Operating Experience Summary

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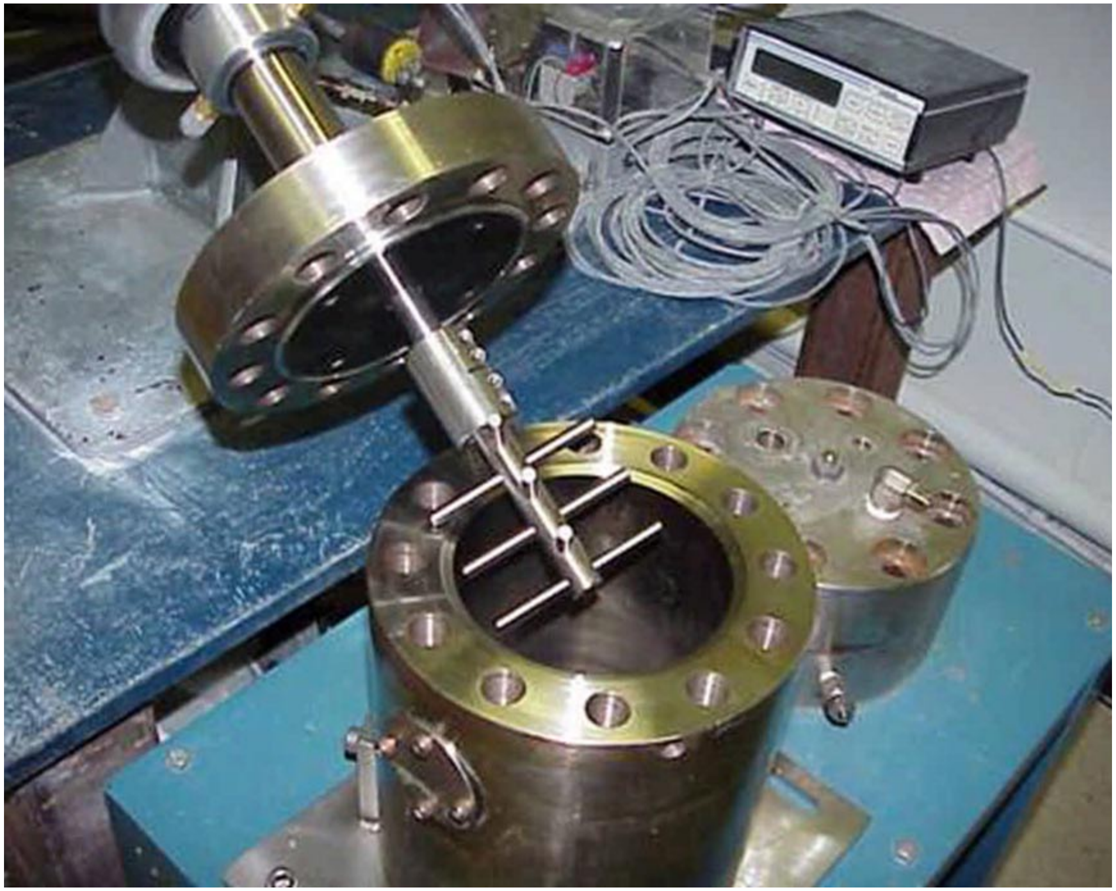

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Flash Fire Warrants Type B Accident Investigation

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On January 10, 2006, at Savannah River National Laboratory, a principal investigator and first-line manager were cleaning an attritor mill vessel (shown in Figure 1-1 on a lifting table) when a fire flashed and caused first- and second-degree burns to the right side of the manager's face and head and his left hand. The manager was treated at a local hospital and released. (ORPS Report EM-SR--WSRC-LTA-2006-0002)

The attritor mill had been used to blend and finely grind metal hydride into powder for use in hydrogen storage technologies. Grinding the metal hydride into fine particles renders it pyrophoric (i.e., capable of spontaneously combusting in air) because its increased surface area oxidizes more readily.

Although this article focuses on recent events involving reactive metals and metal hydrides, almost any finely divided material can present an explosion or fire hazard under the right conditions. See the article, "Accumulation of Dust Causes Explosion at Manufacturing Plant," in OE Summary 2003-16 for a discussion of the general explosion hazards posed by fine particles.

