Operating Experience Summary

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Plutonium Spill at Boulder NIST Facility

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On June 9, 2008, at the National Institute of Standards and Technology (NIST) laboratories, Boulder, Colorado, a guest researcher broke a glass bottle containing a sample of plutonium sulfate tetrahydride during an experiment (Figure 1-1). After the bottle broke, spilling the plutonium, the researcher handled the material, spreading contamination in the work area and on his body. He then left the area, spreading contamination outside the laboratory. Although the laboratory was evacuated shortly after the spill, medical tests indicated that internal plutonium exposures were found in "a small number" of personnel, but those individuals are not expected to suffer any clinically significant health impacts. (http://www.nist.gov/public_affairs/releases/plutonium.html)

The small plutonium sample (smaller than a dime in size) was being used in a research project to develop improved radiation detectors for use by nuclear inspectors outside NIST and contained about 0.25 gram of plutonium. A few days before the accident, the guest researcher tapped the source bottle on a marble laboratory bench in an attempt to "settle the powder" inside the bottle in one location, which may have damaged the bottle. The bottle later broke when it was accidentally knocked against either the lead shield "bricks" or the detector (Figure 1-2).

The guest researcher, who was working alone in the laboratory and who had received no previous training in handling the sample, was not wearing gloves; and, although he noticed that the bottle was cracked, he continued to handle it. When the bottle broke, spilling the plutonium, he was unaware of the course of action that needed to be taken. He spread

Figure 1-1. Broken glass container inside multiple plastic bags (broken bottom in upper right-hand corner)

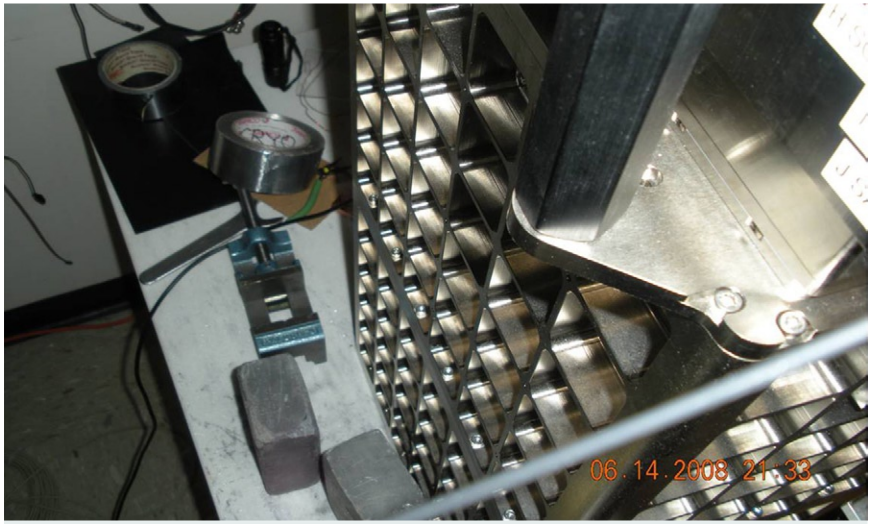

Figure 1-2. Area between detector and electronics rack (note lead bricks)

contamination in the work area (via his shoes and body), then left the area and spread contamination outside the affected laboratory. He contacted the Principal Investigator (PI) and told him that he thought the "sample may be cracked," then went to his office, spreading contamination further.

The PI, who also had limited knowledge and training in working with a plutonium source, took the broken bottle from the container, handled it, and then repackaged it. These actions potentially dispersed more material into the area, increased the contamination in the laboratory, and increased the risk of an intake of radiological material. The PI did realize the serious nature of the spill and ordered evacuation of the laboratory.

Following the event, trace contamination was found on the soles of the shoes and on a few articles of clothing for most of the 22 personnel evacuated from the laboratory. In most cases, the trace contamination was easily removed using soapy water following standard health physics practices, and 20 personnel were sent home contaminant-free.

NIST health safety personnel supervised the careful testing of nearby hallways and adjacent labs and offices. Trace amounts of contamination were found in the office of the guest researcher and in a nearby stairway he used. The soles of the shoes of the researcher's officemate also showed trace contamination, as did one desk, a lab notebook on that desk, and the chair associated with the desk that had been used by the guest researcher. Some areas of trace contamination were also found in the nearby hallways and in a small office area at the end of a hallway. These areas were cleaned and retested to ensure they were contamination free.

