DOE/ORO-2132

U. S. Department of Energy
Oak Ridge Operations Office

Type B Accident Investigation

Exothermic Metal Reaction Event During Converter Disassembly in Building K-33 at the East Tennessee Technology Park on June 27, 2002

July 2002

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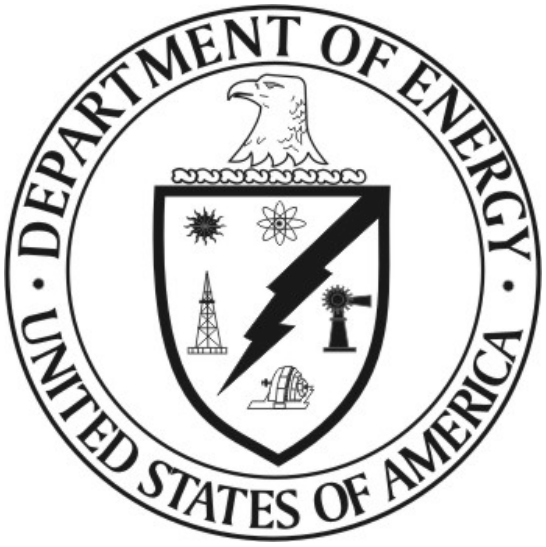

July 2002

Oak Ridge Operations Office
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INDEPENDENT REPORT

This report is an independent product of the Type B Accident Investigation Board (Board) appointed by Michael Holland, Acting Manager, Oak Ridge Operations Office, U.S. Department of Energy. The Board was appointed to perform a Type B investigation of the event and prepare an investigation report in accordance with DOE O 225.1A, *Accident Investigations*.

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

On June 28, 2002, I appointed a Type B Accident Investigation Board to investigate the June 27, 2002, exothermic metal reaction in the BNFL Inc. Decontamination and Decommissioning Workshop in Building K-33 at the East Tennessee Technology Park. The responsibilities of the Accident Investigation Board have been satisfied with respect to this investigation. The analysis and the identification of contributing and root causes and Judgments of Need resulting from this investigation were performed in accordance with DOE O 225.1A, *Accident Investigations*.

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

M. Holland

Michael D. Holland
Acting Manager
Oak Ridge Operations Office

Date Accepted: 7/31/02

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PROLOGUE

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

Many of the activities performed for the Oak Ridge Operations Office (ORO) involve the routine use of potentially dangerous industrial equipment to accomplish the work. This equipment has the potential to cause serious personal injury and property damage unless appropriate safety measures are implemented. Therefore, it is imperative that the guiding principles and core functions of Integrated Safety Management are carried out from the highest level of the organization down to the work being performed.

This Type B Accident Investigation report is important in improving safety at Oak Ridge. The lessons learned contained in this report are applicable to all types of work activities. The report provides lessons on many aspects of conducting work safely and represents ORO's continued commitment to support the U.S. Department of Energy's *Safety Management System Policy*.

I trust that all federal employees and contractors supporting ORO will take the time to read this report, think about its applicability to their work, and recognize that every piece of equipment represents a unique challenge to identify and negate its hazards. I encourage all federal and contractor employees to vigorously continue their efforts to fully implement Integrated Safety Management.

M. Holland

Michael D. Holland
Acting Manager
Oak Ridge Operations Office

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ACRONYMS

APF	Assigned Protection Factor
BIO	Basis for Interim Operation
BJC	Bechtel Jacobs Company LLC
BNFL	BNFL Inc.
Board	Type B Accident Investigation Board
CFR	Code of Federal Regulations
COR	Contracting Officer's Representative
D&D	Decontamination and Decommissioning
DEAR	Department of Energy Acquisition Regulation
DOE	U.S. Department of Energy
EAL	Emergency Action Level
EOC	Emergency Operations Center
ETTP	East Tennessee Technology Park
EWP	Enhanced Work Plan
FCN	Field Change Notice
FHA	Fire Hazards Analysis
FMT	Field Monitoring Team
HEPA	High Efficiency Particulate Air
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
NTS	Noncompliance Tracking System
OE	Operational Emergency
ORO	Oak Ridge Operations Office
PAPR	Power Air-Purifying Respirator
PEW	Project Emergency Warden
PPE	Personal Protective Equipment
PSS	Park Shift Superintendent
Reaction	Exothermic Metal Reaction
SME	Subject Matter Expert

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EXECUTIVE SUMMARY

The Event

On June 27, 2002, an exothermic metal reaction (reaction) occurred during disassembly of a converter using a plasma arc torch in the Decontamination and Decommissioning (D&D) Workshop in Building K-33 at the East Tennessee Technology Park (ETTP). The converters are being removed as part of decontamination and demolition project under contract to BNFL Inc. (BNFL). These converters were a part of the gaseous diffusion process once used to enrich uranium. The converters contain sintered nickel tubes that, under certain conditions, can be involved in a reaction when exposed to the kerf from the plasma arc cutting operation.

The reaction occurred in the tube bundle as a result of cutting operations on a bracket during disassembly operations. The reaction is characterized by glowing hot metal that produces a white smoke. "Exothermic metal reaction" is the term used in this report to characterize the event because no flames are produced, although, technically, it is a fire. The reaction feed is self-sustaining in that it does not require oxygen from the air to propagate. This, coupled with the geometry of the tube bundles, compounds firefighting difficulties.

Upon discovering the tube bundle reaction, the cutter and the fire watch attempted to extinguish it with ABC dry chemical and carbon dioxide fire extinguishers. Contrary to the work instructions that required the workers to evacuate the area, they extracted the tube bundle and attempted to break apart the reacting metal. Extracting the tube bundle caused it to come in contact with a flame-retardant security curtain. Once the foreman arrived on the scene, he ordered the evacuation of the workshop area and pulled the fire alarm. After the evacuation, two overhead sprinklers discharged because the security curtain had caught fire from the reacting tube bundle.

Two previous reactions have occurred during BNFL's disassembly operations. The first reaction occurred on April 4, 2000, in the Building K-33 D&D Workshop after a field change was completed to the work instructions that enabled cutting on the tube bundle sheet. The second reaction occurred on July 21, 2001, in Building K-31 during in-situ disassembly operations in which the cutter angled the plasma arc torch in the direction of the tube bundle contrary to the work instructions. Corrective actions were developed and implemented for the first event. However, 9 of 11 corrective actions remained open for the second event at the time of the third tube bundle reaction.

Oak Ridge Operations Office (ORO), after evaluating the conditions associated with this event and considering the previous two tube bundle reactions in April 2000 and June 2001, requested that a Type B Accident Investigation be conducted in accordance with DOE O 225.1A, *Accident Investigations*. The Accident Investigation Board (Board) convened on July 1, 2002, and began investigating the circumstances involving

the tube bundle reaction and determining the root causes and Judgments of Need to prevent recurrence.

Background

BNFL was awarded the demolition and decontamination, fixed-price contract in August 1997. The original contract called for the removal of gaseous diffusion process equipment, including piping, compressors, and converters. The converters are similar in construction to that of a shell and tube heat exchanger. The equipment is being removed from Buildings K-29, K-31, and K-33, which were constructed during the late 1940s.

BNFL is approximately 65% complete with the project and has removed 802 of 1,536 converters, 713 of 1,534 compressors, and 81,573 tons of metal. Approximately 850 people are employed at the site. Much of the work involves cutting, grinding, and hoisting and rigging. The demolition work and hazards identification are complicated due to the lack of accurate as-built drawings for buildings that are nearly 50 years old.

Results and Analysis

The Board reviewed the work controls involving converter disassembly, the emergency response to the event, fire protection measures, and corrective actions associated with previous tube bundle reaction events. The results of these reviews were factored into the five core functions of Integrated Safety Management (ISM). The Board developed Judgments of Need that considered what actions were necessary to prevent recurrence of this event and other similar events.

The Board focused on strengthening the work controls and the oversight of those controls to ensure proper implementation of the requirements of the work package. Associated with work control improvements, the manner in which BNFL addresses field changes to existing work packages needs greater management control to ensure that the hazards resulting from the changes are appropriately analyzed and actions taken to minimize their adverse consequences. The analysis of the tube bundle reaction needs to be completed, and an appropriate emergency response to this event needs to be developed and drilled so that workers understand and can respond appropriately to this type of event.

Corrective actions planned after the July 2001 reaction were not implemented at the time of this event. Prior to this event, BNFL had determined that problems existed with implementation of its Corrective Action Program which required programmatic correction. These latter actions were also not completed at the time of this event. BNFL has recognized the issues of timeliness and prioritization in its Nonconformance Report. Therefore, the Board considers the BNFL Corrective Action Program to be ineffective.

Conclusions

Direct Cause
The direct cause of the event was kerf from the plasma arc torch intersecting the tube bundle, causing an exothermic metal reaction.

The Board concludes that this event was preventable. The event highlighted weaknesses in key aspects of the five core functions of ISM. The direct cause of the event was kerf from the plasma arc torch intersecting the tube bundle, causing a reaction. For the purposes of this report, "kerf" refers to the white-hot sparks and molten metal splatter that spray out beyond the cut made by a plasma arc torch. Although the workers and supervisors understood that the close proximity of the plasma arc torch introduced a certain level of increased risk, work controls were not appropriately implemented to minimize the possibility of the reaction. Different work shifts had taken different precautionary measures to avoid reactions, and these measures were not fed back into the work control process or shared between shifts.

The Board identified two root causes for this event:

1. The corrective actions from the previous two reactions did not establish the framework that these reactions are a preventable consequence of demolition and decommissioning activities.

2. BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring appropriate emergency response.

Table ES-1. Judgments of Need

JON No.	Judgment of Need	Contributing and Root Causes
Conduct of Work		
JON 1	BNFL needs to develop and implement a system to facilitate sharing of work practices, issues, and solutions across all shifts at the worker, foreman, and supervisory levels.	CC-2, 4, 7, 8 RC-2
JON 2	BNFL needs to revise the Enhanced Work Plan process so that the review of an intent change to an EWP is as rigorous as the original EWP creation process.	CC-1, 3, 6, 7 RC-1, 2
Analysis and Emergency Response		
JON 3	BNFL and ORO need to ensure that the planned analysis of metal chemistry reflects the potential for reactions involving tube bundles anticipated to contain elevated levels of contamination.	CC-3, 9 RC-1, 2
JON 4	Based on the result of the metal chemistry analysis, BNFL needs to revise the current hazards analyses and related documents for converter disassembly to identify effective safeguards for potential accidents.	CC-3, 5 RC-2

Table ES-1. Judgments of Need (continued)

JON No.	Judgment of Need	Contributing and Root Causes
JON 5	BNFL needs to develop a clear and consistent response to abnormal events and emergencies and train workers accordingly.	CC-3, 4, 5, 6 RC-2
JON 6	BNFL needs to improve emergency readiness capability through a combination of drills, exercises, walkdowns, and project emergency warden coverage.	CC-4, 5 RC-2
Management Oversight		
JON 7	BNFL needs to ensure that its management oversight systems effectively implement and reinforce that work is performed within controls, abnormal responses are consistent, and effective communications are conducted between shifts at all levels where work is being performed.	CC-1, 2, 4, 5, 6, 7, 8 RC-1, 2
JON 8	BNFL needs to complete pending corrective actions on its Corrective Action Program, including incorporation of DOE's recommendations into the Issues Management System.	CC-3, 6, 7, 9 RC-1, 2
DOE Oversight		
JON 9	ORO, through its oversight program, needs to evaluate the contractor's implementation of ISM to ensure that work is being performed safely.	CC-1, 2, 3, 4, 5, 6, 7, 8, 9 RC-1

1.0 INTRODUCTION

1.1 Background

On June 27, 2002, an employee of BNFL Inc. (BNFL) was working in the Decontamination and Decommissioning (D&D) Workshop in Building K-33 at the East Tennessee Technology Park (ETTP). The employee was using a plasma arc torch to dismantle a converter when the tube bundle inside the converter began reacting. No injuries were sustained from this event.

On June 28, 2002, U.S. Department of Energy (DOE) Oak Ridge Operations Office (ORO) management categorized the event as a Type B. Michael Holland, Acting ORO Manager, formally appointed a Type B Accident Investigation Board (Board) to investigate the event in accordance with DOE O 225.1A, *Accident Investigations* (see Appendix A). This report documents the facts of the event and the conclusions of the Board.

1.2 Facility Description

ETTP is located approximately five miles west of Oak Ridge, Tennessee. ETTP, formerly known as the K-25 Site, was a gaseous diffusion plant for uranium enrichment during and after World War II. The site is now undergoing remediation and reindustrialization of its facilities.