After preparing the necessary quantity of metal hydride powder, the principal investigator and manager wiped down the attritor mill several times in an argon-inerted glovebox. They then removed the vessel from the glovebox and began wiping it down with isopropyl alcohol. When the vessel was taken out of the glovebox, residual particulate reacted and flashed. The principal investigator extinguished the fire with MET-L-X® powder.

The manager of the Savannah River Operations Office directed a Type B accident investigation of the event because of a metal fire that ignited in a trash can at the same laboratory in February 2005. That fire, which is described in further detail below, resulted when a cleaning rag containing 1 gram of nanoaluminum powder oxidized in a trash can, igniting alcohol-moistened paper towels, grease, and nickel-aluminum alloy debris.

Following its evaluation of the January 2006 fire, the Accident Investigation Board determined that it occurred when metal hydride powder in the vessel boltholes reacted with air and isopropyl alcohol vapors. The root cause was the failure to fully analyze the hazards of working with metal hydrides, particularly cleanup activities after processing. Contributing causes dealt with informally communicating work activities and

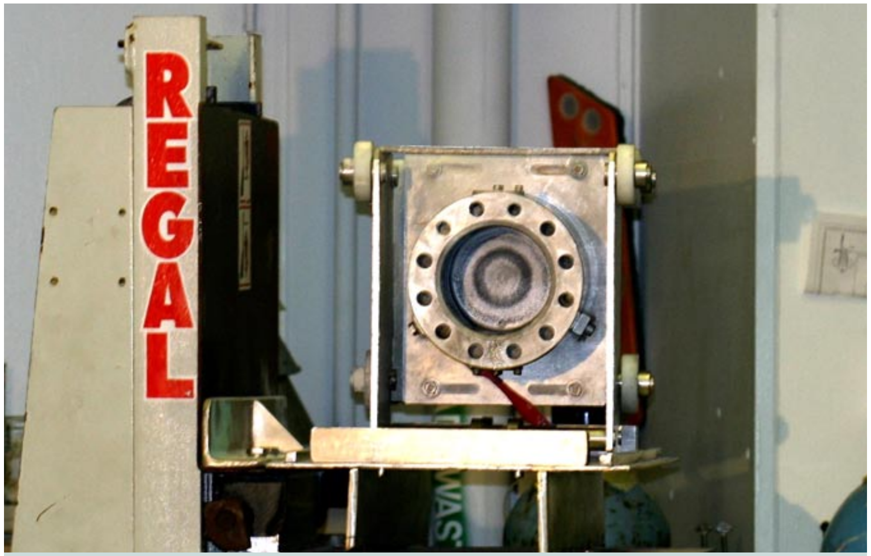

Figure 1-1. Attritor mill on lifting table

instructions and failing to positively ensure that the material was completely removed from the vessel, as well as developing corrective actions in response to the February 2005 fire that were too narrowly focused on waste material disposal.

A search of the ORPS database identified six events over the past 12 months that involved finely divided metal substances. These events and their causes are briefly summarized below.

- On December 8, 2005, at Los Alamos National Laboratory, a worker in an explosives laboratory was handling a piece of fiberglass matting (Figure 1-2) coated with 1 gram of a nanoaluminum-fluoroelastomer mixture when it unexpectedly ignited, causing second-degree burns on the worker's right hand. The mat that ignited was one of a group of mats to which the mixture had been applied, vacuum-dried at 80°C, and cooled to near room temperature. Although facility personnel had worked with this mixture before, they had never used it bonded to fiberglass matting. The accident investigation team determined that the most likely ignition source was energetic buildup within the material and that the hazards of handling the nanoaluminum material had not been properly characterized. (ORPS Report NA--LASO-LANL-FIRNGHELAB-2005-0012)

