Operating Experience Summary

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Near Miss — Excavator Windshield Broken by Flying Debris

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On September 26, 2007, at the Hanford River Protection Project, an operator was using an excavator bucket to pick up a section of concrete and rebar when a piece of entangled rebar dislodged, sprang backwards toward the excavator, and struck the windshield in two locations. The rebar penetrated the windshield approximately 1 inch near the excavator operator's foot. Fortunately, the operator was not struck by the rebar or debris. (ORPS Report EM-RP--BNRP-RPPWTP-2007-0017; final report filed November 9, 2007)

Workers were using two excavators to demolish a reinforced concrete slab. One excavator had a hydraulic hammer attachment (Figure 1-1) to break up the slab; the other had a bucket attachment to remove debris. The excavator with the hammer had an expanded metal windshield guard, but the one with the bucket had no guard. As the excavator with the bucket attachment was relocating a 3-foot-diameter piece of concrete and rebar, it was dislodged, and the windshield was damaged (Figure 1-2). The damaged excavator was removed from the work location, and operators were directed to use only the excavator with the windshield guard. They were also told not to move any material containing rebar over 4 feet long.

A review of Occurrence Reports from January 2005 through October 2007 identified five additional events in which industrial equipment windshields or windows were broken by flying debris during equipment operations. The following is a summary of these events.

Figure 1-1. Hydraulic hammer attachment at location of rebar and concrete debris

Figure 1-2. Cracked windshield on excavator

- On July 7, 2006, at Paducah, while an operator was using an excavator bucket to crush 24-foot lengths of PVC half-pipe, the pipe shattered, and a shard broke the excavator windshield. The safety glass windshield fell out of the frame, and about 10 percent of the glass fell inside the cab. The excavator was not equipped with a metal guard over the windshield when it was procured. Such a guard could have prevented the flying shard from shattering the windshield. The equipment operator assumed that the PVC piping could be safely compacted because the hazard analysis process did not identify the potential for shattering. Corrective actions included adding a screen to the windshield and precluding the receipt of waste greater than 10 feet in length. (ORPS Report EM--PPPO-PRS-PGDPENVRES-2006-0006)
- On April 28, 2006, at the Y-12 Waste Site, the left side door window of a bulldozer was struck and broken out by a piece of debris. The operator had just placed and spread building debris material and was backing out of the work area when the object was kicked up by the dozer track and struck the window. The safety glass shattered as designed, and small pieces of glass entered the cab and landed on the operator's lap and legs and on the floor board. As a corrective action, a polycarbonate material (Macrolon®) was ordered to replace the safety glass installed on bulldozers. (ORPS Report EM-ORO--BJC-Y12WASTE-2006-0002)
- On July 18, 2005, at the East Tennessee Technology Park, a piece of metal (1½ feet by 1 foot by ½ foot) struck and broke the windshield of a trackhoe being used to size-reduce a motor housing for waste disposal. The safety glass windshield shattered as designed, and a few pieces of glass fell onto the operator's legs. (ORPS Report EM-ORO--BJC-K25ENVRES-2005-0018)
- On July 11, 2005, at the Hanford Site, a trackhoe with a hydraulic hammer attachment was being used to resize vitrified rock when a small piece of vitrified debris went through the windshield safety screen and broke the windshield. The windshield was constructed of standard tempered safety glass, which shattered into small pieces and fell to the ground. The safety screen consisted of metal rods that formed 1-inch squares. As a corrective action, a ½-inch-thick Lexan® shield was installed in conjunction with the metal screen for additional operator protection. (ORPS Report EM-RL--BHI-REMACT-2005-0008)
- On February 28, 2005, at Rocky Flats, an operator was size-reducing a 6-inch by 25-foot-long piece of steel pipe debris, using a processor with an articulating head, when the pipe

hit and penetrated the lower Lexan® window shield and the underlying, tempered glass windshield of the processor cab. While the pipe was being bent to reduce its size for disposal, the stored energy in the pipe caused it to spring toward the processor cab. The pipe came into contact with the operator's leg causing a minor abrasion. Requirements were established to add cab protection, such as Lexan® shielding and metal cages. (ORPS Report EM-RFO--KHLL-D&DOPS-2005-0006)

When operating heavy equipment in an environment that can produce flying debris, three worker protection areas should be considered: hazard recognition; barrier analysis; and work planning.

Hazard Recognition — To prevent worker injuries, it is extremely important to recognize job hazards and provide the best level of protection possible. Demolition work, by its nature, can produce flying debris, whether buildings or equipment are being size-reduced by mechanical means or with controlled explosives. The majority of events reviewed involved size-reduction of piping, equipment, rock, and concrete. Some hazards resulted from the energy imparted by striking or shearing, and others involved stored energy from bending or compression.