In August 1997, BNFL was awarded a direct, fixed-price contract with ORO for the ETTP Three-Building Decontamination and Decommissioning and Recycle Project. This project's mission is to dismantle, remove, and disposition the process equipment in the three buildings (K-29, K-31, and K-33) and to decontaminate the interior of the three buildings. BNFL employs approximately 850 workers, running two shifts a day and working 24 hours a day, 7 days a week. The work performed involves heavy construction-type dismantlement, disassembly, and removal operations of process equipment and support materials and waste removal and disposal. Building K-33 contained 632 converters weighing 66,000 pounds each, Building K-31 contained 595 converters weighing 29,400 pounds each, and Building K-29 contained 399 converters weighing 24,800 pounds each. Another 1,534 compressors weighing up to 36,000 pounds each and 1,540 motors weighing up to 16,000 pounds each were also in the three buildings.

BNFL has processed 802 converters and 713 compressors. Almost 1.53 million pounds of material are being removed each week. So far, approximately 174.3 million cumulative pounds of material have been removed from the project site.

1.3 Scope, Conduct, and Methodology

The Board began its activities on July 1, 2002, and completed its investigation on July 31, 2002. The scope of the Board's investigation was to identify all relevant facts;

analyze the facts to determine the direct, contributing, and root causes of the event; develop conclusions; and determine Judgments of Need that, when implemented, should prevent recurrence of the incident. The investigation was performed in accordance with DOE O 225.1A, *Accident Investigations*, using the following methodology:

- Facts relevant to the event were gathered through interviews and reviews of documents and evidence.

- The event scene was inspected, and photographs were taken of the scene.

- Facts were analyzed to identify the causal factors using event and causal factors analysis, barrier analysis, root cause analysis, and change analysis.

- Judgments of Need for corrective actions to prevent recurrence were developed to address the causal factors of the event.

Accident Investigation Terminology

A **causal factor** is an event or condition in the accident sequence that contributes to the unwanted result. There are three types of causal factors: **direct**, which is the immediate event(s) or condition(s) that caused the accident; **root cause(s)**, which is the causal factor that, if corrected, would prevent recurrence of the accident; and the **contributing causal factors**, which are the causal factors that collectively with the other causes increase the likelihood of an accident but which did not cause the accident. The causal factors related to weaknesses in the five core functions of **Integrated Safety Management (ISM)** are analyzed.

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

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

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

2.0 FACTS

2.1 Event Description and Chronology

2.1.1 Event Description

The exothermic metal reaction (reaction) in the tube bundle on June 27, 2002, was preceded by two previous tube bundle reactions in converters on the ETTP Three-Building Decontamination and Decommissioning and Recycle Project. There are six previous non-BNFL converter reaction incidents in the DOE Occurrence Reporting System.

The first BNFL event, a tube bundle reaction in a converter in Building K-33, occurred on April 4, 2000, during the afternoon shift. After unsuccessful firefighting attempts by the workers, the ETTP Fire Department segregated the material and terminated the reaction approximately two and a half hours after its initiation. The Park Shift Superintendent (PSS) did not classify the event as an Operational Emergency (OE).

The second event was a tube bundle reaction in a converter in the Converter In-Situ Disassembly Operation Area of Building K-31, which occurred on July 25, 2001, at approximately 6:30 am. The workers immediately evacuated, and the Fire Department segregated the material and terminated the reaction within an hour and half of its initiation. The event was not classified as an OE by the PSS on duty when it was reported, but it was classified as an OE by his relief at shift turnover.

BNFL constructed the D&D Workshop in Building K-33 to disassemble converters and other process equipment and components, and it has been in operation since September 1999. The Building K-33 day shift first discovered an unanticipated converter configuration on Tuesday, May 14, 2002. The work crew found a difference in the manner in which the converter was constructed (i.e., welded brackets holding the tube bundle instead of bolted brackets). The group manager wrote a Field Change Notice (FCN) to the Enhanced Work Plan (EWP) with assistance from craft personnel and obtained concurrence from the Subject Matter Experts (SMEs). The FCN was approved on May 15, 2002, and work resumed on the converter at the start of the night shift. BNFL incorporated this FCN word for word, as well as adding other enhancements, into the EWP revision and approved the revised EWP on May 22, 2002. The cutter and fire watch involved in the most recent event were both trained on the revised EWP on May 22, 2002.

On the morning of the third reaction, June 27, 2002, the Project Emergency Warden (PEW) departed the site at the end of his shift at 4:00 am. PEW on-site coverage was scheduled to resume at 6:00 am. The cutter and fire watch returned from their 4:30 am break at approximately 5:00 am and resumed dismantling a converter type covered by the revised EWP. Both workers were wearing appropriate Personal Protective Equipment (PPE); however, since the fire watch was standing on the perimeter of the

converter enclosure (outside the 20-foot radius), he was not required to wear a respirator.

At approximately 5:05 am, the cutter noticed a red glow inside the tube bundle. The fire watch entered the converter enclosure without donning his respirator. He and the cutter discharged an ABC extinguisher into the tube bundle, which appeared to have no significant effect on the reaction.

The fire watch returned to the perimeter of the converter enclosure and called his foreman on the radio. At approximately 5:06 am, he donned his respirator and reentered the converter enclosure while the cutter pulled the tube bundle out of shell in order to get at the reaction more directly. This action placed the reacting tube bundle in direct contact with the flame-retardant, plastic security curtain. The fire watch, whose respirator was not functioning properly due to a low battery, and the cutter used shovels to remove reacting metal. The workers discharged the contents of a carbon dioxide extinguisher without seeing any noticeable effect.

The foreman entered the converter enclosure wearing a Tyvek coverall and without wearing a Power Air-Purifying Respirator (PAPR), as required by the converter enclosure Radiation Work Permit, and ordered the workers to evacuate. The foreman shut the rollup doors, left the blast gates open, and left the High Efficiency Particulate Air (HEPA) units running. He pulled the fire alarm box at 5:15 am and left the area.

The flame-retardant, plastic security curtain caught on fire at approximately 5:17 am, which activated the sprinkler system at 5:20 am. The sprinkler system was turned off by the three firefighters who arrived at the D&D Workshop at 5:24 am. BNFL ordered evacuation of the building at approximately 5:30 am. The BNFL Project Emergency Manager/PEW arrived at the scene at 5:40 am.

Power was secured to a portion of Unit 8 in Building K-33 at 6:00 am, since residual water from the sprinkler system was threatening electrical equipment. The firefighters expended the only two Met-L-X extinguishers that they could locate, and at 6:09 am, they requested additional Met-L-X extinguishers, which were brought from Building K-31. Security was briefed on the event at 6:21 am and provided traffic control for the emergency responders. At 6:25 am, the Radiological Control organization set new samples and retrieved the existing samples from the D&D Workshop. By 6:51 am, the firefighters had segregated the material and terminated the reaction.

The PSS shift change occurred at 7:00 am. At 7:03 am, the oncoming shift PSS declared an OE. At 7:05 am, the Emergency Operations Center (EOC) and Technical Support Center were called out. At 7:22 am, the BNFL Radiological Control organization reported that the samples retrieved from the D&D Workshop had nondetectable results. The EOC was declared operational at 8:12 am, and the Technical Support Center became operational at 8:18 am. Three radiation Field Monitoring Teams (FMTs) deployed at 9:34 am to stations outside the building. At 9:50 am, the crisis manager declared the emergency terminated, and the Technical Support Center

operations were deactivated. At 9:58 am, the FMTs were in place and taking samples, all of which returned nondetectable results. The FMTs returned to the EOC as follows: (1) 10:30 am for FMT-3, (2) 10:40 am for FMT-1, and (3) 10:56 am for FMT-2.

2.1.2 Chronology of Events

Table 2-1 provides the events leading up and immediately following the reaction in the converter tube bundle on June 27, 2002.

Table 2-1. Event Chronology

Date	Time	Event
4/4/2000		The first BNFL tube bundle reaction event occurred in a T4 converter in the D&D Workshop in Building K-33. As a result, BNFL issued a Stop Work Order on for all hot work on tube bundles containing barrier tubes.
4/18/2000		The DOE Project Manager/Contracting Officer's Representative (COR) identified 15 issues/events with specific ISM functions.
7/12/2000		Significant shortcomings in BNFL's implementation of its Integrated Safety Management System (ISMS) caused suspension of the Phase II ISM program verification.
7/21/2000		The ORO Manager approved the BNFL ISM program description.
9/29/2000		The ISM verification was completed.
10/20/ 2000		The ORO Manager concurred with BNFL's implementation of its ISM program.
6/15/2001		The Stop Work Order for hot cutting on converters in the D&D Workshop was lifted when a cold-cutting process was approved for tube bundle disassembly.
7/25/2001		The second tube bundle reaction event occurred in a converter during in-situ disassembly in Building K-31.
3/21-26/ 2002		BNFL conducted a converter disassembly demonstration for SMEs and ORO representatives in the D&D Workshop.
3/29/2002		DOE approved restart of converter disassembly operations in the D&D Workshop with comments.
4/10/2002		BNFL approved the EWP *Converter Disassembly*, CONV-111 R1, for use.
5/14/2002		The work crew discovered welded brackets on a tube bundle.
5/15/2002		The group manager created an FCN to CONV-111 R1 and obtained concurrence from the SMEs.
5/16/2002		BNFL initiated CONV-111 R2 to incorporate the FCN.
5/20/2002		SMEs signed off on CONV-111 R2.

Table 2-1. Event Chronology (continued)

Date	Time	Event
5/22/2002		The group manager approved the revised EWP, CONV-111 R2, for use.
		Sixty-three percent of the cutters, including the incident cutter, were trained on CONV-111 R2 via the prejob brief.
5/24/2002		The remaining 37% of the cutters were trained on CONV-111 R2 via the prejob brief.
6/27/2002	0400	The PEW came off shift and left the site.
	~0505:00	The cutter noticed a glow in the tube bundle after his last cut.
	~0505:30	The converter was rotated to facilitate bundle extraction.
		The cutter and fire watch discharged an ABC extinguisher on the tube bundle in the converter shell.
	~0506	The fire watch radioed the foreman and requested assistance.
	~0506	The cutter extracted the tube bundle and placed it in contact with the security curtain.
	~0506-0507	The cutter and fire watch used shovels used to remove reacted material to expose the actively reacting material.
	~0506-0509	The cutter and fire watch discharged a carbon dioxide extinguisher.
	0515	The foreman entered the area, ordered an evacuation, and pulled the fire alarm.
	~0517	The flame-retardant, plastic security curtain caught fire.
	0519	The fire commander arrived at the scene.
	0519:50	The fire suppression system began its activation sequence.
	0520:00	The fire suppression system activated.
	0524	The ETTP Fire Department shut off the water to the sprinkler system.
	0530	BNFL evacuated the building. All personnel were accounted for.
	0540	The BNFL PEW arrived at the scene.
	0600	Power was shut off to a portion of Unit 8 in Building K-33.
	0609	The fire commander reported that the reaction was contained to the converter enclosure in the D&D Workshop. The ETTP Fire Department requested more Met-L-X fire extinguishers.
	0621	Security was briefed on the reaction.

Table 2-1. Event Chronology (continued)

Date	Time	Event
6/27/2002		Security provided traffic control and monitored entering and exiting personnel.
	0623	The PSS notified the BJC Site Manager and DOE.
	0625	The radiological control technicians at the D&D Workshop set up new samples and retrieved the old samples.
	0630	BNFL determined that additional security was not needed.
	0651	The reaction was terminated.
	0700	PSS shift change
	0703	The day shift PSS declared an OE.
	0715	The EOC was activated.
	0722	The samples taken from the D&D Workshop were determined to have nondetectable results.
	0734	The PSS notified DOE Headquarters.
	0812	The EOC was declared operational.
	0818	The Technical Support Center was declared operational.
	0934	Three FMTs were deployed to monitor releases outside Building K-33.
	0950	The crisis manager declared emergency terminated. The Technical Support Center's operations were terminated.
	0958	Three FMTs were in place.
	1030	FMT-3 found nondetectable results, and the team returned to the EOC.
	1040	FMT-1 found nondetectable results, and the team returned to the EOC.
	1056	FMT-2 found nondetectable results, and the team returned to the EOC.
7/1/2002		BNFL Safety Stand Down

2.1.3 Previous Tube Bundle Reactions

April 2000

On April 4, 2000, after successfully completing dismantlement of 62 T-1A converters, workers and managers in the D&D Workshop tube bundle area were dismantling the first T-4 converter. Although shorter in overall length, personnel erroneously assumed that T-4 converters could be disassembled like the T-1As. However, they discovered that the internal setup of the T-4 converter was substantially different such that the tools used for the T-1As were unusable. Also, because the T-4s were not re-tubed, they contained higher levels of uranium deposits.