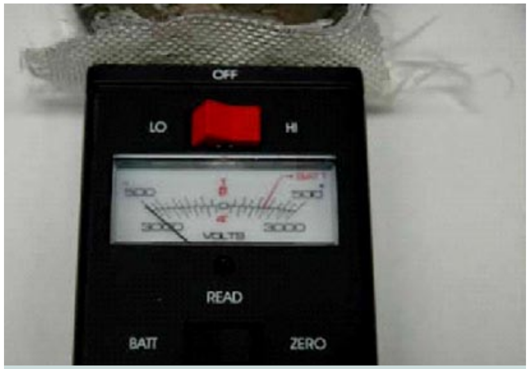

Figure 1-2. Piece of fiberglass matting

- On November 22, 2005, at Y-12, workers were performing maintenance on a crusher-grinder when finely divided material ignited unexpectedly. Thirteen employees were evacuated from the facility. An investigation team learned that several factors caused the fire: the material had been exposed to air for 6 weeks; actuation of the crusher cylinders stirred up the material, exposing the unoxidated material beneath a layer of passivated material; and the material had been exposed to moisture. One of the employees was transported to an offsite medical facility for observation; the rest were uninjured. (ORPS Report NA--YSO-BWXT-Y12NUCLEAR-2005-0036)
- On September 20, 2005, at the Idaho National Laboratory CERCLA disposal facility, a worker was preparing to mix zinc powder with sulfamic acid in a 5-gallon bucket to be used for treating mercury-contaminated soil when flames erupted from the bucket. A co-worker extinguished the flames using MET-L-X, and all employees left the area. The fire department verified that the fire was out, and no one was injured. (ORPS Report EM-ID--CWI-ICDF-2005-0004)
- On August 9, 2005, at Oak Ridge National Laboratory, a visiting student was weighing out about 200 mg of sodium hydride, which reacted with ambient moisture and produced hydrogen gas, which ignited. The student tried to smother the flames using a lab coat and then left the laboratory to get a fire extinguisher and notify others in the area. He put the fire out and left the building. No one was injured. (ORPS Report SC-ORO--ORNL-X10CENTRAL-2005-0011)
- On June 9, 2005, at the Nevada Test Site, a waste handler was characterizing the contents of a transuranic waste container that had been packed in 1976. He found a glass Schlenk® tube (for air-sensitive materials) containing gray powder, broke the tube open, and poured the contents into a tray. The powder spontaneously ignited. The waste handler tried to put the fire out but was unsuccessful. Another waste handler activated the carbon dioxide fire-suppression system (MET-L-X was not available), and all personnel left the building without injury. (ORPS Report NA--NVSO-BN-NTS-2005-0011)

- On February 14, 2005, at the Savannah River National Laboratory, a laboratory technician used a damp rag to clean an attritor mill that had been used to alloy nickel and aluminum powders. When he had finished, he threw the rag into a metal trash can. Powdered aluminum metal residue reacted with water on the rag, generating enough heat to ignite the rag and other flammable materials in the trash can (paper towels, bearing grease, etc.). The laboratory and surrounding areas were evacuated when the smoke alarms sounded. Fortunately, no one was injured and there was little equipment damage. (ORPS Report EM-SR--WSRC-LTA-2005-0002)

These events share some common causal factors, which are listed below.

- Workers encountered unexpected quantities of legacy metallic material or failed to plan for the possibility of its presence. These factors point to faulty pre-job planning.
- Workers may have underestimated the quantity of material they were dealing with.
- Workers used their own previous experience or judgment in dealing with unexpected hazards instead of stopping work to re-evaluate the condition.
- Workers sometimes used flammable cleaning solvents or substituted solvents, without consulting an expert, if the appropriate solvent was not available.
- The more finely divided a substance is, the more reactive it becomes.
- The appropriate subject matter experts were not always present when metals were being handled.

DOE's *Primer on Spontaneous Heating and Pyrophoricity* (DOE-HDBK-1081-94) devotes an entire chapter to the subject of pyrophoric metals and discusses oxidation, ignition, and burning properties of these metals. The Primer includes a table that lists the properties of some of these metals in their solid form. (The table was originally from the National Fire Protection Association (NFPA) Handbook, 17th Edition.) Consider, for example, the differences in ignition temperature when metals are more finely divided.