Barrier Analysis — There are two barriers that need to be considered. The first is the use of physical barriers on the equipment to protect the operator inside the cab. The second is the establishment of an exclusion area (i.e., distance) to protect all others from flying debris.

1. In most cases, contractors rely only on the manufacturer's installed safety glass as the physical barrier to prevent injury. In some cases, the equipment has been modified to include an additional layer of Lexan®, Plexiglas®, Duraplex®, or Makrolon®; and, in others, a metal screen or guard has been added as a second or even third barrier. Contractors should evaluate the need for additional barriers based on the specific work activity and the risk to the operator. If engineered safety features (e.g., metal screens) are to be added, the potential for reduced visibility should also be considered as a safety impact.
2. Establishing an exclusion area is the best way to protect co-workers and others from flying debris when physical barriers are no longer practical. The exclusion area should be designed and managed as part of the overall approach to controlling the safety of the work activity. Personnel not directly involved in the work activity should remain outside the area until cleared to enter. The exclusion area boundary should be as large as practicable.

   There have been events where debris was thrown outside of 50-foot and 100-foot exclusion areas. For example, on April 23, 2007, at the Idaho National Laboratory, a 1-inch by 3-inch piece of steel traveled 250 feet and penetrated the window of a building when an operator was using a hydraulic hammer attachment to size-reduce material. Typically, debris travels only several feet while hammering and sizing; therefore, based upon equipment vendor concurrence, a 75-foot boundary was used. Following the event, an engineering evaluation recommended not using a hydraulic hammer to size-reduce material that contained ductile, high-strength steel. If hammering is the only or best method, then greater exclusion boundaries will be established and physical barriers will be erected.

Work Planning — When planning to use heavy equipment to compact or size-reduce waste materials, care should be taken to ensure that the operator of the equipment is made aware of any unique characteristics of the waste (e.g., release of stored energy) during the compaction or size-reduction process. Choosing the right equipment for the type and size of material involved in the work activity is also important.

In 1999, the Mine Safety and Health Administration conducted a survey of events resulting in operator fatalities that involved broken cab windows on bulldozers and excavators caused by coal surges. They discovered that the standard glass used in the cabs could not withstand the weight of the coal. Experiments were conducted using high-strength glass, which proved successful in holding back tons of coal. Although this is an extreme example, it shows the importance of considering the use of stronger glass as a replacement or installing additional layers of a polycarbonate material or metal screens (Figure 1-3).

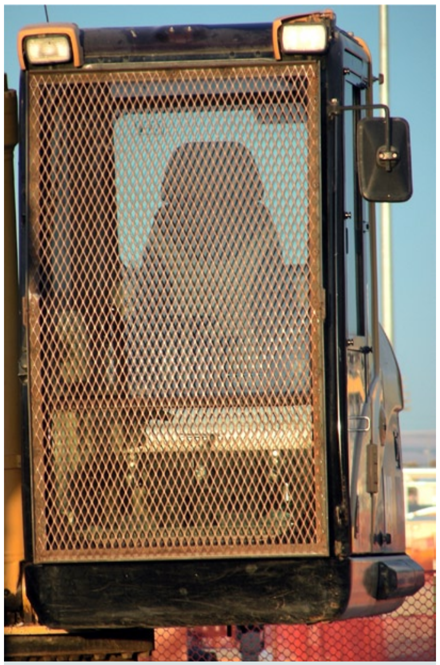

Figure 1-3. Metal screen over windshield of excavator cab used in the Hanford rebar event

No matter what, windows and windshields should always be in place during equipment operation. Heavy equipment manufacturers typically stress this issue. In 2005, an injury case went before the Superior Court of Pennsylvania that involved a product liability claim from a person who was injured while operating an excavator equipped with a hydraulic hammer. While chipping rocks, a piece of the hammer tool broke off, flew into the cab, and struck the claimant in the shoulder. The excavator was equipped with a ¼-inch, laminated, safety glass windshield. However, the claimant knowingly did not have it in place at the time of the accident. A sticker on the windshield clearly warned of the dangers of flying debris and the necessity of having the safety glass windshield in place. For this reason, the case was dismissed.

These events underscore the unpredictability of such hazards associated with demolition and the need to provide additional defense in depth, (e.g., enhanced cab protection) to protect against flying debris. This may prevent similar incidents from resulting in severe consequences. Supervisors and foremen need to ensure that equipment operators wear appropriate PPE (e.g., hardhat, safety glasses, and work shoes) while operating the equipment and that enhanced cab protection is properly used.