D&D Workshop personnel prepared an FCN to the EWP to develop a technique to address this different configuration. The FCN permitted hot cutting on the tube bundle sheet. A Hot Work Permit existed for the tube bundle area, but it did not fully cover the scope of the new hot cutting required. Some initial cuts worked without incident; however, at 2:55 pm a reaction ignited in a group of barrier tubes near the center of the tube bundle. This reaction did not self-extinguish in a matter of seconds as earlier observed ignitions had done in the T-1A converters. Workers fought the reaction by discharging one Class D extinguisher before pulling the alarm box and notifying the PSS. Workers subsequently used a carbon dioxide extinguisher and an ABC extinguisher to fight the reaction without success. The workers left the area to await the ETTP Fire Department.

The Fire Department deployed a reconnaissance team to inspect the scene. They called for more Class D extinguishing agents and made two additional entries to the scene, one to extinguish the reacting tube bundle and the second to smother the embers from the reaction. The reaction was reported terminated at 5:30 pm. The PSS did not declare an OE. To confirm conditions at the scene, a joint team of workers and Fire Department personnel planned and executed a re-inspection of the scene and confirmed that the reaction was terminated at 9:15 pm. No injuries, measurable exposures, or environmental releases resulted from the incident.

The BNFL Deputy General Manager immediately issued a Stop Work Order for all hot work on tube bundles containing barrier tubes and appointed an accident/incident investigation team. The team's findings (in part) were as follows:

- Workers failed to follow work controls. The worker made the cut in the direction of other components instead of away from them as was discussed in the prejob brief.

- Work controls for the activity were insufficient to manage the hazards that resulted.

- The controls in the process requiring separation of specific components before hot cutting were insufficient.

DOE accepted the Noncompliance Tracking System (NTS) report, NTS-ORO-BNFL-K33-2000-0002, which contained 36 corrective actions. All actions are reported closed except for action 34, Validation, which remains open. Corrective actions included revising the Hot Work Permit, obtaining experience data from other sites on hazards, conducting root cause analyses, revising the EWP, revising the prefire plans, revising personnel training, developing lessons learned, and conducting assessments on the revised processes. The Stop Work Order was lifted on June 15, 2001, when a cold-cutting process was approved for tube bundle disassembly.

July 2001

At approximately 6:30 am on July 25, 2001, a work crew had cut approximately 4 feet of the shell on a T-4 converter in Building K-31 using a 150-ampere plasma arc torch.

The fire watch observed excess smoke from this fourteenth unit, after thirteen successful in-situ disassemblies. The fire watch stopped the cutter, and the cutter identified the glow in the area just beneath the cut. Both workers stopped work, notified their supervisor and the PSS, and evacuated Building K-31 per procedure. The workers made no attempt to fight the reaction, and no injuries resulted. The PSS notified the ETTP Fire Department. The next shift PSS declared an OE at 7:00 am and activated the EOC. The Fire Department reported the tube bundle reaction terminated at 7:54 am. BNFL collected air sample data at noon, and the results were available by 1:00 pm. After briefing DOE Headquarters, the emergency was terminated at 2:12 pm. BNFL issued an immediate Stop Work Order, initiated a recovery plan that permitted workers into the area on a case-by-case basis, and initiated an accident investigation.

Corrective actions based on the investigation applied to work practices, EWP content and review, drawings and documentation, and root cause analysis. The NTS report, NTS-ORO-BNFL-K31-2001-0001, contained 11 corrective actions. Two actions were closed when BNFL management decided to cease in-situ converter disassembly in Building K-31 and return the work to the D&D Workshop in Building K-33. The other nine actions remain open. As a result of new BNFL Project Manager's assessment in early 2002 that the initial root cause analysis was unsatisfactory in scope, five new actions were added to the ones required in the initial NTS report. These remain open at this time.

2.2 Integrated Safety Management

The Board examined management systems as potential contributing and root causes of the event. The DOE Accident Investigation Program requires that accidents be evaluated in terms of ISM to foster continued improvements in safety and to prevent or minimize future accidents. The core functions and guiding principles of ISM are the primary focus for contractors in conducting work efficiently and in a manner that ensures the protection of workers, the public, and the environment. Properly implemented, ISM is a standards-based approach to safety, requiring rigor and formality in the identification, analysis, and control of hazards.

BNFL has a direct, fixed-price contract with ORO for the ETTP Three-Building Decontamination and Decommissioning and Recycle Project. The BNFL contract incorporates most of the text of DOE Acquisition Regulation (DEAR) 970.5204-2, *Integration of Environment, Safety, and Health into Work Planning and Execution*, dated June 27, 1997. BNFL is using the set of Work Smart Standards listed in PO-CS-006, *Work Smart Standards*, Revision 2.

The Board reviewed the contract mechanisms to better understand how ISM was implemented. Prior to the ISMS verification, the ORO facility representative expressed concerns to BNFL as a result of 15 issues/events that had occurred on the project. A letter dated April 18, 2000, to the BNFL General Manager from the ORO Project Manager/COR states "The compiled data indicates a very unfavorable trend in hazardous analysis and/or work control that needs BNFL Inc.'s immediate attention."

The letter requests that BNFL perform a thorough internal review concerning the generic issues. BNFL's response is contained in a short letter dated May 11, 2000, that does not specifically address the issues and states only that "We understand that our ISM program is currently reactive in nature, but as our experience base grows our ISM program will become proactive and more predictive in nature."

A combined Phase I/II verification of the BNFL ISMS was begun during June 2000, and Phase I was completed on June 30. However, significant shortcomings in BNFL's ISMS implementation caused DOE to suspend the Phase II portion of the verification on July 12, 2000. The Phase II verification was resumed on September 18 and completed on September 29, 2000. Although a high percentage, 40%, of individual criteria for functional areas Hazard Identification and Operations were not fully met, the conclusions for the functional areas indicated that the objectives were met. Examples are provided in Table 2-2. ORO concurred with BNFL's implementation of its ISMS on October 20, 2000.

Table 2-2. Partial ISMS Verification Results for BNFL, September 2000

Functional Area	Criteria	Met	Not Met
Hazard Identification	Safety Analysis Process	X	
	Authorization Basis		X
	Roles and Responsibilities	X	
	Facility Authorization Basis		X
	Hazard Mitigation		X
	Standards and Requirements	X	
	Maintain Authorization Agreements	X	
Operations	Hazard Identification and Analysis		X
	Roles and Responsibilities	X	
	Work Planning/Analyze Hazards	X with conditions	
	Adequate State of Readiness	X	
	Authorization to Conduct Operations	X	
	Requirements Integrated into Work		X
	Performance Measures/Indicators	X	
	Workers Participate in Work Process	X	

At the time of the contract negotiation, a draft version of DEAR clause 970.5204-2 was included in the contract. The contract has not been revised to include the full version of either DEAR clause 970.5204-2, dated June 27, 1997, or 970.5223-1, dated December 22, 2000. Several requirements from the DEAR clause are not in the BNFL contract. The most notable omission is subparagraph 7(e), which states "Dates for submittal, discussions, and revisions to the System will be established by the contracting officer . . . On an annual basis, the contractor shall review and update, for DOE

approval, its safety performance objectives, performance measures, and commitments consistent with and in response to DOE's program and budget execution guidance and direction."

DEAR clause 970.5223-1, subparagraphs (d) and (e), require DOE and contractor actions to continuously maintain the integrity of the ISMS and to generate revisions as scheduled by the contracting officer. Thus, the ISMS description needs to be maintained valid, current, and consistent with schedules established by the contracting officer. This DEAR clause also requires the contractor to submit ISMS revisions to DOE for approval. The BNFL *ISM Program Description* (PO-SS-017), which implements its ISMS, has been revised four times since the DOE verification. However, ORO has not provided approval to BNFL regarding the changes to its program description. On June 21, 2001, the BNFL Vice President submitted the ISMS program description to the ORO Project Manager/COR. Memorandums between the Project Manager/COR and the ORO Operations Division Director during the summer of 2001 concerning the program description showed that it was reviewed. However, ORO never formally notified BNFL of ORO's comments or approval of the program description. The BNFL program description, Section 4.7, requires that any changes to mechanisms that would affect the objectives, principles, or functions must be approved by ORO in the same manner as changes to the Work Smart Standards set.

The Board evaluated the facts associated with the tube bundle reaction event for each of the ISM core functions. This method of analysis provides a clear understanding of the work processes and allows an accurate determination of the Judgments of Need.

2.2.1 Define the Work

Missions are translated into work, expectations are set, tasks are identified and prioritized, and resources are allocated.

The BNFL fixed-price contract is a performance-based contract in which performance and payment milestones establish a schedule whereby BNFL receives payment for successful completion of specified milestones. DOE's involvement with prioritization of work and tasks is limited to the milestones set forth in the contract. For example, the contractor's budgeting and long-range planning documents, which are normally reviewed during ISM program verifications of managing and operating contractors, were not available for the 2000 DOE verification of the BNFL ISM program due to the fixed-price contract. BNFL is using the Work Smart Standards set identified in PO-CS-006. The "necessary and sufficient" evaluation process for the Work Smart Standards set was concluded in January 1997. The Scope of Work in the contract incorporates the agreed-upon D&D and environment, safety, and health requirements for BNFL. DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, is not included in the contract.

At the individual task level, work control processes are developed for each type of work activity performed. Operational and maintenance activities are described in the EWPs,

which detail the actions that are performed during work execution. The EWP process is BNFL's primary mechanism for implementing the core functions of its ISMS.

The active EWP for this specific event is *Converter Disassembly* (CONV-111 R2), dated May 22, 2002. The EWP relies on the crafts' level of experience in the execution of work. The EWP is neither required to be in hand, nor is it required to be used as a reference or kept out in the open while the task is being completed. However, each step is marked as a "required step." At the time of the event, this EWP was in a desk drawer outside the converter enclosure.

Within the context of ISM, the use of less hazardous techniques would fulfill the requirement to provide appropriate controls to minimize risk. DOE fire safety criteria and National Fire Protection Association standards 1, *Fire Prevention Code*, and 241, *Construction and Demolition Operations*, stipulate that potential ignition sources be appropriately controlled. Such controls include the use of cutting technologies that minimize fire risk.

BNFL considered the following alternatives to the (current) plasma arc cutting methodology:

- Cold-cutting methods, such as milling, saw, lathe, and chip-less wheel cutting
- Manual dismantling
- Shear and laser cutting
- The "wet process" method

At the present time, the disassembly operation consists of a combination of cutting and manual disassembly. In an effort to increase efficiency and reduce the risk from a tube bundle reaction, BNFL has implemented a series of revisions to its operation, including a reduction of hot cutting in favor of manual disassembly. BNFL deems the use of plasma arc cutting in combination with other techniques to be the safest and most cost-effective approach to achieving its contractual performance requirements.

2.2.2 Analyze the Hazards

Hazards associated with the work are identified, analyzed, and categorized.

The analyses of the reaction hazards associated with the converter disassembly operation are described in the following documents:

- *Basis for Interim Operation (BIO) of the Low-Enriched Uranium (LEU) Process Buildings at the ETTP* and the associated Unreviewed Safety Question Determinations and Safety Evaluation Reports

- *Fire Hazards Analysis (FHA) for Buildings K-33, K-31, K-29, K-791B, K-761 and K-903 Supercompactor Facility*

- *Converter Disassembly*, EWP CONV-111 R2

- *ETTP Site Building Pre-incident Plan – BNFL- Building K-33 D&D Shop (K-902-8)*

The FHA evaluates reactions during converter disassembly by discussing the removal of jackscrews as the initiating activity for a reaction. The FHA assumes a 60-minute reaction of tube bundle material. The basis for the analysis is a 1995 tube bundle reaction that occurred at the Paducah Site and consumed an approximately basketball-sized amount of metal that was extinguished with a carbon dioxide fire extinguisher. Further discussion regarding the 1995 tube bundle reaction is provided that presumes it stemmed from the use of an acetylene torch and "disregard on behalf of the worker." The FHA assumes that use of a plasma arc torch will further reduce risk, since it does not generate the residual heat of an acetylene torch. However, the FHA does not recognize the proximity of the plasma arc torch as a fire initiator or that the geometry of a full tube bundle may complicate firefighting strategies.

