects of the project. Subcontract does not adequately define the BBWI oversight role.	Missed opportunity to ensure rigorous implementation of requirements.
Lessons Learned	FAILED	AGEC failed to recognize nozzle plugging with increased pressurization as a hazard to be mitigated. AGEC also failed to analyze past hose and fitting failures and implement corrective actions. BBWI failed to incorporate lessons learned from previous INEEL occurrences with drilling and high pressure operations into the Statement of Work, the Health and Safety Plan and into work planning.	Missed opportunity to correct previous failures noted during the nozzle tests and previous INEEL occurrences to prevent recurrence and to identify hazards associated with nozzle plugging and over-pressurization of grout system. No lessons learned contributed to the operator being injured.

Hazard : High Pressure from Grouting		Target : Operator	
What were the barriers?	How did each barrier perform?	Why did the barrier fail?	How did the barrier affect the accident?
Subcontract	FAILED	No documented "approval for delivery" or acceptance of all AGEC equipment was generated by the BBWI Project Quality Engineer. Neither BBWI nor AGEC followed-up to ensure the subcontract requirements were implemented for quality assurance. AGEC did not follow the process to submit the required vendor data to BBWI Procurement Document Control. Project manager did not communicate or deliver to BBWI Procurement Document Control when the documents had been received. AGEC was allowed to operate with less than the required 4 operators. AGEC was allowed to use GFE for removal and replacement of drill shroud contrary to subcontract requirements. BBWI operators were used to help change AGEC owned drill shroud.	The BBWI Contract Administrator and BBWI Project Manager missed the opportunity to ensure AGEC quality programs were in place and that the quality acceptance criteria for AGEC equipment met specifications prior to operations. The BBWI Contract Administrator and Project Manager did not enforce terms and conditions of subcontract. Failure to follow and enforce contractual terms led to underrated parts being placed into the grout system and injuring the operator.
Integrated Safety Management	FAILED	BBWI's STD-101 did not adequately identify and control high pressure hazards. AGEC and BBWI did not ensure the ISM process was implemented.	Missed opportunity to mitigate known hazards.
Staffing Requirements	FAILED	AGEC failed to provide the required personnel and BBWI accepted the lower levels of staffing, failing to enforce the subcontract requirement.	The manufacturer trained person was not in a position to observe the hose line for leaks or other abnormalities.
Grout setup time	FAILED	Using the grout early in its usable time, the grout is of low viscosity. Toward the end of use time, the grout is higher in viscosity. The Board observed that the holes grouted toward the end of the grout useable time experienced increased problems with nozzle plugging.	Nozzle plugging during operation of the grouting pump increases delivery system pressure.
Physical Barriers			
Whip Checks	FAILED	The whip checks absorbed energy by failing; however, according to whip check manufacturer, the application of whip checks on the grout delivery system was an improper application. The physical arrangement of the whip checks and piping affected the trajectory of the parts when the system failed.	Whip checks did not prevent the operator from becoming injured.

Hazard : High Pressure from Grouting		Target : Operator	
What were the barriers?	How did each barrier perform?	Why did the barrier fail?	How did the barrier affect the accident?
Fittings	FAILED	The 45° swivel elbow failed to contain the system pressure. The 45° swivel elbow working pressure rating was below the expected operating pressure of the system. The straight swivel adapter failed to contain system pressure due to the combination of system pressure and kinetic energy imparted on the swivel nut when the elbow failed. The swivel nut became a projectile that struck the injured employee.	The failure of the 45° swivel elbow nut is believed by the Board to be the initiating event that resulted in the accident. The straight swivel adapter nut broke loose from the system and caused injury to the operator.
Hose	WORKED	Contained system operating pressure. Although no failure occurred, the hoses were under rated.	No effect to the outcome.
Rope Barriers	FAILED	The rope barriers failed to preclude entry of the grout truck drivers into the restricted area. The grout truck drivers did not have any training to the hazards in the area.	No effect to the outcome.
Equipment Layout/Distance	FAILED	The equipment layout was not formatted in a manner to preclude the accident. During the hazard review and planning, energy pathways were not evaluated.	Loss of opportunity to position equipment to protect the workers.
Safety Shutdown (Overpressure Shutdown)	UNCERTAIN	The operation of the automatic shutdown is in question. Pressure recorded by the flow totalizer indicated operation above 700 Bar. The trip point is set at the factory at 600 Bar (8,700 psi). AGEC employees have never changed this trip point.	The shutdown mechanism failed to shutdown the pump during an excursion above the factory set trip point.
Operator Action	FAILED	Failed to prevent pressure excursions before equipment failure. Pressure control relies on human reaction time.	Allowed for operation of pump over the rated working pressure of hose and fittings
Personal Protective Equipment	FAILED	Energy created by the failure exceeded the protection afforded by the PPE. Mitigated the consequence of part failure on the operator.	Did not protect operator. Reduced the consequences of the equipment failure on the employee
Guarding	FAILED	No guarding used or prescribed.	Missed opportunity to protect the worker from unwanted energy flow.
Maintenance	FAILED	Maintenance records reviewed did not provide evidence that the pumping equipment was maintained in accordance with the manufacturer's' recommendations. The pumping equipment did not shut down as designed.	No pumping equipment shutdown during the accident.
Automatic Overpressure Prevention Device	FAILED	No device was incorporated into the system. Would have prevented an overpressure situation.	Lost opportunity to prevent an overpressure excursion.