- Titanium dust clouds can ignite at temperatures as low as 630°F (332°C), which is about one-fifth of the temperature at which a solid titanium mass ignites.
- Finely divided sodium metal ignites spontaneously in moist air at room temperature. In dry air, its ignition temperature is roughly the same as its melting point (208°F or 98°C).
- Zirconium dust can ignite at room temperature, which is much lower than its ignition temperature as a solid mass (2,552°F or 1,400°C).

It is important for facility managers to have a complete understanding of the inventory of reactive chemicals (including metals) for which they are responsible. It is not enough to know that a chemical inventory contains, for example, 2 kg of a certain metal. The manager needs to ask himself or herself questions like the ones in the *Preventing Metal Fires* text box on the next page.

The need for handling and storing reactive metals is often unavoidable. However, managers, supervisors, and workers can arm themselves with the appropriate training about, and knowledge of, any sensitive metallic materials they may have in their inventory and understand how to properly handle and store them to prevent metal fires from occurring.

Preventing Metal Fires

- Is this metal pure or an alloy?
- Is it a solid mass or a particulate?
- Do we have Material Safety Data Sheets on file for each form and type of metal we have in inventory?
- Are there precautionary measures we need to take when storing or handling this metal? (Ask, for example: Must it be kept free of oxygen, water, or other contaminants? Does it need to be stored within a certain temperature range?)
- Is there a less reactive material we can substitute and still accomplish our missions?
- Do we have positive engineering controls in place for controlling metal fires?
- Do we know what PPE our workers should wear when handling metals?
- Are all of the workers in my facility specially trained to handle this metal? Do they know what solvents can and cannot be used with this metal?
- Do we have a ready supply of metal extinguishing agent (MET-L-X and others) in areas where metals could ignite?
- Do our workers know they must never use water on a metal fire?

KEYWORDS: *Metal fire, ignition, oxidation, dust, reactive metal*

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

Challenging a Locking Device Inadvertently Energizes a 480-Volt Line

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On March 4, 2006, at the Hanford K-Basins Closure Project, authorized workers decided to challenge the adequacy of a locking device on a 480-volt circuit breaker. They forced the breaker operating handle in the "Closed" direction, causing the locking device to fail and the circuit breaker to close. This action violated the lockout/tagout (LOTO) and re-energized a panel that had previously been verified de-energized. This event is significant because personnel could have been exposed to 480 volts had they been working on the electrical panel. (ORPS Report EM-RL--PHMC-SNF-2006-0007)

Controlling organization personnel correctly implemented the original lockout/tagout of the electrical feeder to the power panel. They opened the circuit breaker at the motor control center (Figure 2-1) and affixed their lock and tag on the locking device, which is integral to the operating handle of the circuit breaker switch. The lockout/tagout installer verified the adequacy of the lock and the locking device as required by both 29 CFR 1910.333 and NFPA 70E, section 120.2, to ensure the lock was attached in a way to prevent anyone from operating the device unless they resorted to using undue force or tools. This is the only point in the lockout process when someone can challenge the applied lock and tag.

The next day, the authorized workers checked the locked and tagged circuit breaker before placing their own Authorized Worker Lock. However, they decided to challenge the locking device instead of contacting the controlling organization about any concerns they might have had regarding the adequacy of the device. Figure 2-2 shows the circuit breaker operating handle locked in the "Open" position, with the controlling organization's lock in the locking device.

Figure 2-3 is a closeup of the locking device that shows a fresh scrape in the black metal along the top of it. The scrape occurred when a worker forced the locking latch from its detent as the handle was moved in the clockwise direction. The worker apparently had to manipulate the location of the lock in the elongated hole to adjust the locking device so the circuit breaker would close.

Figure 2-1. Motor Control Center with the 480-volt circuit breaker (circled in red)

A causal analysis of this event has not been completed, but investigators did learn that the electricians believed that they were allowed to physically challenge the locking device.