The FHA does not analyze the consequences of removing the tube bundle from the converter shell while the bundle is reacting. The consequence of this action was the ignition of the flame-retardant, plastic security curtain. The security curtain is assumed to be what set off the two overhead sprinklers during the event. The FHA metal reaction analysis concludes that “The resulting tube bundle fire reinforces the need for additional emergency response planning and training, specific to the converter disassembly operation.”

The BIO identifies a tube bundle reaction as an “anticipated event”; however, there is little discussion on the mechanisms for initiation or progression of the reaction development. Appendix B identifies the consequences of a reaction and states that the results of the reaction are largely dependent on the tube bundle temperature. Tube bundle temperatures in excess of 1,000°F exacerbate the consequences of a tube bundle reaction in terms of the material and gases released.

BNFL has not performed an analysis to gain an understanding of what hazards are released during this type of reaction. During the investigation of the April 2000 event, the need for a reaction product analysis of the material released was identified as a corrective action. However, this action was not completed because, for that particular event, cold-cutting methods were employed afterward for that part of the disassembly operation and an analysis was assumed not to be necessary. While the BIO addresses the consequences of a reaction, the products (including the chemicals released) of allowing a reaction to continue until all the material is consumed are not known empirically. Without complete knowledge of the exposure hazards to the workers, risk to the workers was not minimized when plasma arc cutting was allowed within approximately 2 ¼ inches of the tube bundle.

The prefire plan provides instructions for fighting a tube bundle reaction in the D&D Workshop. It also cautions that hydrogen fluoride gas or other highly toxic aerosols can

be released, which require the use of full turnout gear and a self-contained breathing apparatus. The prefire plan states the following:

- "The application of water is not allowed, based on nuclear criticality safety controls."

- "Carbon dioxide or Class D extinguishers may be used."

- "For tube bundle reactions, which cannot be controlled by Class D or carbon dioxide agents:
  - ♦ Remove area combustibles within 20 feet of the fire.
  - ♦ Discontinue HEPA ventilation that is directly connected to the converter by closing the blast gates at the hose connection to the ventilation system or shut down the ventilation system.
  - ♦ Mechanically disperse the barrier material to limit the fuel source and reduce the localized fuel load."

The prefire plan does not address how the ETTP Fire Department is to extract the tube bundle or if it should remain in the converter shell during the reaction. Securing the ventilation can result in consequences involving radiological releases.

The EWP directs workers to "Leave HEPA unit running and leave area. If it does not put people at risk, as exiting any/all HEPA connections tied directly to the converter should be isolated using the blast gates if possible." Directions to the workers to extract the tube bundle from the converter shell during a reaction are not provided.

2.2.3 Develop and Implement Controls

Applicable standards and requirements are identified and agreed-upon, controls to prevent/mitigate hazards are identified, the safety envelope is established, and controls are implemented.

To ensure proper control of operations, BNFL management relies on its EWP process (PR-RO-005, Revision 9). A new revision to the EWP procedure was released on July 15, 2002, as a result of corrective actions previously identified by BNFL. However, the Board did not review it because it was not in effect at the time of the tube bundle reaction event.

The existing EWP process requires the group manager to perform the following steps:

(1) Define the scope of work.
(2) Determine the SME involvement in addition to the list of mandatory SME reviews.
(3) Select craft and supervisor participation on the EWP team.
(4) Manage the EWP team's review.

The EWP team walks down the task, creates steps for task completion, and incorporates any additional controls recommended by the SMEs into the EWP. Any steps required for safety or compliance are marked as required steps. Nuclear criticality safety steps are highlighted with an "NCS" at the end of the step. The team performs a hazards assessment and develops controls for incorporation into the EWP. Any bounding conditions are identified in a separate section, and nonstandard equipment is listed. The team adds any requirements for special training, if applicable. After the task is fully detailed, the SMEs review the EWP for any additional controls or assessments.

If a change to an EWP is required, an FCN is created. Changes can be intent or nonintent. An intent change requires the group manager to contact the mandatory SMEs and, after the hazards analysis is completed, to identify any additional SMEs that will be needed. The process is the same as previously discussed for a new EWP, except the group manager has the option to convene an EWP team. To place the two processes in perspective, an FCN is typically one page in length and a new EWP is at least 11 pages long.

The EWP procedure lists the steps to be taken in the creation and revision processes, but it does not give instructions on the breadth or depth of the SME reviews. The SMEs review the EWP check sheet for their discipline for an EWP revision. Any additional reviews are left to the SMEs' judgment. These additional reviews are neither documented nor formally required by management. For an FCN, the SMEs only review the FCN itself, since check sheets are not completed for FCNs. The EWP team must develop the steps to complete the task, but the process does not provide instructions on the level of detail required for each of the steps. Other EWPs reviewed varied widely in the specificity and consistency used in their creation. Some EWPs have the hazards identified without the corresponding controls being implemented (i.e., lockout/tagouts to ensure that equipment is de-energized when an electrical hazard is identified), and there are other instances where the reverse is true.

One FCN resulted in the revision of the EWP (CONV-111 R1, *Converter Disassembly*). On May 14, 2002, the day shift encountered a converter where the brackets were welded instead of bolted on. The FCN was coordinated with the workers for their input. The same eight SMEs that reviewed the original EWP completed a review of the FCN, after which the group manager approved the FCN for implementation. However, these SMEs approved the FCN without entering the converter enclosure to view the bracket configuration in relation to the tube bundle. This FCN was conceived, completed, reviewed, and approved during the day shift on May 15, 2002. The result was to use the plasma arc torch to cut the brackets off. The existing hazards analysis is based on cutting the jackscrews at a position approximately 12 inches from the tube bundle. The welded brackets are within 2 ¼ inches of the tube bundle.

On Thursday, May 16, 2002, the group manager initiated Revision 2 of EWP CONV-111 R1, which incorporated the FCN word for word, as well as adding other enhancements. On Monday, May 20, 2002, the eight SMEs approved the EWP revision without entering the converter enclosure to view the bracket configuration in relation to

the tube bundle. The group manager approved the revised EWP on Wednesday, May 22, 2002. The cutter and fire watch involved in the event were both trained on the revised EWP that same day in a prejob brief. The FCN and EWP revision processes do not identify the proximity of the plasma arc torch to the tube bundle as a hazard or prompt the consideration of alternative methods to remove the bracket.

For converter disassembly, BNFL also uses the Hot Work Permit as a work control. The *Health and Safety Plan* and the Hot Work Permit require the supervisor or appointee to inspect the work area and confirm that precautions have been taken to prevent a fire. The Hot Work Permit requires that no combustible material be located within 35 feet of the hot work. A flame-retardant, plastic security curtain was less than 35 feet from the hot work at the time of the event. This curtain was permitted under the Hot Work Permit because it was thought to be noncombustible. During the event, the workers extracted the reacting tube bundle and placed it in contact with the security curtain. This contact caused a portion of the security curtain to ignite and activate the fire suppression system. The EWP creation process did not recognize the hazard that the security curtain presented to the disassembly process and to the bounding accident scenario, specifically a tube bundle reaction.

EWP CONV-111 R2 contains a maximum of 35 individual steps to remove a tube bundle from a converter, and 30 of the steps are required steps. The on-the-job training currently in place and the repetition due to the sheer volume of converters to be disassembled provide the emphasis and reinforcement necessary for workers to learn the EWP converter disassembly steps. The EWP contains seven specific bounding conditions where the response is defined to be ". . . mandatory for any conditions listed . . ." The prejob brief is the only place the workers are formally trained on these mandatory responses. Workers are reinforced on these tasks during toolbox meetings; however, these toolbox meetings are not always documented.

Employee training on the EWP for converter disassembly and on other EWPs is a three-step process. The first step is a toolbox meeting. Interviews indicated that the content of toolbox meetings is too superficial and that they are held in a location where distractions and other noise interfere with the employees' ability to hear and learn. The second step is a prejob brief. The prejob brief is conducted in a controlled atmosphere, usually a lunchroom, with a predetermined lesson plan and sign-in sheets to document the training. The third step is where the foreman teaches the employees through on-the-job training. The on-the-job training is focused on performing cuts using a plasma arc torch in the sequence of steps required to properly disassemble the converter. Emphasis is not placed on the bounding conditions because these conditions are discussed in the prejob brief and in toolbox topics. The on-the-job training reinforces the steps for proper converter disassembly but not the proper reaction to conditions that violate the EWP's bounding conditions.

The fire watch was trained and positioned to watch for (fire) threats to the cutter. It was his responsibility to use an all-purpose, dry chemical fire extinguisher to suppress a fire on the cutter. The fire watch and the cutter were trained on the use of Class D

extinguishers. However, neither of them was formally trained to fight a tube bundle reaction. The bounding conditions of the EWP require both workers to evacuate the area in the event of a tube bundle reaction.

The ETTP Fire Department's prefire plan contains several drawings of the building and the D&D Workshop area. It identifies the location of firefighting equipment and provides a general description of the hazards.

2.2.4 Perform Work Safely

Readiness is confirmed and work is performed safely.

Normal Work Controls

BNFL's craft personnel have a fundamental understanding of the steps to disassemble a converter. When asked about any restrictions on the disassembly actions, the cutter and fire watch recited many restrictions pertaining to the setup of the cuts. Neither of them mentioned the bounding conditions in the EWP and their associated required actions. The cutter and fire watch participated in the prejob brief on the revised EWP on May 22, 2002. The revisions to the EWP were an exact incorporation of the approved FCN in effect. The EWP is kept in a desk drawer outside the cutting area/converter enclosure. The foreman, who monitors the cutter's progress during the shift, knew about the EWP and its location, but neither the cutter nor the fire watch was aware of the EWP's location when asked about it on two occasions by different Board members.

On the day of the event, the craft personnel made several errors with respect to the EWP steps, all of which were required steps. The cutter, fire watch, and foreman tried to extract the tube bundle before they removed the brackets. They did not realize their error until the brackets contacted the converter shell, preventing the extraction. They then pushed the tube bundle back into the converter shell. The foreman observed the cutter remove one bracket using the plasma arc torch and released him to cut the remaining three brackets. The EWP requires the brackets to be removed before extracting the tube bundle. The workers skipped Step 5.5 of EWP CONV-111 R2 and then returned to it to complete that part of the disassembly.

The Board noticed a marked difference in the shift operations and apparent incomplete shift turnover practices. The day shift has developed a homemade blast shield to deflect kerf from the tube bundle. Only the most proficient cutters are allowed to cut the welded brackets. Finally, an observer (in addition to the cutter and fire watch) is added to the area to watch the tube bundle when a welded bracket is encountered. Only selected night shift cutters are allowed to cut the welded brackets. The foreman occasionally observes the first bracket cut and then releases the cutter to complete the remaining ones. The weekend shift foreman is the only one that cuts the welded brackets when they are encountered.

Emergency Response

The workers involved in the tube bundle reaction event had conflicting instructions concerning firefighting response in the D&D Workshop. In part, this might be due to the lack of clear delineation of actions in the *Fire Emergency Response* procedure, as illustrated below.

- PR-SS-500, *Fire Emergency Response*, Appendix G, "Guidance for Response to Likely Emergency Situations," states "If the fire is a small, well contained fire, and can be managed using one extinguisher by the person identifying the fire: . . . Select the appropriate fire extinguisher and extinguish the fire."

- Appendix H, "Special Emergency Response Protocols for the D&D Workshop," provides further direction in Section 3, "Fire Fighting in the Workshop," which states "Do not use water or CO2 as they may create hazardous gases . . . therefore addressing a metal fire requires a different type of extinguisher—a Class D extinguisher."

- The remainder of the fire response discussion (using Class D extinguisher) is the same as is discussed in Appendix G for all other fires. Specifically, it states the following:

  a) "If the involved employee is able to control the fire using one fire extinguisher, they should do so. They should then notify their supervisor . . .

  b) If the involved employee feels that assistance is warranted, they should pull a fire alarm in the Workshop . . ."

- Appendix G, Section 5, "Bundle Reaction," states "In the event of a reaction in this area (D&D Workshop) workers leave the enclosure in a safe configuration, exit the enclosure, initiate the new D&D Workshop fire alarm pull box system, and evacuate the workshop."

EWP bounding condition 6, "Tube Bundle Reaction," states "Leave HEPA unit running and leave the area. If it does not put people at risk, as exiting any/all HEPA connections tied directly to the converter should be isolated using the blast gates if possible." The workers and foreman did not follow the EWP bounding condition requirement in CONV-111 R2 when they attempted to fight the tube bundle reaction. The foreman shut the rollup doors, left the blast gates open, left the HEPA units running, and left the area.

