Operating Experience Summary

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1 Chemical Safety Board Completes Investigation of Danvers Explosion

On May 13, 2008, the Chemical Safety Board (CSB) issued the final report on an 18-month investigation into an explosion at the CAI ink manufacturing facility in Danvers, Massachusetts, a suburb of Boston. Ten local residents were injured in the November 22, 2006, event, when the impact of the explosion shattered windows and collapsed walls; 24 homes and 6 businesses were demolished. Figure 1-1 shows the damage to one of the homes located approximately 150 feet from the CAI facility. (http://www.chemsafety.gov/index.cfm?folder=completed_investigations&page=index)

CAI employees told CSB investigators that they began mixing a 2,000-gallon ink vehicle batch in a mix tank at approximately 1:00 P.M. The CAI production manager said he opened the steam valve at about 3:00 P.M. to begin heating the mixture. While waiting for the mixture temperature to increase to the 90°F target, he and other employees unloaded a shipment of resin and pigment from a truck outside, then loaded the day's ink production into the truck.

The production manager told investigators that before he left for the day he checked the mixture temperature, which he recalled was about 90°F. He also said that he "thought" he had closed the steam valve at that time. However, investigators believe he forgot to perform this critical step before he left for the day because other work activities had distracted him. Because there was no written procedure or checklist to remind him to close the valve and no tank alarms or indicators to alert him that the steam valve was open, he likely just forgot to close the valve.

Figure 1-1. Nearby home destroyed in CAI explosion

The CSB investigators concluded that the open steam valve would have caused the liquid to boil. As long as the steam valve remained open, the boiling mixture continued to release many hundreds of pounds of flammable vapor into the unventilated production area. Because the mix tank was not vented to the building's exterior, uncontrolled tank heating caused the mixture to rapidly vaporize and release enough vapor into the production area to fuel the explosion. They determined that an unknown ignition source ignited the flammable atmosphere, causing the explosion, and that thousands of gallons of flammable liquids stored inside the building and some 51,000 pounds of industrial-grade nitrocellulose material stored nearby were ignited. The resulting fire burned for over 17 hours. Figure 1-2 shows the area surrounding the CAI facility before the accident; Figure 1-3 shows the same area following the explosion.

Figure 1-2. Area surrounding CAI before the explosion (plant circled)

Figure 1-2. Aftermath of explosion

The CSB identified the following causes of the explosion.

- CAI management did not conduct a process hazards analysis or similar systematic review to ensure that the flammable liquids processes were safely designed and operated.
- CAI heated Class I flammable liquids in unsealed tanks inside a closed building.
- CAI did not install or use automated process controls, alarms, or safeguards when heating flammable liquids in process equipment inside a closed building.
- CAI did not maintain adequate building ventilation during all flammable liquids process operations.
- CAI management did not use written procedures or checklists to ensure that flammable liquids manufacturing processes were operated safely.

Unlike CAI, DOE facilities operate under the principles of Integrated Safety Management (ISM) and its five Core Functions to ensure process and facility safety. CAI's failure to perform a process hazards analysis (ISM-2, Analyze the Hazards) and failure to properly vent tanks, install automated processes and alarms, and develop written procedures (ISM-3, Develop and Implement Hazard Controls) resulted in this accident. The lack of written procedures and the failure to include engineered safety features in the design of the equipment are factors that could have broken the chain of events and prevented the accident.

The CSB released a video about the explosion, "Blast at Danvers," on August 25, 2008. The CSB Chairman stated that the "video clearly illustrates how the lack of checklists, automatic shutoff systems, process controls, and hazard analyses can lead to a catastrophic chemical accident." The 20-minute video can be accessed from the CSB website video room at http://www.chemsafety.gov/index.cfm?folder=video_archive&page=index#.

OSHA requirements for preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals are found in 29 CFR 1910.119, *Process Safety Management of Highly Hazardous Chemicals*. The regulations can be accessed at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9760.