Hazard : High Pressure from Grouting		Target : Operator	
What were the barriers?	How did each barrier perform?	Why did the barrier fail?	How did the barrier affect the accident?
High Pressure Grout Delivery System	FAILED	Working pressures were known and understood however, there is no evidence that this information was reviewed from a systems (inter-connectivity) standpoint. Sudden pressure excursions from a single plugged nozzle were known. Components were used in the system which were rated below the known working pressures.	The under rated component failed during an overpressure excursion.
Analog gage	UNCERTAIN	Unknown if the gage is working properly. Proper calibration of the grout pressure gage is relied upon to allow the operator to control the delivery system pressure.	Unknown until the performance of the grout pressure gage can be verified.
Flow Totalizer	UNCERTAIN	Proper calibration of the flow totalizer is relied upon to allow the operator to control the delivery system pressure.	Unknown until the performance of the flow totalizer can be verified.

APPENDIX D
Acronyms Used in This Report

AGEC	Applied Geotechnical Engineering and Construction, Inc.
ASME	American Society of Mechanical Engineers
BBWI	Bechtel BWXT Idaho, LLC
BNFL	British Nuclear Fuels Limited, Inc.
CAIRS	Computerized Accident/Injury Reporting System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
CTPS	Cold Test Pit South
DOE	U. S. Department of Energy
DOE-ID	U. S. Department of Energy, Idaho Operations Office
EIRMC	Eastern Idaho Regional Medical Center
EMS	Emergency Medical Services
EMT	Emergency Medical Technician
EPA	Environmental Protection Agency
ER	Environmental Restoration
ERD	Environmental Restoration Division
ESH&QA	Environment, Safety, Health and Quality Assurance
FFA/CO	Federal Facility Agreement and Consent Order
FSME	Focused Safety Management Evaluation
FTL	Field Team Leader
HASP	Health and Safety Plan
HIM	Hazard Identification and Mitigation
HMG	Hazard Mitigation Guide
HPSC	Hazard Profile Screening Checklist
HSO	Health and Safety Officer
IAG	Interface Agreement
INEEL	Idaho National Engineering and Environmental Laboratory
ISG	In Situ Grouting
ISMS	Integrated Safety Management System
JHA	Job Hazard Analysis
JSA	Job Safety Analysis
LMA	Line Management Assessment
LO/TO	Lockout/Tagout
LWC	Lost Workday Case Rate
MCP	Management Control Procedure
MSA	Management Self-Assessment
NPL	National Priorities List
NQA-1	Quality Assurance Requirements for Nuclear Facility Operations
ORPS	Occurrence Reporting and Processing System
OSD	Operational Safety Division
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PAD	Performance Assurance Division
PDD	Program Description Document
PM	Project Manager
PMP	Program Management Plan
POD	Plan of the Day

PPE	Personal Protective Equipment
PRD	Program Requirements Document
PSD	Procurement Services Division
PSI	Pounds per Square Inch
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
RFP	Request for Proposal
RI/FS	Remedial Investigation/Feasibility Study
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SME	Subject Matter Expert
SO	System Operability
STD	Standard
TRC	Total Recordable Cases
VPP	Voluntary Protection Program
WAG	Waste Area Group
WCC	Warning Communications Center
WMOD	Waste Management Operations Division
WO	Work Order