The workers and foreman were trained in the use of Class D extinguishers, but they were neither formally trained how to fight a tube bundle reaction, nor were they wearing the appropriate PPE to do so. The foreman was in a Tyvek coverall without a

respirator. The cutter had a functioning respirator, but he had to lift it occasionally to communicate with the fire watch. The fire watch's respirator did not have the required airflow due to a low battery.

BNFL requires respirators to be worn within 20 feet of cutting operations per the Radiological Work Permits associated with cutting operations. The 3M PAPR is the standard respirator worn in the building. PAPRs are assigned to individuals, and they store their own respirator equipment. There are normally two batteries assigned to each respirator, and the chargers are kept in the cabinet with the PAPR or in a cabinet by themselves next to the PAPRs. When operating and worn properly, a PAPR possesses an Assigned Protection Factor (APF) of 1,000. If the blower is not operating, no APF is credited by the Radiological Control organization. Toolbox meetings have communicated the guidance that under normal operating conditions, the mask may be raised for brief conversations using the three-finger rule. No guidance is available for lifting and not lifting the mask to communicate during emergencies or tube bundle reactions. Procedure PR-SS-001, *Powered Air Purifying Respirator Issue and Use*, states that batteries should be charged for a minimum of 14 hours before they are used and that verification of the airflow is required once a shift. (Airflow meters are attached to the respirators. A low or dead battery or a clogged filter usually causes insufficient airflow.) BNFL's Respirator Protection Training is an annual, two-hour classroom instruction. All three individuals involved in the event were current in their respirator training.

The *Project Emergency Plan* (PO-GM- 004) states "Drills and exercises may be arranged by the project specifically for the project or they may be coordinated activities with the ETTP-ERO drills/exercises." BNFL performs an annual Radiation Criticality Accident Alarm System evacuation and accountability drill as required by the *BNFL Project Emergency Plan* and American National Standards Institute requirements. These drills are coordinated and supported by Bechtel Jacobs Company LLC (BJC), the site's lead contractor for emergency management. In addition, the ETTP Fire Department has conducted response drills. In 2002, BNFL personnel participated with BJC personnel in a criticality event tabletop drill/training exercise.

BNFL performs management assessments of actual events to maintain readiness. To date this calendar year, there have been 18 emergency response events and the annual evacuation and accountability drill. Management self-assessments were performed on each event, indicating the positive and negative findings and providing corrective actions, when warranted. ETTP site exercises have not involved emergencies emanating from a BNFL facility, and none are planned for calendar year 2003.

The PEW is the initial point of contact for BNFL operations that interface with emergency organizations. The PEW is responsible for briefing the incident commander as soon as he arrives at the scene, and the PEW remains throughout the incident to advise the incident commander and the EOC, if activated. The PEW is knowledgeable about issues that are required to make appropriate decisions concerning emergency response activities. This would include such items as the enrichment limits of the

converter. However, it would not include details such as the current status of the converter disassembly. The PEW also knows the BNFL SMEs (such as industrial hygiene, nuclear criticality safety, electrical, and ventilation) and will contact them directly if they are needed. BNFL procedure PO-GM-004 indicates that, among other duties, PEWs act as BNFL's incident commanders and will direct all BNFL emergency response activities, including directing evacuation of buildings, accounting for employees, notifying the PSS, and assessing emergency scene conditions.

BNFL procedure PR-SS-501 provides detailed direction to PEWs for emergency command and incident response duties and responsibilities. One of the corrective actions resulting from the second tube bundle reaction, which occurred on July 25, 2001, was to train PEWs to assume control of emergency situations and act as the single point of contact between BNFL and BJC.

The five-person PEW shift schedule is as follows:

- Two people on day shift from 6:00 am to 4:30 pm
- One person on night shift from 6:00 pm to 4:00 am
- One person on weekend day shift from 6:00 am to 6:00 pm
- One person on weekend night shift from 6:00 pm to 6:00 am

This schedule leaves two gaps every weekday in the on-site qualified PEW presence: (1) 4:00 – 6:00 am and (2) 4:30 – 6:00 pm. This is consistent with procedure PO-GM-004, which states that a PEW will be on duty whenever project activities are taking place, even though the PEW is not required to be on site. The response time for the fire commander to be on scene at Building K-33 during the event on June 27 was four minutes. If the PEW is on call rather than on site, he cannot support the tasks delineated in the applicable procedures. The shift foreman performs the PEW's function during these gap periods; however, these foremen are not trained or qualified PEWs according to Appendix G of the *BNFL Project Emergency Plan*. The shift foreman is responsible for performing evacuation and accountability of personnel. Another recent event, the release of hydrogen fluoride gas on June 6, 2002, also occurred during a gap period in PEW coverage. One of the corrective actions resulting from the hydrogen fluoride gas incident was for the BNFL Emergency Management organization to evaluate the need for a PEW to be on site as long as work is being performed. This corrective action is identified in the self-assessment report *Emergency Response – Release of H.F. Gas*, dated June 6, 2002, but it was not implemented by the time of the tube bundle event.

The emergency response organizations (firefighting, radiological control, industrial hygiene, security) responded to the event as planned.

ETTP Fire Department – The firefighters arrived at Building K-33 four minutes after receiving the call box alarm and entered the D&D Workshop nine minutes after receiving the alarm. The firefighters shut off the sprinkler system, since it was not contributing to the termination of the reaction. The firefighters had difficulty locating

the additional Met-L-X fire extinguishers in the vicinity of the converter enclosure after they had depleted a small and a large extinguisher. They requested additional Met-L-X extinguishers, which were brought from Building K-31. The firefighters terminated the tube bundle reaction by segregating the reacting portions of the bundle and using the Met-L-X extinguishers on the debris. The firefighters were frisked out without incident.

As part of a lessons learned from this tube bundle reaction event, the incident commander and firefighters walked down the exact location of all (existing and new) Met-L-X extinguishers for the D&D Workshop. Another corrective action was the procurement of additional Met-L-X extinguishers for the D&D Workshop.

Radiological Protection – The radiological control technician on duty at 5:15 am and two instrument technicians, who were also qualified as radiological control technicians, responded to the reaction event from 5:15 am to its termination. In addition to surveys and air sampling, nasal smears were taken of the fire watch whose respirator was not functioning properly, along with the cutter, the foreman, and two other individuals who were in the general area. All of the nasal smears had nondetectable results for radioactive contamination. These five individuals also underwent bioassays, although the results of these are not yet available. Three FMTs were deployed at 9:34 am to selected locations under the direction of the EOC, and they were in place by 9:58 am. Each FMT reported nondetectable results, and the teams returned to the EOC at 10:30 am, 10:40 am, and 10:56 am. The delay in FMT deployment (from the time of fire initiation) was due in part to the time required for EOC activation.

EOC Activation – Activation of the EOC is determined by the classification of the event as an OE by the PSS on shift. The Emergency Action Level (EAL) associated with activation is listed in the "Discretionary EAL" section of the *Site EAL Classification Guide* (BJC/OR-863, Revision 0), which provides guidance for the prompt classification of an emergency based on the EALs. These discretionary EALs were developed to include situations not specifically covered in a facility-specific EAL. The *Site EAL Classification Guide* states "The guide should be used in conjunction with the sound judgment of the PSS and the EOC Crisis manager, if the EOC is activated, to arrive at the proper categorization and classification for the particular event."

The *Site EAL Classification Guide*, "EAL Table," lists a report of a fire and smoke contained to facility and involving less than 1,000 kilograms of uranium as an OE. There have been different categorizations of these events in the past by PSS supervisors who received input from BNFL personnel. Of the five PSS supervisors associated with the three tube bundle reactions related to converters, two of them categorized the events as OEs and three did not categorize them as OEs. The first reaction, which occurred on April 4, 2000, was not categorized as an OE by the PSS on duty. The second reaction, which occurred on July 25, 2001, was not classified as an OE by the PSS on duty when the reaction was reported, but it was classified as an OE by his relief a half an hour later. Likewise, the PSS on duty at the time of the June 27, 2002, reaction did not categorize the event as an OE at the time (fire box pulled at 5:15 am), but his relief categorized it as an OE at 7:03 am after he came on duty at 7:00 am (the reaction was

reported terminated at 6:51 am). The first and third reactions involved converters that had less than 2.5% enriched uranium, while the second reaction involved depleted uranium. In all three reactions, the HEPA filtration system was operating properly. Even without HEPA filtration, BNFL's analyses indicate that off-site consequences from these events are negligible.

Security and Industrial Hygiene – Industrial hygienists were involved in sampling activities throughout the building, including one sample station inside the converter enclosure during the tube bundle reaction event, from approximately 6:00 am to termination of the event. The security response consisted of monitoring personnel entering and exiting, directing traffic to facilitate the emergency responders' response, and providing additional personnel on an as-needed basis.

2.2.5 Feedback and Improvement

Feedback information on the adequacy of controls is gathered, opportunities for improving the definition and planning of work are identified and implemented, line and independent oversight is conducted, and, if necessary, regulatory enforcement actions occur.

BNFL's feedback and improvement requirements are included in the *Integrated Safety Management Program Description* (PO-SS-017). Corrective actions are required as part of the Title 10 Code of Federal Regulations (CFR) Part 830, *Nuclear Safety Management*, Subpart A, "Quality Assurance Requirements." Specific requirements are described in paragraph 830.122, Criterion 3, "Management/Quality Improvement." BNFL has a Quality Assurance Program Plan based on the International Standard for Quality Assurance, ISO 9000. BNFL implements Subpart A of 10 CFR 830 through the *East Tennessee Technology Park Three-Building Decontamination and Decommissioning and Recycle Project Quality Assurance Program Plan (QAPP) for 10 CFR 830 Subpart A* (PO-CS-004, Revision 4, dated October 24, 2001).

Requirements for quality improvement and corrective actions include the following:

- Establish and implement processes to detect and prevent quality problems.
- Identify, control, and correct items, services, and processes that do not meet the established requirements.
- Identify the causes of problems and work to prevent recurrence as a part of correcting the problem.
- Review item characteristics, process implementation, and other quality-related information to identify items, services, and processes needing improvement.

BNFL has adopted the requirements verbatim and added a requirement that states "Management shall establish, document, and maintain policies and procedures for

investigating the cause of nonconforming product and the corrective action needed to prevent recurrence." Implementing procedures applicable to corrective actions include *Issues Management* (PR-CS-002, Revision 4, dated March 28, 2002*)* and *Nonconformance Identification, Correction, Closure, Tracking and Trending* (PR-CS-014, Revision 2, dated May 23, 2002). *Independent Assessment* (PR-CS-006, Revision 2, dated January 2, 2001) is used for, among other things, verifying completed corrective actions. Other procedures used include *Formal Root Cause Analysis* (PR-CS-023) and *Receipt Inspection Process* (PR-CS-008). Reporting is addressed in *Occurrence Reporting* (PR-CS-024). Also, the Price-Anderson Amendments Act (as amended) permits DOE compliance enforcement. The DOE Office of Price-Anderson Enforcement (EH-10) is responsible for enforcement. BNFL uses *Price-Anderson Amendments Act Noncompliance Identification, Evaluating, and Reporting Process* (PR-AD-005, Revision 0, dated August 9, 2001) to implement DOE's guidance.

The three tube bundle reactions, which occurred on April 4, 2000; July 25, 2001; and June 27, 2002, all resulted in occurrence reports to DOE management in accordance with existing procedures. BNFL also provided Price-Anderson Amendments Act NTS reports in accordance with the guidance established by the DOE Office of Price-Anderson Enforcement (EH-10). Corrective action plans are required as part of the NTS process. These plans are tracked in both NTS and the BNFL Issues Management System. A letter from the ORO Project Manager/COR to the BNFL General Manager dated April 18, 2000, lists 15 DOE concerns from then-current events. Even though BNFL responded to ORO by letter on May 11, 2000, the concerns were never entered into the Issues Management System because the Compliance Support organization did not see the letters. Also, ORO created a "Project Team to evaluate BNFL's response to safety concerns regarding the converter disassembly process" and transmitted the team's results to BNFL on March 29, 2002, but ORO's recommendations were not incorporated into the Issues Management System. BNFL did not enter the concerns into the Issues Management System because they were identified as concerns rather than findings.

BNFL prepared NTS report NTS-ORO-BNFL-K33-2000-0002 as a result of the April 4, 2000, tube bundle reaction. A total of 36 corrective actions were identified, 35 of which have been officially closed. BNFL delayed the last action (number 34, Validation) and scheduled it for a June 30, 2002, completion date (i.e., when an independent assessment was to be performed by the Compliance Support organization). This action remains open, even though the Issues Management System states that it was closed in December 2001.