Process safety management requires an ongoing effort to prevent catastrophic accidents involving hazardous process materials and energies. It applies management principles and analytic techniques to reduce risks to processes during the onsite manufacture, use, handling, storage, and movement of chemicals. Its focus is on hazards related to the materials and energies present in chemical process facilities. Information about OSHA's Process Safety Management Rule, as well as its implementation at DOE sites can be found in DOE-HDBK-1101-2004, *Process Safety Management for Highly Hazardous Chemicals*, which can be accessed at http://www.hss.energy.gov/nuclearsafety/techstds/standard/hdbk1101/doe-hdbk-1101-2004.pdf.

These events illustrate the importance of performing hazard analyses, implementing proper controls, and ensuring that all procedures are followed to the letter. The Danvers accident also points out the need to develop and use checklists to ensure that essential steps are not overlooked when performing hazardous tasks.

KEYWORDS: Explosion, Chemical Safety Board, industry, flammable mixtures, chemical safety

ISM CORE FUNCTIONS: Analyze the Hazards, Develop and Implement Hazard Controls, Perform Work within Controls

Worker Receives Electrical Shock from Oven Thermocouple

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On May 28, 2008, at the Pacific Northwest National Laboratory (PNNL), a researcher investigating a spurious temperature reading from a laboratory oven thermocouple received a "small buzz" when he touched the thermocouple wire. His co-worker then touched the wires with his bare fingers and also felt a buzz. However, the second researcher continued to trace the wires until he saw two wires touching each other. He believed that the wires were low voltage wires, so had no concern about using metal forceps to move one wire away from the other. When he contacted one of the thermocouple leads with the forceps, the researcher received a non-injury shock (i.e., no burns). The researcher was taken to the onsite medical facility for evaluation and later returned to work without restrictions. (ORPS Report SC--PNSO-PNNL-PNNLBOPER-2008-0012; final report issued September 3, 2008)

After the incident, an electrician tested both the oven and the control unit and determined that the control unit had been miswired. Incoming 240-volt power and the thermocouple leads were both landed on the thermocouple terminals in the controller. Figure 2-1 shows the over-temperature controller and the green power supply wires, which are attached to the same terminals as the thermocouple wires. The electrician determined that the researcher encountered 118 volts when he touched the wires.

Investigators learned that it was standard procedure for laboratory staff to install the thermocouple wires from the oven to the control unit because the hazard-level of the task is considered to be minimal. The applicable procedure allows the work to be performed as "de-energized, cord and plug in hand work." Based on interviews, investigators also learned that the researchers handled the replacement task in different ways: some put in a request for crafts support; others performed the replacements themselves.

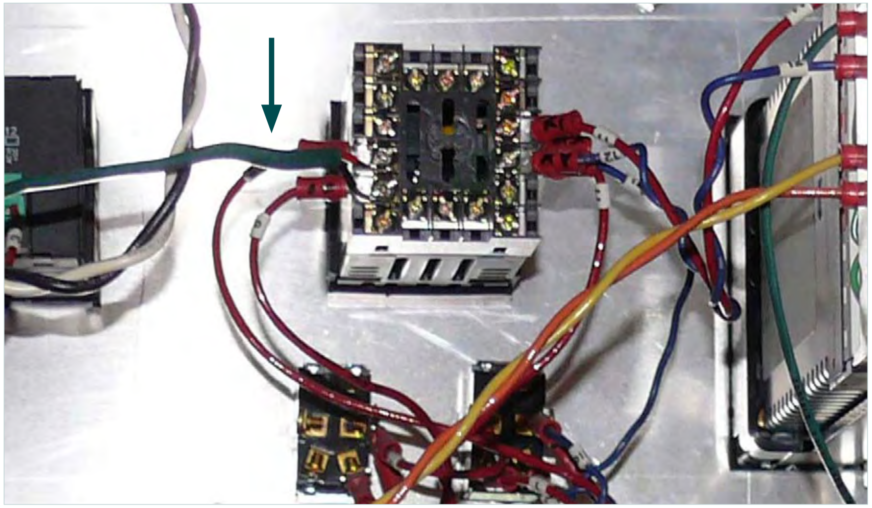

Figure 2-1. Closeup of controller showing power supply wires (green) attached to same terminals as the thermocouple wires (red)