A similar event occurred on September 2, 2004, at the Oak Ridge K-33 decommissioning project, where a subcontractor decided to operate an electrical disconnect switch that was locked and tagged in the "Open" position. The subcontractor was attempting to verify the adequacy of the locking device on the disconnect switch. No one was injured as a result of this event. (ORPS Report EM-ORO--BNFL-K33-2004-0003)

Investigators learned that subcontractor workers considered it appropriate to physically challenge the lock. In fact, they claimed their formal lockout/tagout training suggested that they could challenge a locked-out switch. This misconception was later addressed when the subcontractors attended additional training on lockout/tagout requirements as part of the corrective actions for this event. The site lockout/tagout procedure states: "No employee may attempt to start, energize, or use any equipment/system that is locked and tagged out."

Figure 2-2. Lock installed in circuit breaker handle locking device

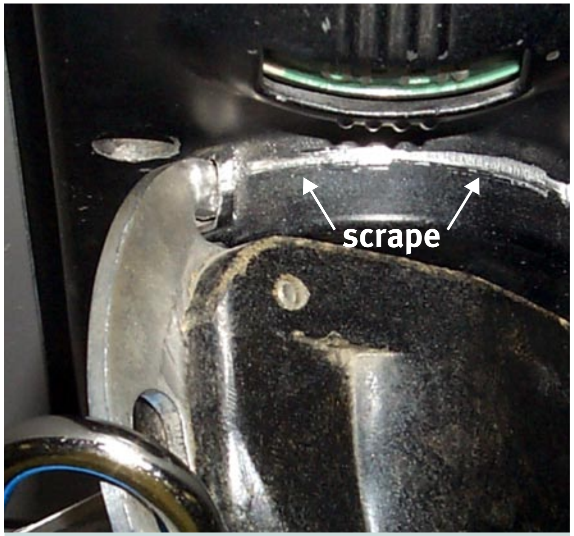

Figure 2-3. Close up of locking device

Operating or removing tagged-out equipment is never permitted, and tagout devices must clearly warn that operation is not permitted (e.g., "Danger, Do Not Operate"). Lockout devices must be substantial enough to prevent removal without using excessive force or unusual techniques. Most locking devices are fairly robust and are designed not to fail when subjected to normal and reasonable force. If a component is already tagged (from another lockout/ tagout) it must not be operated or removed, and its position should be verified by other appropriate means, such as observation of system parameters or valve position indicators.

Tags and locks should be attached to all isolation devices to clearly indicate that operation is prohibited. In some large, centrally controlled facilities, including most commercial power plants, tags alone are sufficient for protection. This is because of the training that all personnel receive and the strict procedures that govern operation of equipment at these facilities.

Although a worker's reason for challenging the adequacy of a lockout device may seem understandable, instructions on the tag should not be ignored and the procedures that control it should not be violated. It is important for affected workers to verify that the lockout/tagout provides the level of protection necessary to perform work safely. However, if there is any doubt regarding the isolation points (barriers) or the integrity of the locking devices, the affected worker should contact the authorized worker who signed the tagout or the authorizing organization that implemented the lockout/tagout.

In 2005, lockout/tagout ranked 5th among the list of Top 10 OSHA violations, with 3,711 violations cited. Lockout/tagout was also one of the Top 10, most-cited "willful" violations.

Once a lock has been installed and the danger tag has been attached, no one should tamper with the isolating device without authorization. The danger of changing the status or position of a locked or tagged device is that others may already have started work under its protection and could be exposed to the hazard they believed was isolated. The time to verify the effectiveness of a locking device is at the initial installation.

Lockout/Tagout Definitions
(DOE-STD-1030-96)

- **Affected Person** — Person whose job requires operation or use of equipment on which maintenance is being performed under lockout/tagout, or whose job requires work in an area in which such maintenance is being performed.
- **Authorized Person** — Person qualified through system knowledge and lockout/tagout training and authorized by the facility to install lockout/tagout on machines or equipment in accordance with facility procedures.
- **Lockout Devices** — Devices that use a positive means, such as a combination or key lock (key locks are preferred), to hold an energy isolating device in the safe position and prevent the energizing of equipment. Hasps, chains, and other devices may be treated as lockout devices when used in conjunction with locks.

DOE-STD-1030-96, *Guide to Good Practices for Lockouts and Tagouts*, provides guidance and practices that should be considered when planning or reviewing lockout/tagout programs. This guidance follows the intent of 29 CFR 1910.147, *The Control of Hazardous Energy (Lockout/Tagout)*.