Prior to completion of the above-named corrective actions, a tube bundle reaction occurred on July 25, 2001, during in-situ D&D work in Building K-31. BNFL generated an NTS report, NTS-ORO-BNFL-K31-2001-0001, which included 11 corrective actions. A change in project management in early 2002 required the root cause analysis of this event to be re-done, and the corrective actions were modified as a result. Nine actions remain to be completed. These are more programmatic in nature and include the following:

- Implementing enhancements to the EWP process.
- Assuring the adequacy of worker and supervisor training.
- Implementing an effective system of management oversight.
- Investigating the basic metal chemistry and bundle reaction suppression.

A subsequent tube bundle reaction in Building K-33 occurred on June 27, 2002. An NTS report has not yet been drafted. The June 27 reaction resulted in this DOE-required Type B Accident Investigation. BNFL is tracking the corrective actions for all three tube bundle reactions in its Issues Management System, although DOE has not yet accepted a formal corrective action plan for the June 27 reaction.

The Board notes that BNFL has delayed, extended, and changed a number of the corrective actions for the April 4, 2000, and July 25, 2001, tube bundle reactions. Nineteen of the thirty-six actions for the April 4, 2000, reaction were delayed and/or rescheduled, and some were changed several times. Three of the nine actions for the July 25, 2001, reaction were delayed and changed, and an additional three actions are past due.

The Board observes that, as a result of numerous BNFL Nonconformance Reports impacting its Corrective Action Program, BNFL has self-identified and initiated a corrective action plan for the Corrective Action Program, and the plan is being tracked to closure against NCR 2002-064, dated April 15, 2002. BNFL has not specified a completion date for the corrective action plan; however, part of the plan—Compliance Support organization approval of all EWPs—is scheduled for implementation on July 15, 2002. Planned actions that remain to be completed for the Corrective Action Program include training appropriate personnel involved in the program and upgrading the Issues Management System database.

Both BNFL and DOE management use forms of management assessments to identify, resolve, and prevent issues and problems. BNFL conducts emergency management self-assessments in accordance with procedure PR-CS-009. The assessments usually react to incidents and result in a report identifying requirements, positive and negative findings and observations, assignment of corrective actions required, and required completion dates for the actions. Unless or until a Nonconformance Report is written against a requirement or the actions are incorporated into a more formal report (accident investigation report, NTS report, etc.), BNFL does not capture the corrective actions in its Issues Management System. The manager who prepares the assessment report is responsible for establishing and closing the corrective actions.

DOE uses an operational awareness review process wherein technical functional reviews are scheduled either monthly or quarterly. The ORO Project Manager/COR transmits these review reports to his BNFL counterpart monthly. BNFL has two weeks to respond and develop corrective action requirements, which are entered into the Issues Management System. Sometimes ORO disagrees with the BNFL response and requests additional and/or modified actions. When BNFL agrees, these actions are also entered into the Issues Management System. In reviewing reports from operational awareness

reviews from January 2001 through July 2002, it is noted that the monthly schedules are usually met. The functional areas covered in these reviews include environmental compliance, radiation protection, industrial safety, and industrial hygiene. Sometimes the areas reviewed do not yield findings of great significance.

After the tube bundle reaction on July 25, 2001, ORO imposed corrective actions on itself and documented these in a memorandum dated October 26, 2001, from the ORO Manager to the Assistant Secretary for Environmental Management. The memorandum states that ORO will correct its failings by performing the following actions:

- Documented reviews of training records of workers and supervisors on a random basis.

- Random field interviews and observations of workers, safety personnel, and supervisors to check their knowledge of work plan requirements.

- Random field verifications of work plans to verify that the actual method of work matches the requirements.

- Sharing the documented results of the reviews with senior management monthly or as appropriate.

The Board's investigation confirmed that, with the exception of a review of training records, the facility representative assigned to BNFL is meeting these commitments directly or through the formal operational awareness reviews using ORO SMEs. The Board observed that effective DOE oversight of BNFL operations is constrained by resources. An additional facility representative position has been formally assigned but is not yet implemented.

The Board observed that DEAR clause 970.5204-2, subparagraph 7(e), is not included in the BNFL contract. This subparagraph requires annual review and update of "safety performance objectives, performance measures, and commitments consistent with and in response to DOE's program and budget execution guidance and direction." Since this requirement is not in the contract or being implemented, the ISMS performance measures and evaluations are not being factored into the maintenance, feedback, and improvement of the BNFL ISMS.

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3.0 ANALYSIS

The Board used several analytical techniques to determine the causal factors of the event. Events and causal factors were charted using the ISM core functions. The Board used change and barrier analysis techniques to analyze the facts and identify the causes of the event. The causal factors related to weaknesses in implementation of the ISM core functions collectively contributed to the event. Judgements of Need are presented in Tables ES-1 and 4-1.

The Board compared the corrective actions from the April 4, 2000, tube bundle reaction, the July 25, 2001, tube bundle reaction, the BNFL Nonconformance Report on the Corrective Action Program, and the NTS report dated May 9, 2002, with the Judgments of Need. This analysis is presented in Table E-1.

3.1 Barrier Analysis

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

3.2 Change Analysis

Change is anything that disturbs the "balance" of a system which is operating as planned. Change is often the source of deviations in system operations. Change can be planned, anticipated, and desired, or it can be unintentional and unwanted. Change analysis examines planned or unplanned changes that caused undesired results or outcomes related to the event. This process analyzes the difference between what is normal (or "ideal") and what actually occurred. The results of the change analysis are used to support the development of the causal factors. Appendix C, Table C-1, contains the change analysis.

3.3 Events and Causal Factors Analysis

An events and causal factors analysis was performed in accordance with the DOE Workbook *Conducting Accident Investigations*. The events and causal factors analysis requires deductive reasoning to determine which events and/or conditions contributed to the accident/event. Causal factors are the events or conditions that produced or

contributed to the occurrence of the accident/event, and they consist of direct, contributing, and root causes.

The direct cause is the immediate events or conditions that caused the accident/event. The contributing causes are the events or conditions that, collectively with the other causes, increased the likelihood of the event but which did not cause this tube bundle reaction event. Root causes are the events or conditions that, if corrected, would prevent recurrence of this and similar events. *The direct cause of the event was kerf from the plasma arc torch intersecting the tube bundle, causing an exothermic metal reaction*. A summary of the Board's causal factors analysis is presented in Appendix D, Table D-1.

3.4 Integrated Safety Management

Table 3-1. Weaknesses in Implementation of the ISM Core Functions

There are significant weaknesses in BNFL's implementation of the five core functions of ISM that contributed to this event. These weaknesses include the following:

Core Function 1
Define the Work

- DEAR clause 970.5204-2, subparagraph 7(e), is not in the BNFL contract, and ISMS performance measures and evaluations are not being factored into the maintenance, feedback, and improvement of the BNFL ISMS.
- ORO has not approved the BNFL ISMS program description after four revisions.
- ORO has not formally approved or evaluated the BNFL ISMS program since the initial verification in 2000.
- BNFL contract is a fixed-price contract, and ORO's involvement in prioritizing work is limited to milestones in the contract.
- The Work Smart Standards set was developed in 1997, and DOE 5480.19, *Conduct of Operations Requirements for DOE Facilities*, is not in the contract.
- The EWP relies on the crafts' skill level to execute work, and BNFL does not require the EWP to be in hand, nor is it required to be used as a reference or kept out in the open while the task is being completed.
- DOE directives and National Fire Protection Association standards stipulate that ignition sources be appropriately controlled. Such controls include the use of cutting technologies that minimize fire risk.

Contributing Cause 8: ORO's and BNFL's lack of rigor contributed to less-than-adequate implementation of the core functions of the of the ISM program.

Table 3-1. Weaknesses in Implementation of the ISM Core Functions (continued)

Core Function 2
Analyze the hazards

- The hazard analyses were developed on the basis of an incomplete understanding of tube bundle metal chemistry in a reaction environment.
- The analyses do not reflect the potential for worker intervention during a tube bundle reaction event.
- The hazard analyses do not consider the consequences of the removal of a reacting tube bundle from the converter shell.
- The hazard analyses do not consider the geometry of reacting tube bundles in relation to the potential effectiveness of available fire safety features.
- The FHA does not completely evaluate the consequences of a sustained tube bundle reaction on HEPA filter integrity.
- The FHA does not explicitly address the flammability of the flame-retardant, plastic security curtains.
- The EWP does not address the risks to workers (e.g., the fire watch) attempting to suppress a tube bundle reaction with manual firefighting equipment.
- The EWP does not relate the hazards of a tube bundle reaction to the use of appropriate fire extinguishers.
- The ETTP Fire Department prefire plan does not explicitly address appropriate tactics for a tube bundle reaction.
- The prefire plan does not reflect the inaccessibility of the tube bundles within the converter shell.

Contributing Cause 3: The hazards associated with converter disassembly were not adequately identified and analyzed.

Contributing Cause 7: The FCN process and the EWP change process did not recognize the increased danger of a tube bundle reaction.

Core Function 3
Develop and Implement Controls

- The EWP creation process did not provide instructions on the level of detail required for each step to complete the task.
- The FCN and EWP revision processes did not identify the proximity of the plasma arc torch to the tube bundle as a hazard.
- The FCN and EWP revision processes did not prompt the consideration of alternative methods to remove the welded brackets.
- The EWP creation process did not recognize the effect the flame-retardant security curtain created to the tube bundle reaction accident scenario.
- None of the eight SMEs entered the converter enclosure to view the bracket configuration in relation to the tube bundle for the FCN or the EWP revision.

Table 3-1. Weaknesses in Implementation of the ISM Core Functions (continued)

- BNFL does not provide a method to reinforce the proper reaction to conditions that violate the EWP's bounding conditions.

Contributing Cause 6: Training on the EWP was inadequate.

Core Function 4
Perform Work Safely

- The workers did not follow the proper sequence of steps, per the procedure, during the disassembly process.
- The workers and foreman lacked clear direction for their response to a tube bundle reaction.
- The workers and foreman were neither formally trained nor drilled to fight a tube bundle reaction.
- The foreman did not wear appropriate PPE to enter the converter enclosure.
- The workers improperly used their appropriate PPE in a fire environment.
- The BJC emergency responders were not familiar with the location of Met-L-X extinguishers, and BNFL's PEW, whose emergency function is to interface with emergency responders, was not on site at the time of initial responder arrivals.

Contributing Cause 1: The EWP for the converter disassembly was not followed.

Contributing Cause 4: The workers took inappropriate emergency actions, which led to less-than-adequate results.

Contributing Cause 5: The response to emergency conditions at Building K-33 was less than adequate.

Core Function 5
Feedback and Improvement

- Corrective action plans from two previous tube bundle reactions in converters did not prevent this reaction.
- The Nonconformance Report for the Corrective Action Program, NCR 2002-064, of April 16, 2002, is incomplete. It has no end dates.
- For NTS-ORO-BNFL-K33-2000-0001 on the April 4, 2000, tube bundle reaction, the NTS report corrective action plan still has one action past due (action 34, validation) as of June 30, 2002. The action was closed in the Issues Management System in December 2001.
- Actions from ORO COR's letter of April 18, 2000, to BNFL were never entered in the Issues Management System because the Compliance Support organization did not see the letter.

Table 3-1. Weaknesses in Implementation of the ISM Core Functions (continued)

- BNFL did not incorporate recommendations from the DOE Project Team (ORO COR letter dated March 29, 2002) into the Issues Management System.
- DEAR clause 970.5204-2, subparagraph 7(e), is not in the BNFL contract. This clause states "Dates for submittal, discussions, and revisions to the System will be established by the contracting officer . . . On an annual basis, the contractor shall review and update, for DOE approval, its safety performance objectives, performance measures, and commitments consistent with and in response to DOE's program and budget execution guidance and direction." Since this requirement is not in the contract and is not being implemented, the ISMS performance measures and evaluations are not being factored into the maintenance, feedback, and improvement of the BNFL ISMS.
- The timeliness on completion of corrective actions is less than adequate:
  - Tube Bundle Reaction #1 – The validation action is incomplete.
  - Tube Bundle Reaction #2 – Nine of the eleven corrective actions are still open.
- There is lack of communication and sharing of lessons learned between shifts.
- BNFL management changes in early 2002 required the root cause analysis to be redone. Five corrective actions were added.

Contributing Cause 2: Communications and lessons learned between shifts are less than adequate.

Contributing Cause 9: The BNFL Corrective Action Program is ineffective.

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4.0 CONCLUSIONS AND JUDGMENTS OF NEED

Judgments of Need are the managerial controls and safety measures determined by the Board to be necessary to prevent or minimize the probability or severity of a recurrence. These Judgments of Need are linked directly to causal factors, which are derived from facts and analyses and form the basis for corrective action plans, which are the responsibility of line management.