The controller had last been replaced in 2006 based on a wiring diagram made by a third researcher. Figure 2-2 shows the diagram (drawn on the controller unit). The researcher told investigators that he was certain that he had rewired the controller correctly, but they determined that the wiring diagram did not include enough detail to successfully perform the task.

Although it was not required by procedure, a key step missing in the replacement process was a post-maintenance function test to ensure that work was properly performed. Had such a test been performed on the over-temperature controller, the miswiring would have been discovered and corrected.

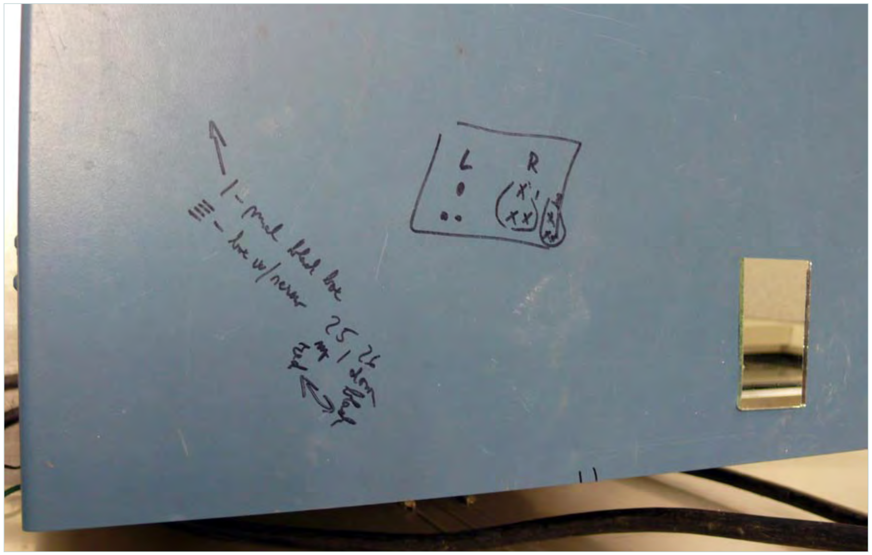

Figure 2-2. Wiring diagram drawn on controller unit

Corrective actions included revising the electrical safety procedure to require electrical worker qualification for all staff members performing maintenance, modification or component replacement and repair of electrical equipment. In addition, an inspection checklist that includes performing post-maintenance testing will be developed for staff use.

A similar incident occurred at Argonne National Laboratory on April 10, 2008, when a worker realized that a wire thought to be 24 volts actually carried 240 volts. Fortunately, the worker discovered the discrepancy before he performed any work and did not receive an electrical shock. (ORPS Report SC--ASO-ANLE-ANLEAPS-2008-0002; final report issued May 30, 2008)

The worker was tasked with replacing a unit in an Oxford Cryocooler system that was operating erratically. No exposure to hazardous energy was anticipated because the worker was to remove cables connected to the back panel of the unit (similar to removing cables from the back of a personal computer). He removed the lid from the unit to disconnect a cable he could not access from the back of the unit and saw three wires connected to three terminal points on a relay mounted on the circuit board. He removed the terminals and pulled the cable out through a port on the back panel, and then he realized he had not determined zero voltage on the three wires in the cable. When he measured the voltage levels, he discovered that the voltage level between wires was approximately 208 volts.

Investigators determined that the system was originally designed in accordance with European-standard electrical systems and had been modified to provide easier use with U.S. electrical systems. Vendor documentation did not provide enough information for staff to understand the internal wiring and operations. All 15 of the systems inspected after this event were found to have a similar problem. The units have been labeled with a tag reading "CAUTION – This unit has multiple line sources."