There was no evidence of any contamination outside of the immediate area or in the doorways leading out of the building. However, it was later determined that plutonium had been released into the Boulder, Colorado, sewer system when the guest researcher washed his hands in the sink following the spill, but failed to ensure that water did not flow out of the sink. The researcher did not report his use of the sink until a week after the spill.

On June 12, 2008, the NIST Ionizing Radiation Safety Committee (IRSC) started an investigation of the spill to identify the causes and contributing factors; evaluate the response to the accident; and recommend corrective actions, methods of avoiding similar events, and ways to improve safety performance and incident response. The report can be accessed at http://www.nist.gov/public_affairs/releases/IRSC_Pu_Report_Final.pdf. The IRSC also requested help from the DOE Radiological Assistance Program (RAP) to deal with the incident, and asked an independent group of five experts in radiation safety to review and provide comments on the rupture of a plutonium source. All of these reports contain additional details about the spill from various perspectives, and can be accessed at http://www.nist.gov/public_affairs/releases/boulder-incident.html.

Major findings identified by the IRSC included the following.

- Three plutonium sources were acquired without adequate hazard analysis or management approval. The wrong conclusions were reached regarding the hazards posed by the sources.
- Sources were received; all protective barriers were removed except the screw-topped glass bottle in a sealed plastic bag; inadequate and inappropriate controls were established; controls were informally communicated to the PI; and no specific training was provided to the PI.
- Inexperienced and untrained researchers began work on the detector project using radioactive sources.
- Researchers developed an inappropriate work plan (involving removal of glass-bottled sources from their secondary

barriers, directly manipulating the glass-bottled source with ungloved hands, and taping the bottled source to a fixed device in order to achieve a desired instrument response).

- The guest researcher handled the source and significantly spread contamination in the work area and on his body (shoes and hands), causing potential intake of radioactive material.
- The guest researcher left the area and spread contamination outside of the affected laboratory. He did not seem to understand or recognize the potential to spread contamination; was untrained and had no experience related to dealing with a contamination event; and did not act with any apparent sense of urgency (e.g., stopped to talk to other researchers on the way out), indicating that he may not have recognized the hazardous conditions in the contaminated laboratory and the need for immediate corrective action.
- After the spill, the guest researcher reported to the PI, stating that the "sample [glass-bottled source] may be cracked" and left for his office, leaving the PI to assess the situation alone. He did not seem to understand the severity of the contaminated conditions in the lab; had no training or experience in reporting a potential radiological event; did not adequately describe the nature of the incident, the current status in the laboratory, or the actions he had taken; and did not appear to convey any sense of urgency to the PI.
- The PI reopened a closed metal container containing the broken glass source container, handled it in order to assess the situation, and then repackaged it. These actions potentially dispersed more material into the area and increased contamination of the laboratory and the risk of intake of radioactive material. The PI was untrained and inexperienced in dealing with spreadable contamination; did not consider the potential hazards associated with the investigation of a potentially broken source containing a radioactive powder; apparently did not realize the risk of airborne contamination and did not establish appropriate controls; did not appear to have immediately recognized the need to establish access control to the laboratory; and did not seek qualified assistance from health physics personnel before examining the source.

Based on their preliminary analysis, the IRSC believed that the most probable root cause of the incident was a failure in the existing safety management system as it was applied to the detector project. The failure was exacerbated by a casual and informal research environment that appears to have valued research results above safety considerations.

The IRSC also indicated that the acquisition of the source was a pivotal moment in the unfolding of the event. They stated that "by failing to adequately identify the potential hazards associated with these sources—in spite of the fact that more than enough specific information was available to do so—a sequence of actions and decisions took place that had a direct impact on the accident with the source and the resulting contamination." These actions and decisions included lack of training specific to the source, lack of appropriate controls, missing or inappropriate hazard communication, lack of experiment planning, and lack of review and reporting.

Among the recommendations the ISRC made, those regarding the NIST safety culture are of particular interest. The IRSC recommended the following.

> NIST should strengthen its safety culture by… developing and executing a well-defined plan to effectively integrate safety management practices into core management functions. The full integration of safety practices into routine management functions is at the heart of promoting

> and sustaining a "safety culture." It is essential to implement a routine set of practices that ensures that high quality research is done in a way that minimizes the risk to safety and health.... This change will involve integrating safety policy and practice into all core management functions, including: decision making, priority setting, business systems, organizational performance review, and personnel performance management...and will require a strong and sustained commitment on the part of management to be implemented effectively.

The use of visiting scientists, researchers, and students occurs routinely at many DOE laboratories. Many of these guests are involved with the operation of hazardous equipment or the handling of hazardous materials such as plutonium, radioactive sources, and acids, as illustrated in the following event.