The Board reviewed the work controls involving converter disassembly, emergency response to the event, fire protection measures, and corrective actions associated with previous tube bundle reaction events. The results of these reviews were factored into the five core functions of ISM. Judgments of Need were developed that considered what actions were necessary to prevent recurrence of this event and other similar events.

The Judgments of Need are focused management systems that will accomplish the following:

- Impact workers to improve performance
- Ensure safe response to abnormal conditions and changes to unanticipated conditions
- Manage performance to ensure that work is conducted within controls
- Ensure that DOE assesses performance within the work controls

The Board focused on strengthening the work controls and the oversight of those controls to ensure proper implementation of the requirements of the work package. Associated with work control improvements, the manner in which BNFL addresses FCNs to existing work packages needs greater management control to ensure that the hazards resulting from the changes are appropriately analyzed and that actions are taken to minimize their adverse consequences. The analysis of the tube bundle reaction needs to be completed and an appropriate emergency response to this event needs to be developed and drilled so that workers understand and can respond appropriately to this type of event.

Corrective actions planned after the July 2001 tube bundle reaction were not implemented at the time of this event. Prior to this event, BNFL had determined that problems existed with implementation of its Corrective Action Program that required programmatic correction. These latter actions were also not completed. BNFL has recognized the issues of timeliness and prioritization in its Nonconformance Report. Therefore, the Board considers the BNFL Corrective Action Program to be ineffective. One Judgment of Need recommends implementation of a revised corrective action program.

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Table 4-1. Judgments of Need

JON No.	Judgment of Need	Contributing and Root Causes
Conduct of Work		
JON 1	BNFL needs to develop and implement a system to facilitate sharing of work practices, issues, and solutions across all shifts at the worker, foreman, and supervisory levels.	CC-2: Communications and lessons learned between shifts are less than adequate. CC-4: The workers took inappropriate emergency actions, which led to less-than-adequate results. CC-7: The FCN process and the EWP change process did not recognize the increased danger of a tube bundle reaction. CC-8: ORO's and BNFL's lack of rigor contributed to less-than-adequate implementation of the core functions of the ISM program. RC-2: BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring an appropriate emergency response.
JON 2	BNFL needs to revise the EWP process so that the review of an intent change to an EWP is as rigorous as the original EWP creation process.	CC-1: The EWP for the converter disassembly was not followed. CC-3: The hazards associated with converter disassembly were not adequately identified and analyzed. CC-6: Training on the EWP was inadequate. CC-7: The FCN process and the EWP change process did not recognize the increased danger of a tube bundle reaction. RC-1: The corrective actions from the previous two tube bundle reactions did not establish the framework that these reactions are a preventable consequence of D&D activities. RC-2: BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring an appropriate emergency response.

Table 4-1. Judgments of Need (continued)

JON No.	Judgment of Need	Contributing and Root Causes
Analysis and Emergency Response		
JON 3	BNFL and ORO need to ensure that the planned analysis of metal chemistry reflects the potential for reactions involving tube bundles anticipated to contain elevated levels of contamination.	CC-3: The hazards associated with converter disassembly were not adequately identified and analyzed. CC-9: The BNFL Corrective Action Program is ineffective. RC-1: The corrective actions from the previous two tube bundle reactions did not establish the framework that these reactions are a preventable consequence of D&D activities. RC-2: BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring an appropriate emergency response.
JON 4	Based on the result of the metal chemistry analysis, BNFL needs to revise the current hazards analyses and related documents for converter disassembly to identify effective safeguards for potential accidents.	CC-3: The hazards associated with converter disassembly were not adequately identified and analyzed. CC-5: The response to emergency conditions at Building K-33 was less than adequate. RC-2: BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring an appropriate emergency response.
JON 5	BNFL needs to develop a clear and consistent response to abnormal events and emergencies and train workers accordingly.	CC-3: The hazards associated with converter disassembly were not adequately identified and analyzed. CC-4: The workers took inappropriate emergency actions, which led to less-than-adequate results. CC-5: The response to emergency conditions at Building K-33 was less than adequate. CC-6: Training on the EWP was inadequate. RC-2: BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring an appropriate emergency response.

Table 4-1. Judgments of Need (continued)

JON No.	Judgment of Need	Contributing and Root Causes
JON 6	BNFL needs to improve emergency readiness capability through a combination of drills, exercises, walkdowns, and PEW coverage.	CC-4: The workers took inappropriate emergency actions, which led to less-than-adequate results. CC-5: The response to emergency conditions at Building K-33 was less than adequate. RC-2: BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring an appropriate emergency response.
Management Oversight		
JON 7	BNFL needs to ensure that its management oversight systems effectively implement and reinforce that work is performed within controls, abnormal responses are consistent, and effective communications are conducted between shifts at all levels where work is being performed.	CC-1: The EWP for the converter disassembly was not followed. CC-2: Communications and lessons learned between shifts are less than adequate. CC-4: The workers took inappropriate emergency actions, which led to less-than-adequate results. CC-5: The response to emergency conditions at Building K-33 was less than adequate. CC-6: Training on the EWP was inadequate. CC-7: The FCN process and the EWP change process did not recognize the increased danger of a tube bundle reaction. CC-8: ORO's and BNFL's lack of rigor contributed to less-than-adequate implementation of the core functions of the ISM program. RC-1: The corrective actions from the previous two tube bundle reactions did not establish the framework that these reactions are a preventable consequence of D&D activities. RC-2: BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring an appropriate emergency response.
JON 8	BNFL needs to complete pending corrective actions on its Corrective Action Program, including incorporation of	CC-3: The hazards associated with converter disassembly were not adequately identified and analyzed. CC-6: Training on the EWP was inadequate.

Table 4-1. Judgments of Need (continued)

JON No.	Judgment of Need	Contributing and Root Causes
	DOE's recommendations into the Issues Management System.	CC-7: The FCN process and the EWP change process did not recognize the increased danger of a tube bundle reaction. CC-9: The BNFL Corrective Action Program is ineffective. RC-1: The corrective actions from the previous two tube bundle reactions did not establish the framework that these reactions are a preventable consequence of D&D activities. RC-2: BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring an appropriate emergency response.
DOE Oversight		
JON 9	ORO, through its oversight program, needs to evaluate the contractor's implementation of ISM to ensure that work is being performed safely.	CC-1: The EWP for the converter disassembly was not followed. CC-2: Communications and lessons learned between shifts are less than adequate. CC-3: The hazards associated with converter disassembly were not adequately identified and analyzed. CC-4: The workers took inappropriate emergency actions, which led to less-than-adequate results. CC-5: The response to emergency conditions at Building K-33 was less than adequate. CC-6: Training on the EWP was inadequate. CC-7: The FCN process and the EWP change process did not recognize the increased danger of a tube bundle reaction. CC-8: ORO's and BNFL's lack of rigor contributed to less-than-adequate implementation of the core functions of the ISM program. CC-9: The BNFL Corrective Action Program is ineffective. RC-1: The corrective actions from the previous two tube bundle reactions did not establish the framework that these reactions are a preventable consequence of D&D activities.

5.0 BOARD SIGNATURES

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Appendix A – Appointment of Type B Accident Investigation Board

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Insert Board Memo here, page 2.

Appendix B – Barrier Analysis

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Table B-1. Barrier Analysis

Barrier	Purpose	Analysis/Effect on Accident
EWP CONV-111 R2	Safely and efficiently guide disassembly operations	Personnel were placed at risk while operating outside analyzed parameters. Extracting the reacting tube bundle caused the security curtain to catch fire. Personnel were placed at risk by using insufficient PPE for firefighting.
Converter outer shell	Enclose the tube bundle	The converter shell could have been relied on as an effective barrier if it had been analyzed for that purpose.
Training for tube bundle reactions in converter disassembly operations	Mitigate the effects of the tube bundle reaction and ensure proper response	Training was inefficient for workers and emergency response personnel. Problems were identified with the following: • Use of ABC extinguishers • Improper use of respirators • Delay in pulling the fire box alarm • Delay in evacuating personnel
EWP bounding conditions	Personnel safety and fire evacuation	The accident was made worse because the reacting tube bundle was extracted and placed in direct contact with the security curtain (<35 feet) so that it caught fire and activated the sprinkler system.
Worker PPE	Personnel safety	Personnel received unnecessary exposure to hazards.
PEW	Coordinate emergency response activities	On-site emergency response expertise (the PEW) was not immediately available for the event.
PSS categorization of a tube bundle reaction in a converter	Proper and timely response to accidents	There was inconsistency in the declarations of OEs for tube bundle reactions in converters.
Scheduled emergency response exercises and drills	Maintain readiness and coordination	Confusion existed over the availability of proper extinguishing materials.

Table B-1. Barrier Analysis (continued)

Barrier	Purpose	Analysis/Effect on Accident
Communication between shifts	Exchange lessons learned and techniques to facilitate task completion	Each shift used different methods to complete bracket removal, as follows: • The day shift used a homemade fixture and an additional observer. • The night shift foreman observed the first cut and then released the cutter to make the remainder of the cuts. • The weekend shift foreman made all cuts on welded brackets.
Hot Work Permit requires the removal of combustibles from 35 feet around the cutting area	To prevent any fires due to the cutting operation	The reacting tube bundle was extracted and placed in direct contact with the security curtain (<35 feet) so that it caught fire and activated the sprinkler system.

Appendix C – Change Analysis

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Table C-1. Change Analysis

Normal "Ideal"	Actual	Analysis
Coordinated, integrated site emergency response and preparedness training	BJC has not performed exercises that include BNFL's facilities.	Emergency responders have less-than-adequate familiarity with BNFL's facilities. The emergency responders were not able to easily locate the existing extinguishing materials.
Workers evacuate in the event of a tube bundle reaction	The workers attempted to suppress the tube bundle reaction.	The workers acted outside of the established norms. • Not prepared • Respirators (not fully operational, not worn, lifted to communicate) • Delay in pulling fire box alarm • Use of ABC extinguisher • Delay in evacuating Pulled out the reacting tube bundle
Proper worker PPE	The workers and foreman wore improper PPE to fight a tube bundle reaction.	<u>Cutter</u> • Lifted his respirator mask to communicate <u>Fire Watch</u> • Entered without a respirator • Entered wearing a respirator with insufficient airflow <u>Foreman</u> • Entered without a respirator • Entered wearing a Tyvek coverall

Table C-1. Change Analysis (continued)

Normal "Ideal"	Actual	Analysis
PEW on site	The foreman was substituting as the PEW.	The foreman was not qualified as a PEW.
Timely categorization of OEs	Categorization of an OE was delayed.	Activation of the BJC emergency EOC response was delayed.
Shift turnover and communication between shifts are continuous	There are inconsistent work practices between shifts.	Best practices and lessons learned are not shared between shifts.
Kerf exit path is straight	The kerf's exit path is random.	The random exit path of the kerf increased its chances of contacting the tube bundle.
The EWP creation process provides instructions on the level of detail required for each step to complete the task	The EWP creation process did not provide instructions on the level of detail required for each step to complete the task.	Instructions were not created with the level of detail required for each step to complete the task to ensure consistent operations and quality control.
The FCN and EWP revision processes identify the proximity of the plasma arc torch to the tube bundle as a hazard	The FCN and EWP revision processes did not identify the proximity of the plasma arc torch to the tube bundle as a hazard.	Identification of new hazards before operations commence ensures worker safety.
The FCN and EWP revision processes prompt the consider-ation of alternative methods to remove the welded brackets	The FCN and EWP revision processes did not prompt consideration of alternative methods to remove the welded brackets.	Processes that prompt the consideration of alternative methods to remove the welded brackets ensure worker safety.
The EWP creation process recognizes the effect that the flame-retardant security curtain created to the tube bundle reaction accident scenario.	The EWP creation process did not recog-nize the effect that the flame-retardant security curtain created to the tube bundle reaction accident scenario.	Processes that recognize the effect of a process change on a bounding accident scenario ensure worker safety.

Table C-1. Change Analysis (continued)

Normal "Ideal"	Actual	Analysis
All of the eight SMEs entered the converter enclosure area to view the bracket configuration in relation to the tube bundle for the FCN or the EWP revision	None of the eight SMEs entered the disassembly area to view the bracket configuration in relation to the tube bundle for the FCN or the EWP revision.	Since none of the eight SMEs entered the converter enclosure in the D&D Workshop, they did not fully appreciate the hazards presented by the proposed change.
BNFL provides a method to reinforce the proper reaction to conditions that violate the EWP's bounding conditions	BNFL does not provide a method to reinforce the proper reaction to conditions that violate the EWP's bounding conditions.	Reinforcement of the proper reaction to conditions that violate work procedures ensures the workers will act appropriately and protect themselves if the situation arises.