OE Summary 2004-05 reported on an electrical shock that resulted when a journeyman electrician installed a plug on a heater and incorrectly connected a hot leg of a three-phase, 480-volt conductor to the ground screw and the ground wire to a power prong. The article can be accessed at http://www.hss.energy.gov/csa/analysis/oesummary/oesummary2004/oe2004-05.pdf.

The textbox, taken from the Summary article, identifies several good practices that can ensure that modifications to electrical equipment are made safely. Corrective actions for the 2004 event also stressed the necessity of developing a guidance document that requires electricians to inspect their work and perform circuit testing at the completion of a task.

OSHA requirements for electrical wiring are outlined in 29 CFR 1926.404, *Wiring Design and Protection* (http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10705), which states that "all required tests shall be performed before first use; before equipment is returned to service following any repairs; and before equipment is used after any incident which can be reasonably suspected to have caused damage." Additional wiring requirements can be found in the National Electrical Code®, Section 305.

These events point out the importance of testing equipment after performing maintenance or making modifications. It is also important to promptly address any unexpected signals that could indicate a hazardous condition. Workers who are unqualified to work on equipment should not be permitted to make modifications to existing equipment, and all such work should be performed based on accurate information and diagrams provided by manufacturers or vendors.

KEYWORDS: Electrical shock, thermocouple, laboratory oven, wiring

ISM CORE FUNCTIONS: Analyze the Hazards, Develop and Implement Hazard Controls, Perform Work within Controls

Good Practices for Electrical Component Modifications

- Perform a self-check of work before putting the component or equipment into service.
- Require competent, independent, verification of tasks as they are completed.
- Perform checks on modified circuitry (e.g., voltage, continuity, phasing and polarity).
- Avoid distractions when performing tasks that could create hazards if not performed correctly.
- Perform integrated acceptance testing of the component or equipment upon the completion of work.

3 Ensure Your Job Hazards Analysis Covers All Activities of the Job, Including Cleanup

On June 23, 2008, industrial hygienists at Sandia National Laboratories determined that three of four subcontract workers were exposed to respirable silica during concrete-floor grinding operations that exceeded the assigned protection factor of their half-face air purifying respirators. The majority of the exposure is believed to have occurred during cleanup activities while the workers emptied a vacuum and cleaned vacuum filters. (ORPS Report NA--SS-SNL-NMFAC-2008-0013; final report filed August 7, 2008)

The job involved resurfacing a concrete floor, which included using grinders to prepare the floor before applying an epoxy coating. Controls included grinders with vacuum attachments (boot attachment) and a vacuum with high-efficiency filters, although they were not HEPA filters. Personal protective equipment (PPE) for the grinding operation included half-face respirators with P100 cartridges, ear plugs, safety glasses, hardhats, and leather gloves.

The workers were dumping the material from the vacuum into plastic bags. They were also removing the filter from the vacuum, taking it over to the plastic bag, shaking it, then hitting the filter on the side of the bag to remove dust from it. They then replaced the filter in the vacuum and resumed grinding. The industrial hygienist who performed the air sampling observed that the controls used during grinding appeared to be effective, but the techniques used for emptying the vacuum and cleaning the filters produced visible airborne dust.

Oversight compliance monitoring was performed on June 17, 2008, and samples were sent to the lab for analysis on June 18. The results, which were received on June 23, indicated that all four of the workers were exposed to respirable silica dust in excess of the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) of 0.025 mg/m^3. Although the half-face respirators worn by the workers provided a protection factor of 10 times the TLV (i.e., 0.25 mg/m^3), calculations indicated the exposures were approximately 14 times the TLV, as shown by the following results for each of the workers.

