Operating Experience Summary

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Confined Space Events Result in Industry Fatalities

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OSHA's general industry standard 29 CFR 1910.146, *Permit-Required Confined Spaces*, defines a confined space as any space that is large enough or configured so that an employee can bodily enter and perform assigned work, has limited or restricted means of entry or exit (e.g., tanks, vessels, silos, storage bins, hoppers, vaults, and pits), and is not designed for continuous employee occupancy. By their nature, confined spaces concentrate the hazards, whether they are atmospheric, toxic, flammable, or physical. Hazards associated with a confined space are often not recognized as being hazardous because an oxygen deficient condition is not readily apparent. The Bureau of Labor Statistics data for 2006 show 64 fatalities nationwide from oxygen deficiency. The following recent industry events underscore the severe consequences of failing to recognize a confined space and failing to provide adequate protection for the workers.

On December 1, 2007, a supervisor found two workers dead inside a 20,000-gallon tank at a dry cleaning plant in Linden, New Jersey. The workers, who were not specially trained or equipped for handling hazardous materials or situations, were overcome by fumes while power-washing chemical buildup from the inside of the tank. The supervisor attempted a rescue by entering the tank from a ladder, but was quickly forced to leave because of the strong fumes. He called the police and Hazmat emergency crews. The Hazmat crew found the men wearing cloth coveralls with plastic wrapped around their lower legs to shield them from the chemical sludge at the bottom of the tank. They also took air samples from inside the tank and found high methane levels and very low oxygen levels.

It is essential that rescue procedures and equipment are in place before workers enter a confined space. Although the workers were supposed to wear protective equipment, including masks, no safety equipment or respiratory equipment was evident, nor was a supervisor on the scene while the men worked,

In addition, there was no rescue crew, equipped with respirators or supplied air, onsite. The large tank held a highly toxic dry cleaning solution, which was diluted with water and other chemicals before being flushed out of the tank to the sewer system. Cleaning the tank, which is done every few years, was not part of either man's regular job. OSHA has taken over the investigation into the deaths of the two workers.

On November 1, 2007, at the Linde AGA plant in Bogota, Columbia, two workers died of nitrogen asphyxiation while inside a cold box. Initial investigation suggests that one worker entered the cold box (Figure 1-1) to photograph an argon re-boiler and lost consciousness. The second worker was found face-down on top of the first worker, suggesting that he was trying to rescue him. A nitrogen purge was in operation at the time of the incident. A work permit had not been issued to perform the task.

On June 21, 2007, two workers collapsed and died in an underground vault at a water treatment plant in Stickney, Illinois. After the first worker collapsed in the vault, which was 10 feet below street level, the second worker went in to help him. Both succumbed from fumes or from a lack of oxygen.

The first worker was in the vault inspecting a new water main for leaks. Two motors, which produced poisonous carbon monoxide gas, were running near the vault. Emergency personnel from the fire department arrived at the scene and

Figure 1-1. The cold box (inset) and the plant where two workers were asphyxiated by nitrogen

removed the two men from the vault. Air measurements taken from the bottom of the vault indicated 19.2 percent oxygen, just short of the 19.5 percent that is considered normal; however, members of the subcontractor's crew had been trying to blow fresh air into the vault before firefighters arrived, which could have affected the measurements. OSHA conducted an investigation.

Statistics from the National Institute for Occupational Safety and Health (NIOSH) indicate that more than 60 percent of confined space deaths occur among would-be rescuers. Some rescuers knew the hazards but wrongly believed they could hold their breath. The physical exertion of entering and moving about the confined space causes increased heart and respiration rates, which causes the body to quickly consume more oxygen. Couple this with poisonous fumes, and you have a recipe for disaster. It is essential that rescue procedures and equipment are in place before workers enter a confined space.

Fortunately, examples of confined space fatalities are primarily found in non-DOE industries and agricultural situations. A review of confined space-related events reported in ORPS over the past 7 years indicates that nearly 50 percent occurred because entry requirements were either not established or not followed (Figure 1-2). This is illustrated by the following event.