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Appendix D – Events and Causal Factors Analysis

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Table D-1. Events and Causal Factors Analysis

CC No.	Contributing Causes	Discussion	Related JONs
CC-1	The EWP for the converter dis-assembly was not followed.	• The cutter and fire watch tried to extract the bundle before the brackets were removed. • The EWP requires the brackets to be removed before the bundle is extracted. • Step 5.5 of EWP CONV-111 R2 was skipped. • The EWP boundary control requires evacuation of the area in the event of a tube bundle reaction. • The cutter saw a glow (reaction) in the tube bundle after the last cut. • The fire watch and cutter fought the reaction with ABC and carbon dioxide extinguishers. • The cutter and fire watch were using PPE approved for cutting operations but not firefighting. • The workers rotated the converter shell to allow for easy extraction of the tube bundle. • The workers extracted the reacting tube bundle and placed it in contact with the security curtain. • The security curtain caught fire. • The EWP boundary control requirement was not followed.	JONs 2, 7, 9
CC-2	Communications and lessons learned between shifts are less than adequate.	• None of the three shifts used the same work practices. • The day shift developed a homemade blast shield to deflect the kerf from the tube bundle. • The blast shield was not used on other shifts. • The day shift foreman permitted only experienced cutters to remove welded brackets. • The night shift cutters rotated responsibility for cutting welded brackets to gain experience. • The weekend shift foreman made all welded bracket cuts. • The day shift added an observer to watch the tube bundle in addition to the fire watch (which concentrates on the cutter).	JONs 1, 7, 9

CC No.	Contributing Causes	Discussion	Related JONs
		• The night and weekend shifts did not use an extra observer. • The night shift foreman observed the first bracket cut and then released the cutter to cut the remaining brackets.	
CC-3	The hazards associated with converter disassembly were not adequately identified and analyzed.	• The various hazard analyses were developed on the basis of an incomplete understanding of tube bundle metal chemistry in a reaction environment. • The hazard analyses do not reflect the potential for worker intervention during a tube bundle reaction. • The hazard analyses do not consider the consequences of removing the tube bundle from the converter shell while the bundle is undergoing a reaction. • The hazard analyses do not consider the geometry of reacting tube bundles in relation to the potential effectiveness of available fire safety features. • The FHA does not completely evaluate the consequences of a sustained reaction in a tube bundle on HEPA filter integrity. • The FHA does not explicitly address the flammability of the flame-retardant, plastic security curtains. • The EWP does not address the fire risks to workers (i.e., fire watch) attempting to suppress a tube bundle reaction with manual firefighting equipment. • The EWP does not relate the hazards of a tube bundle reaction to the use of appropriate fire extinguishers. • The ETTP Fire Department prefire plan does not explicitly address appropriate tactics for a tube bundle reaction. • The prefire plan does not reflect the inaccessibility of tube bundles within the converter shell.	JONs 2, 3, 4, 5, 8, 9
CC-4	The workers took inappropriate emergency actions, which led	• The cutter and fire watch stayed to fight the tube bundle reaction instead of evacuating in accordance with procedure PR-SS-500, Appendix G, Section 5.	JONs 1, 5, 6, 7, 9

CC No.	Contributing Causes	Discussion	Related JONs
	to less-than-adequate results.	• The workers pulled the reacting tube bundle out of the converter shell without a procedure or training. • The workers used inappropriate emergency equipment (i.e., the cutter and fire watch used an ABC extinguisher and a carbon dioxide extinguisher). • Inappropriate PPE was selected. The foreman entered the converter enclosure wearing a Tyvek coverall. • The workers improperly used the appropriate PPE. The cutter lifted his respirator mask to communicate, and the fire watch had insufficient airflow from his respirator.	
CC-5	The response to emergency conditions at Building K-33 was less than adequate.	• Time period gaps existed in the PEW's on-site coverage. • BNFL's drill scenarios do not include a tube bundle reaction in a converter. • Emergency responders are not as familiar as they need to be with BNFL's facility specifics (e.g., the ETTP Fire Department's ability to locate the existing extinguishing materials and the PSS' time delay in categorization of the event).	JONs 4, 5, 6, 7, 9
CC-6	Training on the EWP was inadequate.	• The foreman had input to the EWP revision. • Prejob briefs and demonstrations of the EWP are the methods used to train foremen. • The foreman trains the cutter by demonstration. • The foreman monitors the progress of the cutter during the shift. • The cutter and fire watch participated in a prejob brief on the revised EWP. • The cutter and fire watch could not identify which document controlled the dismantlement operation. • The controlling EWP was kept in a desk drawer outside the converter enclosure and was not usually referred to during cutting operations. • The foreman knew about the EWP and its location.	JONs 2, 5, 7, 8, 9

CC No.	Contributing Causes	Discussion	Related JONs
		• The cutter and fire watch did not know the EWP's location. • No routine reinforcement of required actions in response to the bounding condition actions has been performed. • The cutter and fire watch tried to extract the tube bundle before removing the brackets. • The EWP requires the brackets to be removed before the tube bundle is extracted. • The workers skipped or missed required steps and mandatory actions in the EWP.	
CC-7	The FCN process and the EWP change process do not recognize the increased danger of a tube bundle reaction.	• On May 14, 2002, the day shift encountered a converter with welded brackets instead of bolted brackets. • The group manager initiated an FCN to cut the brackets with the plasma arc torch on May 15, 2002. • The cut to remove the welded bracket is within 2.25 inches of the tube bundle. • The FCN to cut the welded brackets was approved by eight SMEs and the group manager on May 15, 2002. • None of the SMEs entered the converter enclosure to view the welded brackets and their proximity to the tube bundles before approving the FCN. • The group manager initiated EWP CONV-111 R2 on Thursday, May 16, 2002. • The EWP revision incorporated the FCN exactly as written. • Eight SMEs signed off on the EWP revision on Monday, May 20, 2002. • None of the SMEs entered the converter enclosure to view the welded brackets and their proximity to the tube bundles before approving the EWP revision. • The group manager gave final approval of EWP CONV-111 R2 on Wednesday, May 22, 2002.	JONs 1, 2, 7, 8, 9
CC-8	ORO's and BNFL's lack of rigor contributed to less-than-	• DEAR clause, 970.5204-2, subparagraph 7(e), is not included the BNFL contract; therefore, ISMS performance measures and evaluations are not being factored into the maintenance,	JONs 1, 7, 9

CC No.	Contributing Causes	Discussion	Related JONs
	adequate implementation of the core functions of the ISM program.	feedback, and improvement of the ISMS. • The BNFL ISMS program description has not been approved by ORO after four revisions. • ORO has not formally approved or evaluated the BNFL ISMS program since the initial verification in 2000. • The weaknesses identified in the ISM core functions contributed to the tube bundle reaction event.	
CC-9	The BNFL Corrective Action Program is ineffective.	• Corrective actions from the two precursor tube bundle reaction events failed to prevent this event. • Some precursor corrective actions are not yet completed. • There has been incomplete implementation of ORO's recommendations. • Many precursor corrective actions have been delayed, modified, and extended. • BNFL has self-identified defects in its Corrective Action Program (see NCR 2002-064). • Nonconformance Report 2002-064 has no established closure date. • Some DOE-proposed actions were not incorporated into the Issues Management System. • After a recent change in BNFL project management, the new management found prior root cause analyses to be less than adequate.	JONs 3, 8, 9

Root Causes

RC No.	Root Causes	Discussion	Related JONs
RC-1	The corrective actions from the previous two tube bundle reactions did not establish the framework that these reactions are a preventable consequence of D&D activities.	Self-explanatory.	JONs 2, 3, 7, 8, 9
RC-2	BNFL's management systems and processes were not effective in preventing the tube bundle reaction and ensuring an appropriate emergency response.	Self-explanatory.	JONs 1, 2, 3, 4, 5, 6, 7, 8

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Appendix E – BNFL Corrective Actions vs. Judgments of Need

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Table E-1. BNFL Corrective Actions vs. Judgments of Need

The Board compared the corrective actions from the April 4, 2000, tube bundle reaction, the July 25, 2001, tube bundle reaction, the BNFL Nonconformance Report on the Corrective Action Program, and the NTS Report dated May 9, 2002, with the Judgments of Need.

Action #	BNFL Corrective Action	JON #
April 4, 2000, Tube Bundle Reaction		
1	Maintain the Stop Work Order on hot cutting.	---
2	Revise the work package description of the hazards.	2
3	Develop a classified appendix for the EWP.	2
4	Review and revise the Nuclear Criticality Safety Approvals.	4
5	Issue Hot Work Permits for the tube bundle area.	4
6	Revise the work plan facilitator training to enhance the EWP.	5
7	Request historical data on converter fires at other sites.	---
8	Analyze historical data – provide information to managers.	5
9	Revise the task plan to enhance the FCN process.	2
10	Conduct a formal root cause analysis.	---
11	Reinforce work bounding conditions for worker response.	5
12	Enhance the prefire plan for hot cutting near pyrophoric materials.	6
13	Enhance the prefire plan by deployment of the revised plan.	6
14	Perform management assessment on all project prefire plans.	7
15	Develop prefire plans based on management assessment findings.	7
16	Revise the fire watch training for metal fires.	5
17	Develop a metal fire Safety Note for toolbox meetings.	7
18	Revise hot work training and procedures.	5
19	Improve communication training for supervisors and radiological safety technicians.	5
20	Prepare a Safety Note on effective prejob briefings.	5
21	Perform a management assessment on FHA recommendations.	7
22	Perform a management assessment on managers' understanding of the authorization agreement.	7
23	Revise the BIO for the effects of nickel fluoride during a fire.	7
24	Provide managers with ISM training.	5
25	Provide eight management assessments (one for each group manager) on feedback quality.	7
26	Perform a detailed visual inspection of fire debris.	7
27	Inspect a Building K-31 converter involved in the 1985 fire.	7
28	Revise the FHA to address a full bundle fire.	6
29	Request guidance from DOE on management of T4 Converters.	---

Table E-1. BNFL Corrective Actions vs. Judgments of Need (continued)

Action #	BNFL Corrective Action	JON #
30	Select risk-based work control documents for review.	7
31	Complete a phase II review of tube bundle reaction data.	7
32	Revise the *General Employee Response* procedure, "Evacuation" section only.	2
33	Verify closure of all actions.	---
34	Validate effectiveness of actions. (INCOMPLETE)	---
35	Revise the EWP procedure to require reasons for hazard controls.	2
36	Train personnel on revisions to the EWP procedure.	5
July 27, 2001, Tube Bundle Reaction		
1	Revise the EWP (for cutting, marking, etc.).	2
2	Provide a prejob briefing.	1
3	Conduct a walkthrough drill with the Fire Department. (Completed November 23, 2001)	6
4	Train the crew members.	5
5	Investigate the basic metal chemistry with the Oak Ridge National Laboratory.	3
6	Evaluate lessons learned.	7
7	Revise the EWP procedure for second party verification.	7
8	Revise the procedure for prejob briefs to be immediately before hot work.	1
9	Process for transfer of authority between PEWs.	5
10	Visual identification of PEW needed.	---
11	Revise initial and annual emergency refresher briefings.	5
	Nonconformance Report 2002-064 (Revise Corrective Action Program)	8
1	Develop a plan of action.	7
2	Bring in implementation resources.	---
3	Consolidate related issues.	---
4	Complete a root cause analysis.	---
5	Review/revise the existing root cause analyses.	---
6	Reduce open actions in the Issues Management System by 75% by May 30, 2002.	---
7	Review/enhance procedures.	---
8	Provide training for appropriate persons.	---
9	Streamline the Issues Management Database.	---
NTS Report dated May 9, 2002		
1	Personnel qualification and training	5, 6
2	Quality improvement	1, 8
3	Work process improvement	2, 4, 5, 7

Summary

Event or Report	Judgments of Need Addressed	Judgments of Need Omitted
April 2000 Tube Bundle Reaction	5 of 9	1, 3, 8, and 9
July 2001 Tube Bundle Reaction	7 of 9	4 and 9
Nonconformance Report	2 of 9	1-6, 9
NTS Report	7 of 9	3 and 9

BNFL's corrective actions were either incomplete, less than adequate in scope, and/or failed to address the correct personnel levels (managers instead of workers). Therefore, the results of this analysis support Causal Factor 9 (i.e., the BNFL Corrective Action Program is ineffective).

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