Prevent Events

Management

- Are personnel trained on the elements of the lockout/tagout program?
- Does this training address the proper use of locking devices?

Supervisors and Workers

- Do you enforce strict adherence to lockout/tagout procedures?
- Do you observe the use of locking devices and the installation of locks and tags?
- Do you check locking devices for signs of excessive wear or tampering?
- Do you challenge the adequacy of the locking device only during initial installation of the lock?
- Do you stop work if you question the adequacy of the locking device to prevent operation of the locked component?

These events underscore the importance of strict adherence to the procedures and the process for implementation and approval of lockout/tagouts, as well as their importance to worker safety. The lockout/tagout program is a critical part of the Integrated Safety Management System, and it works only as well as the degree of discipline and attention to detail that is given by those individuals who use locks and tags for the control of hazardous energy and personnel protection.

KEYWORDS: *Lockout, tagout, LOTO, locking device, lock*

ISM CORE FUNCTION: *Perform Work within Controls*

Poor Housekeeping Poses Fire Hazard

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Good housekeeping reduces the potential for fire and is an essential part of workplace safety. As can be seen from the following events, poor housekeeping has contributed to a number of fires across the Complex.

On September 18, 2005, at the Idaho National Laboratory Advanced Mixed Waste Treatment Facility, an operator noticed a fire burning in a room that contains a box-opening gantry robot used to cut lids from waste boxes. The operator notified the site fire department, and a supervisor directed all personnel to evacuate the building. The fire burned itself out, and there were no injuries as a result of the event. (ORPS Report EM-ID--BBWI-AMWTF-2005-0016)

Investigators determined that this event was the result of poor housekeeping. Workers had used a mineral-oil-treated dust cloth attached to a foam mop head to clean the floor because the vacuum system was not working properly. When they exited the room, they left the mop and dust cloth behind on the floor. The mop was in a direct line with one of the boxes workers were cutting, and sparks created when the saw blade cut into the box ignited the dust cloth.

Workers were directed to remove any combustibles that were not needed for box-opening operations (e.g., cleaning materials, cloth, paper, and plastic bags) from the area. They were also directed to cover combustible materials required for box cutting or move them out of the direct line of any sparks generated during cutting operations.

At the West Valley Site, housekeeping issues contributed to a fire on the floor of a vitrification cell on January 4, 2005. A decommissioning crew was working remotely to size-reduce a steel beam with an abrasive cutting saw. As the beam was being cut, it became unstable and fell to the floor, so the crew secured the saw while they re-evaluated the cutting strategy. Just as the saw was secured, one of the crew members looked out the viewing window and noticed flames about 1 foot high under some cut-up metal pieces piled on the cell floor. The fire remained concentrated in a 1-foot-square area and self-extinguished in about 30 minutes. There were no personnel injuries or spread of radiological contamination as a result of the fire. (ORPS Report EM-OH-WV-WVNS-VFS-2005-0001)

Small pieces of wood and wood splinters from previous work activities were scattered on the floor of the cell, and some of the debris was underneath the metal pieces on the floor. Although the fire could not be clearly seen through the viewing window or by closed-circuit television, investigators believe that sparks from the saw-cutting operation ignited the wood debris underneath some of the larger metal pieces.

Before resuming hot-work operations, safety, operations, engineering, and management personnel developed the following measures to prevent or mitigate the potential for a fire during work in the cell.

- Remove combustibles from the cell to the extent possible.
- Use barriers to protect any remaining combustibles from ignition sources.
- Position spark-producing equipment so that sparks are directed away from combustible material.