Distribution of Commonly Made Confined Space Mistakes

(ORPS 2000 – 2007)

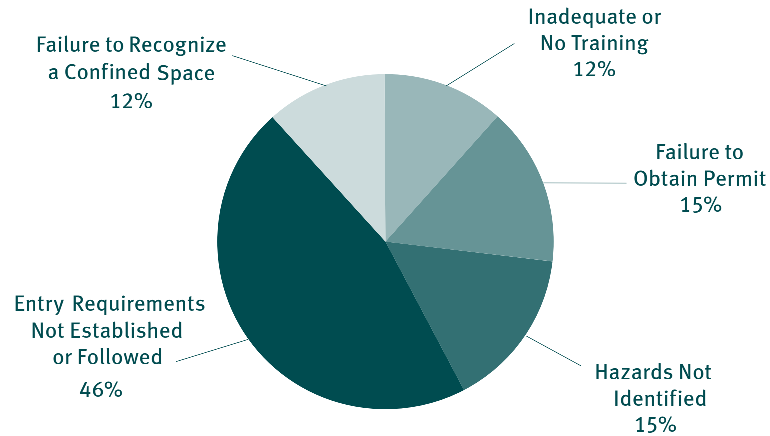

Figure 1-2. Distribution of commonly made confined space mistakes

On July 13, 2006, at the Hanford Site, personnel entered the Tank D-4 pit (permit-required confined space) before completion of required air sampling and authorization to enter. In addition, the confined space entry log was not completed and approved before the entry. When an Industrial Hygienist learned that personnel had entered the space, the Person-In-Charge directed a controlled egress from the tank pit. Personnel were wearing appropriate personal protective equipment (i.e., clothing and hoods with supplied air) at the time of entry, and the sample results were negative. (ORPS Report EM-RL--PHMC-PFP-2006-0018)

Although this event was without incident, the potential always exists for danger inside a confined space, particularly regarding oxygen deficiency or poisonous gasses. The following industry event illustrates the dangers of entering a space before it has been sampled.

On May 28, 2003, a municipal engineer in New York State collapsed in a landfill manhole while attempting to retrieve a flow meter for a regularly scheduled battery replacement. He was pronounced dead at the hospital. The flow meter was attached to a rung of a fixed ladder about 3 feet below the manhole opening. The engineer used a metal hook to retrieve the flow meter, but it slipped off and fell 7 feet to the bottom of the manhole (Figure 1-3). He decided to descend the ladder to pick up the fallen meter, but he lost consciousness and collapsed.

Figure 1-3. Landfill manhole where fatality occurred

A second engineer knew not to attempt a rescue on his own, and elected to wait for a qualified rescue team. He called 911 on his cell phone, and firefighters performed a rescue. The oxygen concentration at the bottom of the manhole was only 2.1 percent. Oxygen levels should have been 19.5 percent. (New York Fatality Assessment and Control Evaluation Report 03NY027)

Previous articles in the OE Summary have addressed the hazards of confined spaces (2004-22), nitrogen-enriched atmospheres (2003-14), and carbon monoxide encountered when using small gasoline-powered tools in enclosed or semi-enclosed spaces (2003-19). Environment, Safety and Health Bulletin, *Hazards of Nitrogen Asphyxiation in Confined Spaces*, was issued in December 2005. This bulletin also referenced a June 2003, Chemical Safety Board safety bulletin on *Hazards of Nitrogen Asphyxiation*.

These events underscore the importance of recognizing a confined space or area in which an oxygen-deficient atmosphere could exist (e.g., bulk nitrogen storage and filling stations or areas supported by carbon dioxide fire suppression systems). Procedures and checklists need to be in place that address hazards identification and mitigation, ventilation and sampling, personal protective equipment, and rescue response.

KEYWORDS: *Confined space, atmosphere, nitrogen, ventilation, fatality, toxic, fumes, poisoning, asphyxia, oxygen deficient*

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

Recognizing Changed Conditions — An Important Safety Practice

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Two lessons learned recently submitted to the DOE Lessons Learned Database address how changes in conditions or work tasks can impact safety and the necessity of staying within the scope of work. Both submittals stressed the importance of stopping work to determine any potential hazards and identify controls for them when a work scope changes or a change of conditions is identified.

In the first lessons learned, a worker at Lawrence Livermore National Laboratory was attempting to drain a tank when he was splashed in the face and chest by liquid that had been only partly characterized to determine if it was hazardous. The worker was taken to a nearby eyewash station, where his eyes were flushed, and then to an onsite medical facility, where medical personnel determined he was uninjured. (Lessons Learned Identifier LL-2007-LLNL-28)

Workers were repairing an air-compressor line when an adjacent plastic pipe at the bottom of a water-treatment system tank was damaged. (Figure 2-1 shows the location of the break.) The damage allowed the liquid in the tank to leak into a secondary containment system. Environmental protection staff, who responded to the spill to prevent the uncharacterized liquid from reaching a storm drain, decided to reconfigure the system pumping equipment to route the contents of the tank to other containers, thus changing the work scope. Problems with the piping equipment led to using buckets to transfer the liquid to other containers, so responders decided to reactivate the piping equipment. However, no one made sure the output hose was secured, which resulted in the liquid spraying the worker.