- Worker #1: 0.36 mg/m^3
- Worker #2: 0.32 mg/m^3
- Worker #3: 0.24 mg/m^3
- Worker #4: 0.36 mg/m^3

During the critique of the event, participants learned that a bead-blaster was to have been used for the bulk of the floor preparation, and hand grinders were to be used only around the edge of the floor or where there were obstructions. Using the bead-blaster would have reduced the potential for an overexposure, and the half-face respirators workers were wearing would have provided adequate protection. However, because it was too difficult to lift the bead-blaster onto the mezzanine floor, hand grinders were used for the entire surface of the floor, and the work took approximately 6 hours. Had workers used the bead-blaster their exposure time would have been greatly reduced. In addition, it would not have been necessary to empty the vacuum reservoirs and shake the filters clean numerous times if the bead blaster, rather than hand grinders, had been used.

Critique members learned that the subcontractor's contract-specific safety plan addressed the controls for the floor-grinding job (i.e., use of filtered vacuums on the grinders and half-face respirators), but did not address the methods that would be used to clean and change the filters in the vacuums or those used to dump the material collected in the vacuum during floor grinding. These activities are believed to have greatly contributed to the silica dust overexposures.

Industrial Hygiene support personnel indicated that cleanup is often missed as a hazardous activity when hazards associated with work activities are identified and evaluated. If the filters had been changed instead of "cleaned" and reused, and if wet methods had been implemented while emptying the vacuum contents, the dust created would have been reduced and the overexposure potentially eliminated.

Methods for reducing the potential for overexposures include limiting the length of time that workers perform a task or increasing respiratory protection measures. In this event, when the contractor identified that grinding would be performed for more than 2 hours, additional work planning should have identified the need to wear full-face respiratory protection instead of the half-face masks.

This event underscores the importance of analyzing the hazards throughout all phases of the work activity and ensuring that controls are maintained to protect the workers until job completion. It is also important that workers maintain a high level of diligence throughout the whole job and not relax controls as the job winds down because the hazards may still remain.

KEYWORDS: Hazards analysis, job planning, respirable silica, exposure, industrial hygiene

ISM CORE FUNCTIONS: Analyze the Hazards, Develop and Implement Hazard Controls, Perform Work within Controls

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Commonly Used Acronyms and Initialisms

Agencies/Organizations	
ACGIH	American Conference of Governmental Industrial Hygienists
ANSI	American National Standards Institute
CPSC	Consumer Product Safety Commission
DOE	Department of Energy
DOT	Department of Transportation
EPA	Environmental Protection Agency
INPO	Institute for Nuclear Power Operations
NIOSH	National Institute for Occupational Safety and Health
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration

Units of Measure	
AC	alternating current
DC	direct current
mg	milligram (1/1000th of a gram)
kg	kilogram (1000 grams)
psi (a)(d)(g)	pounds per square inch (absolute) (differential) (gauge)
RAD	Radiation Absorbed Dose
REM	Roentgen Equivalent Man
TWA	Time Weighted Average
v/kv	volt/kilovolt

Job Titles/Positions	
RCT	Radiological Control Technician

Authorization Basis/Documents	
JHA	Job Hazards Analysis
JSA	Job Safety Analysis
NOV	Notice of Violation
SAR	Safety Analysis Report
TSR	Technical Safety Requirement
USQ	Unreviewed Safety Question

Regulations/Acts	
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
D&D	Decontamination and Decommissioning
DD&D	Decontamination, Decommissioning, and Dismantlement
RCRA	Resource Conservation and Recovery Act
TSCA	Toxic Substances Control Act

Miscellaneous	
ALARA	As low as reasonably achievable
HEPA	High Efficiency Particulate Air
HVAC	Heating, Ventilation, and Air Conditioning
ISM	Integrated Safety Management
MSDS	Material Safety Data Sheet
ORPS	Occurrence Reporting and Processing System
PPE	Personal Protective Equipment
QA/QC	Quality Assurance/Quality Control
SME	Subject Matter Expert