On January 17, 2007, at Lawrence Berkeley National Laboratory, a student guest was etching a silicon wafer in a mixture of nitric and hydrofluoric acids in a fume hood. He had not performed this particular operation previously but had received clear verbal instructions from another member of the research group. The resulting reaction, although normal, was more aggressive than he expected so he closed the hood and waited until the reaction slowed before reopening the hood to recover the sample. When he opened the sash he smelled a strong odor of acid and felt something "warm" on his cheek and sought the help of another student in the group, who applied calcium gluconate as a first aid measure and then called for paramedics. The student suffered no injury and was released without treatment. (ORPS Report SC--BSO-LBL-MSD-2007-0001)

Investigators determined that the student was previously part of a different research group and had only recently joined the group where the incident occurred. Staff in this lab believed the student's training to perform acid etching was more advanced than it actually was. Thus, the guidance the student was given was general rather than specific and not adequate under the circumstances. The lessons learned from the ORPS report stated "Do not assume that new members of a research group, including guests and users, have the necessary training and skills to work safely. Closely supervise each individual until it is clear that they understand the work, the safety controls, and how to respond to an off-normal event or emergency."

These events underscore the importance of ensuring that all personnel, especially those who are working visitors, students, or guests, have all the requisite training to safely perform the tasks to which they are assigned, are properly mentored (if required), and understand all emergency actions and reporting requirements if something should go wrong. In addition, all work documents, procedures, and instructions should clearly address the hazards associated with the work activity such that the significance of these hazards is understood and safety controls and barriers are in place.

KEYWORDS: Plutonium, spill, contamination, guest researcher, training, safety culture

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

Unsafe Liftgate Operation Results in Worker Injuries

2

Powered liftgates are work-saving additions to light, medium, and heavy duty trucks for loading and offloading materials. They can be operated either hydraulically or electrically to raise or lower the liftgate. Personnel who operate these liftgates need to be aware of potential pinch points since many of the operating mechanisms have exposed moving parts. It is also important for workers to be aware of the movement of the platform relative to the ground and the bed of the truck. Safe work practices can help prevent injuries.

On June 17, 2008, at the Savannah River Site, a worker with an equipment supplier for the South Carolina Commission for the Blind (SCCB) sustained a "buckle fracture" (incomplete fracture) and a laceration of the right forearm when his arm was caught between two sections of a truck liftgate mechanism. The SCCB supervisor wrapped the worker's arm and transported him to Aiken Regional Medical Center, where x-rays showed the fracture. (ORPS Report EM-SR--WSRC-FSSBU-2008-0005; final report issued August 5, 20008)

The worker offloaded a refrigerator being transported to the SCCB trailer warehouse and was putting a pallet jack back inside the delivery truck. He was holding the pallet jack with his left hand, operating the liftgate control switch (Figure 2-1) with his right hand, and riding on the liftgate.

When the pallet jack began to slide, the worker reached down to maintain control of it, while continuing to engage the lift switch. This positioned his right arm in the path of the liftgate operating mechanism. As the liftgate came up, his right

Figure 2-1. Control switch (circled) on right side of the delivery truck (arrow shows the scissor-like movement of the mechanism)

forearm (a few inches from the wrist) was pinched between the two sections of the liftgate (Figure 2-2).

Investigators determined that the cause of the accident was inattention to the task. The worker was not watching his surroundings; the load (pallet jack) was not properly secured; and the worker placed his arm in an area where it would be in a pinch point. The manufacturer of the liftgate (Tommy Gate®) warns that their lifts are industrial products for material handling only and are not to be used as a personnel lift, so the worker should not have been riding on the lift gate.

There have been other occurrences across the DOE complex in which workers were injured when using liftgates, as the following events illustrate.

On February 15, 2007, a plumber at the Brookhaven National Laboratory sustained a fractured rib when a liftgate fell and struck him in the upper torso. The plumber had lowered the liftgate of a Laboratory pickup truck to verify that a load was secure. After checking on the load, he lifted the gate upward to re-latch it; however, his gloved hand slipped off the cold surface of the gate, and the liftgate fell back and struck him. (ORPS Report SC--BHSO-BNL-PE-2007-0001)

On February 28, 2006, at Lawrence Berkeley Laboratory, a subcontract worker caught his gloved hand in a liftgate and suffered a complex fracture of the left ring finger. The worker was closing the truck liftgate during routine transportation