Several issues contributed to this incident, including the following.

1. At different times, different people from different organizations were directing the work.
2. The facility point of contact believed the system was not under facility oversight, which led to confusion about who should direct the work.
3. The pumping equipment was altered and operated by personnel who were not authorized to do the work, which led to work being performed outside the approved scope and responsibilities of the worker.
4. Emergency response personnel were called to contain the water leak, which was not perceived as an "emergency." This led to confusion about who was in charge.
5. The hazards of the liquid were not fully determined, and the lack of easily identifiable markings on the water tank, containment shell, and piping resulted in confusion about the contents.

Figure 2-1. Line break location

In this event, a change in work scope resulted in deficient hazard control. It is essential to identify all hazards and control them before any work begins and to repeat this process if the scope of the work task changes. When work is not covered in the approved scope of work or operating limits and controls are not being followed, work should be stopped until these changes can be addressed.

A review of the ORPS database identified a number of events across the complex that can be traced to changing conditions that were not recognized or addressed. As the following examples show, even what might be considered an insignificant change in conditions can impact safety.

- A subcontractor electrician apprentice fell, breaking her wrist and forearm, while carrying work materials up a grassy hill during construction of an underground electrical duct bank. Work on the construction activity was suspended to review the work scope, job site conditions, hazards, and hazard controls. Investigators determined that the root cause of the accident was a changed condition (rain that made the slope slippery) that was not adequately addressed by workers or supervisors. (ORPS Report SC-ORO--ORNL-X10UTILITY-2005-0003)
- Workers dropped a 2,800-pound stainless steel table from a height of about 12 feet when sharp edges on the table cut through the straps holding it. Management scheduled the lift even though the work crew that would perform the lift was not the crew that usually performed such tasks. Investigators determined that the "near-root cause" of the event was failure to identify and react to a changed condition and circumstances (i.e., the change in crew) and inadequate management supervision. (ORPS Report EM-ID--BNFL-AMWTF-2002-0005)
- A forklift operator transporting a waste material container to a loading pad made contact with an overhead line. The operator stated that the route was not normally used to transport waste containers, but was selected to avoid traffic near the usual route. He also told investigators that the forklift was in service for the first time and had replaced a smaller forklift with a shorter mast. Investigators determined that changed conditions were not identified and that there had been no walkdown of the route to ensure that potential hazards had been addressed. They also determined that project personnel did not recognize the use of a larger, taller forklift as a changed condition for which a new hazards analysis was appropriate. (ORPS Report EM--PPPO-BJC-PGDPENVRES-2004-0007)
- A subcontractor employee used a penknife to cut through ties connecting a water hose to a water truck and lacerated his arm, resulting in hemorrhaging and possible tendon damage. The water truck normally used was being repaired, and the supervisor decided to use another approved vehicle. Investigators determined that the work control package did not address the procedure, precautions, or proper tools associated with the substituted vehicle and the hazards analysis did not consider the hazards posed by using unapproved personal tools or contain language prohibiting them. Neither the supervisor nor the employee recognized that using a different vehicle was a changed condition, so the employee found himself in a changed condition and tasked with an infrequently performed activity without adequate guidance. Instead of stopping work and contacting his supervisor, he made a poor decision and used an improper tool. (ORPS Report EM-ORO--BJC-K25GENLAN-2005-0011)

The second submittal to the Lessons Learned Database stresses that the best response to a changed condition or task is to stop work, discuss the situation, and ask for help. This ensures that any hazards will be analyzed and that the needed controls will be put in place. Based on a review of 20 lessons learned, the submittal identifies the following core situations that may help prevent events caused by changed conditions. (Lessons Learned Identifier G-2007-OR-BJCECP-1201)

Change in Location — Changes in location can introduce new hazards (e.g., overhead power lines, differing soil conditions, and other hazards) that may interact with the task in an unknown way.

Change in Sequence — When the sequence of work changes, a hazard control may be skipped because workers may not understand that a step implemented a specific hazard control or they may forget to implement the control later in the process.

Change in Equipment — If new tools are used, the associated hazards must be understood. Some equipment and tools are specific for a given task, are not suitable for other tasks, or may introduce unanalyzed hazards.