Combustible materials left in a glovebox ignited and caused a fire at Rocky Flats on May 6, 2003. Two D&D workers intended to cut sheet metal panels from the glovebox to provide an airflow path for ventilation before cleaning out the glovebox and size-reducing it. Within minutes of starting the task, the workers observed smoke coming from the glovebox, poured water onto it, and then saw flames. Although the workers attempted to extinguish the fire using eight or nine dry-chemical fire extinguishers, each time it reignited. Site firefighters arrived at the scene and extinguished the fire, but four of them received minor skin contamination while fighting the fire. The firefighters did not receive an uptake of radioactive material, and no other personnel in the building were observed to have an uptake or external exposure. (ORPS Report EM-RFO--KHLL-371OPS-2003-0011)

Investigators determined that, contrary to procedures, combustible materials were left in the glovebox without appropriate characterization, analysis, or approval. After the fire, investigators identified five types of fuel in the glovebox: cerium nitrate-soaked cotton towels; nitric acid-soaked cotton towels; degraded leaded gloves; oxidized plutonium or calcium metal; and other, ordinary combustibles (e.g., paper). Some of these combustibles were legacy materials left inside when the glovebox was closed; however, other materials were left during more recent decontamination of adjacent gloveboxes. D&D crew members indicated that they had placed wipes used during decontamination activities in the glovebox and that they may have missed some while removing them.

Corrective actions for this event included ensuring that adequate hazard identification was completed before work began on the gloveboxes, reviewing combustible control program procedures, and clarifying requirements for glovebox inspections.

Requirements for proper housekeeping as a method of fire control are found in 29 CFR 1910.39, *Fire Prevention Plans*. Section 1910.39(c)(2) requires employers to control accumulations of flammable and combustible waste materials and residues so that they do not contribute to a fire emergency.

Among the various types of combustibles, ordinary solid combustibles (wood, paper, rags, plastics, etc.) are the least hazardous. However, these combustibles can readily contribute to a fire when a sufficient amount of heat source is available.

Prevent Events

Precautions for basic fire-safe housekeeping include the following.

- Combustible materials should be present only in the quantity needed for the job and the shift and should be moved to safe storage in marked containers at the end of the day.
- Quick-burning and flammable materials should be stored only in designated locations that are away from ignition sources and have appropriate fire-extinguishing provisions.
- Flammable waste, including cloths soaked with flammable liquids, should be properly disposed of in metal bins covered with lids.
- Vessels or pipes containing flammable materials should have no leaks, and spills should be cleaned up immediately.
- Passageways, means of escape, and fire doors should be well-marked and free of obstructions.
- Materials of any sort must not obstruct sprinkler heads or be piled around extinguishers, hose-reel locations, sprinkler and standpipe controls, electrical switches, or fuse panels.

To minimize the risk of fires involving such combustibles, the following precautions should be taken.

- Avoid excessive accumulations of waste.
- Keep the work area orderly to minimize fuel paths that facilitate the spread of fire.
- Keep combustibles away from ignition sources.
- Plan work to minimize the storage of excess combustibles.
- Keep soiled rags in an approved container with an automatic self-closing lid, and empty the container frequently.

In addition to requiring a fire prevention plan, OSHA requires that access to firefighting equipment be maintained at all times (29 CFR 1926.150). Proper housekeeping procedures are necessary to ensure that this requirement is met. Figure 3-1 shows a fire extinguisher surrounded by clutter, nearly hidden from view, making it likely that workers could not easily find or access it in case of a fire.

Ensuring that proper housekeeping is maintained is a continuous process that requires a commitment from managers, supervisors, and workers.

- Managers must decide that good housekeeping will form an integral part of work procedures, convey this decision to workers, and assign key personnel to monitor work areas for poor conditions.
- Supervisors should be responsible for ensuring that proper housekeeping standards are met in their work areas and for reinforcing the need for these standards.
- Workers should be responsible for housekeeping in their individual work areas and should take responsibility for cleaning up and properly disposing of debris generated by work tasks.

Figure 3-1. Can you find the fire extinguisher?
(Photo courtesy of SAFTENG.net)

These events illustrate the serious fire hazard that can result from poor housekeeping. It is essential to ensure that flammable debris is disposed of properly, particularly in areas where sparks from cutting operations may be generated. It is also essential to ensure that clutter does not block hallways and exits or the visibility and access of fire extinguishers. The responsibility for good housekeeping lies with all site personnel—managers, supervisors, and workers.

KEYWORDS: *Housekeeping, fire, combustibles, debris, chemical reaction*

ISM CORE FUNCTIONS: *Analyze the Hazards, Develop and Implement Hazard Controls, Provide Feedback and Improvement*

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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

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
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