Figure 2-2. Injured worker reenacts the accident, showing how he was positioned on the lift while operating the control switch (note worker's bandaged arm)

activities and was not focused on the task. To raise safety awareness, a sticker stating "CAUTION Pinch Points Keep Hands Clear" was applied to liftgates. (ORPS Report SC--BSO-LBL-OPERATIONS-2006-0002)

On August 16, 1993, a Westinghouse Hanford Company pipefitter severed the tip of his left index finger on a liftgate. The liftgate, manufactured by Tommy Gate®, was installed on a bottle truck. As the pipefitter was changing out nitrogen bottles, one of the bottles shifted toward the liftgate, causing the pipefitter to fall off the truck. He tried to grab the side of the truck as he fell, but accidently grabbed the lifting mechanism, which severed his finger at the first knuckle. Investigators determined that the direct cause of the event was a violation of the operating instructions of the liftgate (no riders). The operating instructions were posted on the liftgate, but were not followed. (ORPS Report EM-RL--WHC-TANKFARM-1993-0075)

Both liftgates and their operating mechanisms must remain in good repair. Old and neglected equipment can cause problems such as the following near-miss event.

On October 4, 2007, at the Idaho National Laboratory, a warehouseman was delivering a 400-pound lifting unit for a network server to the Information Operations and Research Center when the load fell off the liftgate of the delivery truck. The warehouseman used a pallet jack to move the server lifting unit onto the hydraulic lift platform. When the weight of the load was on the liftgate platform, the platform suddenly tilted downward. Because the equipment was old and had deteriorated over time, it did not maintain a level stance when loaded with the server lifting unit. Investigators found that the lift pivot mechanism was very worn, which caused the liftgate to sag downward. The warehouseman failed to notice the downward slope of the liftgate. (ORPS Report EM-ID--CWI-INLPROGM-2007-0005)

Liftgate Safety Practices

What to Do:

- Ensure all drivers and material handlers are properly trained before allowing them to operate the liftgate.
- Ensure the vehicle brakes are set before using the liftgate and, wherever possible, operate the liftgate on a level surface.
- Ensure the area in which the liftgate platform opens and closes is clear and that the platform area, including the area in which loads may fall from the platform, is clear before and during liftgate operation.
- Ensure the surface of the platform is not slippery (e.g., oil, rain, ice or snow).
- Keep hands and feet clear of all pinch points.
- Operate the liftgate with the control switches only.
- Read and follow all warning decals, operation decals, and the owner's manual.
- Keep all decals in place and legible and retain the owner's manual in the vehicle.
- Visually inspect the liftgate daily as part of the vehicle's trip inspection and report any defects or deficiencies to maintenance.

What Not to Do:

- Never allow the liftgate to be used by persons not familiar with the operation of the liftgate.
- Do not use the liftgate if there are signs of abuse or it fails to operate freely.
- Never permit the motor to run after the liftgate is raised to the bed level of the truck.
- Do not overload the liftgate. Follow manufacturer's capacity chart or load limitations.
- Never use the liftgate for any purpose other than to lift or lower cargo from the truck (i.e., never use as a personnel lift).

These events underscore the importance of employing safe work practices when using powered liftgates. Although liftgates can save time and work, they can also be dangerous when not used or maintained properly. Users need to follow manufacturer's instructions and obey posted warning and caution signs. In addition, the operating mechanism of the liftgate should be serviced per the manufacturer's recommendations to ensure it remains safe to use.

KEYWORDS: Liftgate, tailgate, material handling, pinch point, injury, dropped load

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

Addressing the Health and Safety of an Aging Workforce

3

Like the worker shown in Figure 3-1, many U.S. workers are now 55 years of age or older. According to research published in the *Monthly Labor Review*, the share of the labor force of the 55 and older age group was expected to increase from 14.3 percent (2002) to 19.1 percent (2050), and the percentage of workers 55 to 64 and over 65 would grow by 48 percent and 40 percent, respectively, between 2002 and 2012. (http://wistechnology.com/articles/3807/)

These older workers bring a wealth of experience and knowledge to the workplace and are a valuable part of the workforce, so it is important to evaluate equipment, facilities, and work processes and make any necessary changes to address the health and safety issues that accompany an aging population.

Department of Labor workplace statistics for 2004 indicated that workers 64 and older had the lowest number of workplace injuries across all age groups. (http://www.ishn.com/Articles/Industry_News/5b84b6f0b91c7010VgnVCM100000f932a8c0) Although they may be less prone to injury than other workers and have fewer work-related accidents, aging does result in physical changes, such as loss of strength and muscular flexibility, more limited range of motion, loss of sense of balance, diminished hearing and vision, and reduced respiratory function. These physical changes in older workers result in limitations that can have an impact on their safety in the workplace.