Changes in Roles and Responsibilities — When personnel changes or an additional task must be performed, there is a potential for an incident to occur. Workers and supervisors must make sure that both the work to be performed and who will perform it are clearly understood as work progresses.

Performing Similar Work — A minor difference between two tasks (e.g., changed weather conditions, pipe size, soil conditions) may not be readily apparent. Pre-work planning must determine if similar tasks may have different hazards, and there must be continual awareness of how a task is performed to understand that new hazards may be introduced or a different approach to hazard control is needed.

The textbox shows conditions that may indicate that one or more of these core situations are applicable to the work process.

It is important to identify and address even minor changes in conditions or work scope and ensure that work does not proceed until all hazards are identified, communicated, and controlled. Work should be stopped if a situation arises that is not in the approved scope of work or if operating limits and controls are not being followed.

Identifying Changed Conditions

- **Change in Location** — Be aware when the work location changes, including equipment re-positioning.
- **Change in Sequence** — Be aware when the order of the work steps changes.
- **Change in Equipment** — Be aware when a new tool or new equipment is introduced to an ongoing task.
- **Change in Roles and Responsibilities** — Be aware when a different person is performing a task or when additional tasks must be performed.
- **Similar Work** — Be aware when performing similar tasks that may have different hazards.

KEYWORDS: *Changed conditions, lessons learned, hazard control, hazard analysis*

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

3 Type A Accident Investigation of the Mixed Waste Spill at Hanford Tank Farms—Part 3: Emergency Management and Response

A July 27, 2007, spill of about 85 gallons of tank waste from a ruptured dilution hose at the Hanford Tank Farms resulted in high radiation levels in the area surrounding a transfer pump. Following the event, a Type A Accident Investigation Board conducted an independent investigation to determine causal factors and identify Judgments of Need (JON) to address deficiencies. Although the Board identified the cause of the spill as an overpressure of the dilution hose due to the lack of a required backflow device, they identified additional deficiencies in five program areas as contributing causes. OE Summary 2007-09 reported on work control deficiencies that contributed to the spill. This article focuses on identified weaknesses in emergency management and response. (ORPS Report EM-RP--CHG-TANKFARM-2007-0009)

The Accident Investigation Board determined that response to the accident in the areas of incident command, event categorization, notification and communication, and radiological consequence assessment were effective overall. However, weaknesses in emergency response to the spill were identified.

The Board determined that the Emergency Planning Hazards Assessment (EPHA) and Emergency Action Levels (EAL) did not adequately address releases of mixed waste at the tank farms. Additionally, assumptions used for EPHA analyses were not adequately documented, and the EALs did not identify whether the protective action distances were based on radiological or chemical hazards. A more conservative approach would have addressed the potential for airborne hazards, as well as the high radiation area.

The Board found that tank farm EPHA consequence analyses and EALs were developed using event scenarios from the Documented Safety Analysis (DSA). High-probability, low-consequence events were identified in the DSA as having only minor onsite impact on personnel and the environment; thus, they were not analyzed. In addition, the EPHA does not postulate or analyze waste-spill events that include the full range of possible initiators and severity levels, as recommended in *Emergency Management Guide*, DOE Guide 151.1. Because consequence analyses were not performed, an EAL was not developed that addressed promptly recognizing and performing predetermined protective actions for the event. The Board also found that some assumptions (e.g., those used for consequence assessment analyses in the EPHA and for EAL development) were not adequately documented.

Procedures and checklists used by the emergency response organization were generally comprehensive and provided for an integrated response. However, the Board found that the abnormal operating procedure for responding to a high radiation area did not require precautions be taken for a release until the cause of the high radiation could be determined. The Board also identified the following weaknesses.

- An informal entry/re-entry plan (with concurrence of the RadCon Manager and Building Emergency Director) was used in lieu of established work control processes, such as a radiological work permit.
- Quick reaction checklists are used for declared emergencies and protective actions, but not for abnormal events or operational emergencies not further classified.

- The crash phone announcements in the quick-reaction checklists are specifically written for emergencies, and some of the language was not applicable to the spill, which was an abnormal event.
- The procedure for responding to a high radiation area required a call to 911, but did not specify what actions were expected as a result of the call, and there was no formal training on abnormal events for the patrol officers who received the calls.
- The announcement for this abnormal event (read from the checklist) stated only that there was an emergency, so workers were confused about the significance of the event.

Although there were detailed emergency response plans, event response plans, and procedures applicable to the event (all of which were adequate in many aspects), the spill was not identified until nearly 8 hours after the event, and the abnormal operating procedure for responding to a high radiation area did not require taking precautions for a release until the cause of the high radiation was determined. A number of weaknesses contributed to the failure to recognize the accident as a hazardous waste spill. One of the most significant weaknesses was the mindset of the personnel involved. They believed that the high radiation reading was caused by a slug of waste in the transfer line. The first indication of a potential hazardous waste spill was when a health physics technician noticed that the personnel contamination monitoring instrument (frisker) in a Change Trailer indicated approximately double the normal background rate.

The incident command team response was effective for both the initial and ongoing response. Incident Command Team members used their position-specific checklists to guide them in performing their assigned functions, and the Emergency Coordination Team provided support and additional expertise. In accordance with procedures, incident command positions were properly staffed, and the Incident Commander implemented the same checklists as he would have used for an emergency response. An appropriate set of priorities was established to ensure personnel safety and to mitigate the potential hazards of the waste spill, but the Board identified several weaknesses in implementation of protective actions to ensure worker safety. In an event with more severe consequences, weaknesses such as the following would have posed an unnecessary risk to workers and responders.

- When under a take-cover order, workers are instructed to close doors and windows and secure ventilation. Nine workers were left in a change trailer for an extended time without ventilation on a day when outside temperatures exceeded 90°F.
- Subcontractors working outside the Tank Farm fence took cover in their vehicles when the siren sounded. General employee training includes instructions to take cover inside the nearest building upon hearing the siren, but because they were not near a building the subcontractors were not sure about what to do or where to go to find a building nearby. They waited several hours before they were permitted to leave the area.
- Responders were permitted to enter and exit areas in proximity to the spill without personal protective equipment and before hazards were characterized.
- Access controls were not adequately implemented to prevent personnel from entering/exiting areas under take-cover conditions.

The text box shows the Board's specific findings in the area of emergency management and response. The following JONs address those findings.

1. Analyze events of higher probability, but lower consequence, in the tank farm emergency planning hazards assessment, covering the full range of possible initiators and severity levels, as required by DOE Order 151.1C, *Comprehensive Emergency Management System,* and its predecessors. Analysis needs to include adequate documentation of assumptions.
2. Improve procedures for responding to abnormal events at tank farm contractor facilities.
3. Correct weaknesses and inconsistencies in the implementation of take-cover protective actions.

The detailed two-volume Accident Board report is available on the DOE Office of Health, Safety and Security website at http://www.hss.energy.gov/csa/csp/aip/HanfordTankFarm.html. The Board's conclusions and JONs in the area of Industrial Hygiene will be the topic of an upcoming article in the *OE Summary*.

This event illustrates the importance of ensuring that procedures in place for emergency response provide specific steps to take in any abnormal event, including high-probability, low-consequence events, as well as the importance of ensuring that analyses of potential emergency events are complete and appropriately documented. It is also essential that all site personnel, including any subcontractor personnel, are fully aware of what actions they should take in the event of an emergency and that emergency announcements are clearly understandable.

The Board's Emergency Management/Response Findings

- The Tank Farm EPHA and EALs are based only on events analyzed in the DSA.
- High-probability, low-consequence events are not analyzed in the EPHA. As a result, appropriate EALs have not been developed.
- Assumptions used in EPHA consequence assessments are not adequately documented.
- EAL tables do not indicate whether the results were determined from the radiological isotopes or the chemical constituents.
- The abnormal operating procedure for responding to high radiation areas does not require the cause of the high radiation area to be conservatively assumed as a release until it could be determined otherwise.
- The abnormal operating procedure for responding to a high radiation area required calling 911, but did not specify what actions were expected as a result of that call; quick reaction checklists are not developed for 911 calls on abnormal events.
- The crash phone announcements in the quick-reaction checklists were specifically written for emergencies, and some of the language was not applicable to the spill, which was an abnormal event.
- Workers were sheltered in a trailer for an extended time without ventilation on a day when outside temperatures exceeded 90°F. During this time responders entered and exited without personal protective equipment and before hazards were characterized.
- Persons working outdoors in areas beyond facility boundaries took cover in their vehicles when the siren sounded. They were not directed by Hanford Patrol officers, the incident command post, or the event coordination team to take cover in a building.
- Access controls were not established for all areas under the take cover order.

KEYWORDS: *Type A accident, emergency planning, emergency response*

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
SELLS	Society for Effective Lessons Learned Sharing

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