On-the-job injuries experienced by the older working population often are caused by falls, which can be attributed to poor balance, slowed reaction time, visual deficits, lack of concentration, or complacency. The Bureau of Labor Statistics (BLS) issued a report in 1996 indicating that fractures made up 11 percent of injuries suffered by workers 55 years and older, compared with about 5 percent for workers under age 55. Moreover, older workers took 35 days to recover from a fracture sustained by falling to the floor or other non-elevated surface, compared with 25 days for younger workers. (http://www.bls.gov/iif/oshwc/ossm0002.pdf) To prevent such falls, employers need to identify specific hazards for slipping and tripping and incorporate engineering and administrative controls to reduce hazards (e.g., flooring and matting designed to deter slips, trips, and falls).

Providing adequate lighting is important to the safety of older workers because of changes in their vision. Older workers may have trouble adapting from an illuminated environment to a darker one, may have problems with glare, or may have an increased need for contrast between a target and its background, especially in dim light. It is important to improve illumination in work areas and to add color contrast. It is also important to reduce glare and to ensure that all signage and labels have lettering that is large enough to be seen clearly by workers of all ages.

Figure 3-1. Example of older worker engaged in work task

Respiratory functioning also declines with age. There is a decline in function from 15 percent to 25 percent from age 20 to age 65. Oxygen uptake sharply declines after the age of 50, making intense physical activity more difficult. Older workers should not be assigned strenuous work in hot and humid or cold weather and should be encouraged to take frequent breaks. They also should be provided with respirators when necessary.

The older worker's thinking processes tend to be slower than those of younger workers. To address issues with memory deficits, slower decision-making, and difficulty with multi-tasking, experts recommend minimizing distractions in the tasks that older workers perform and making an effort to assign tasks that do not require the recall of information from long-term memory. It is also helpful to ensure that each procedure step is as short and precise as possible and that all procedures are clearly written in active voice to avoid misinterpretation.

The following suggestions can help enhance the safety and health of all workers, including those who comprise the aging workforce.

- Eliminate heavy lifts, elevated work from ladders, and long reaches.
- Design work floors and platforms with smooth and solid decking while still allowing some cushioning.
- Reduce static standing time.
- Remove clutter from control panels and computer screens and use large video displays.
- Reduce noise levels.
- Install chain actuators for valve hand wheels, damper levers, and similar control devices.
- Install skid-resistant material for flooring, especially for stair treads.
- Install shallow-angle stairways in place of ladders when space permits and where daily elevated access is needed to complete a task.
- Increase task rotation, which will reduce the strain of repetitive motion.
- Lower sound system pitches, such as on alarm systems, as they tend to be easier to hear.
- Lengthen time requirements between steps in a task.
- Increase the time allowed for making decisions.
- Consider the reaction time required, especially when assigning older workers to tasks.
- Provide opportunities for practice and time to develop task familiarity.

The text box on page 10, taken from an article distributed by the New Jersey Department of Health & Senior Services, provides additional information about how employers can protect older workers from accidents and injuries. The article, which also includes information about potential health issues that may affect older workers, can be accessed at http://www.state.nj.us/health/eoh/survweb/olderwkinfo.pdf. In addition, the State of Texas has developed a fact sheet, "Aging in the Workplace," which lists the physical challenges that face the older worker, as well as safety measures that can be taken to address them. The fact sheet can be accessed at http://www.tdi.state.tx.us/pubs/videoresource/fsageinwork.pdf.

Most experts agree that even though older workers face additional obstacles to performing their jobs, they bring experience and knowledge and an excellent work ethic to the workplace, making them a valuable part of the work force. Improving equipment, facilities, and work processes can help offset the limitations of older workers while taking advantage of their experience and capabilities. In addition, implementing improvements to help ensure the safety and health of the older worker enhances the safety of all workers.

Protecting Older Workers from Illness and Injuries

- Conduct hazard communication training to increase employee awareness of the workplace environment and job risks.
- Perform frequent monitoring to ensure older workers can handle job tasks as well as when they started the job (especially if there have been changes in health status).
- Provide personal protective equipment to reduce risk, such as slip-resistant shoes and respirators, when warranted.
- Install fall protection systems where needed.

As the workforce ages, work planners, managers, and supervisors should consider the physical changes that come with age in job planning and should ensure that measures are in place to address these changes and mitigate any resulting hazards.

KEYWORDS: Aging workforce, limitations, injuries, safety, health

ISM CORE FUNCTIONS: Analyze the Hazards, Develop and Implement Hazard 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