KEYWORDS: *Windshield, window, safety glass, near miss, debris, missile, shattered, excavator, demolition, industrial equipment*

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

Type A Accident Investigation of the Mixed Waste Spill at Hanford Tank Farms — Part 1: Engineering Design Factors

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On July 27, 2007, at the Hanford Tank Farms, a health physics technician performing a tank waste transfer shutdown radiological survey identified unexpected high radiation levels (about 200 mrem/hr) in an area 8 to 12 feet from a transfer pump. An entry team responded, took initial radiation readings, and measured 25 rem/hr (beta window open) and 1 rem/hr (beta window closed) within a foot of the liquid. The entry team also found a dark stain and standing liquid around the pump pit. (Figure 2-1, taken post-event, shows a "bathtub ring" on the inside of this cavity several inches deep along the top of the hose and on the north face of the pump pit wall.) Access to the area was immediately restricted, and the spill area was stabilized. Subsequent analysis indicated that as much as 85 gallons of tank waste, including suspended solids and vapors, were released in a short period of time from a ruptured dilution hose near the pump. (ORPS Report EM-RP--CHG-TANKFARM-2007-0009)

When the accident occurred, there were no workers in the area of the spill. However, in the hours and days following the spill, a number of Hanford workers identified odors, experienced symptoms or health effects, or expressed concerns about their potential exposure to waste chemicals from the spill. Because the potential for worker exposures was not fully considered either during or shortly after the accident, the Chief Health, Safety and Security Officer established a Type A Accident Investigation Board to conduct an independent investigation of the accident.

Figure 2-1. Double-sided arrow shows "bathtub ring" along the top of the hose and on the pump pit wall

The Board identified deficiencies in five program areas: engineering design; work control; industrial hygiene/medical; emergency management; and management and oversight. To fully address the Board's findings and Judgments of Need (JON), each of these program areas, as well corrective actions that may be applicable to other DOE sites with similar waste transfer pumps, will be the topic of an article in the *Operating Experience Summary* over the next few issues. This article focuses on the engineering design factors and the JONs addressing them.

The Hanford Tank Farms are designated as a Category 2 nuclear facility. The tanks, pumps, and related safety systems are covered by a Documented Safety Analysis (DSA) and by Technical Safety Requirements (TSR). The pump that was involved in this accident was installed in mid-July 2007, and was operated for only a few days before the accident occurred. The pump dilution water and sparge water nozzles are shown in Figure 2-2.

On the day before the spill, the pump stopped or was shut down several times because of issues such as high discharge pressures and high electrical current indications. Before the accident occurred, operators restarted the pump and ran it in reverse to clear the pump of clogs, but it shut down again, and they could not restart it. The Operating Engineer called a work crew to try to restart the pump with manual rotation in reverse and electrical "bumping," and the crew was able to restart the pump. The pump ran for about 2 minutes, then clogged with waste, and a portion of the waste was forced into the dilution line,

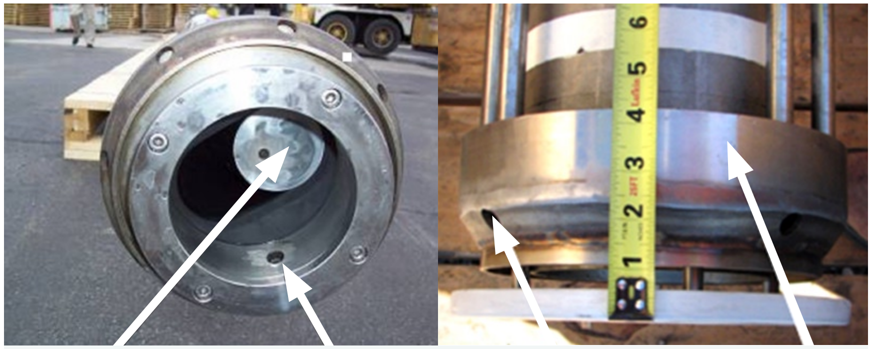

Figure 2-2. Dilution water and sparge water nozzles

pressurizing it. At that point, the hose connected to the dilution line failed, releasing the mixed waste to the ground near the pump platform at the top of the tank.

The Board concluded that the direct cause of the spill was an overpressure of a hose connected to a dilution line on the retrieval pump system.

The overpressurization and spill resulted from the lack of an isolation device (e.g., a backflow preventer) between the dilution water system (a non-waste transfer system) and the waste transfer route. Both the DSA and TSRs require such a device. The Board also determined that the sparging water system met the DSA definition of a "non-waste transfer system not physically connected" to the waste transfer route and, thus, also required an isolation device. However, there was no isolation device in place. They identified the root cause of the event as the failure to implement the DSA requirement to provide isolation of the hose from the waste transfer route as prescribed in the TSRs.

Engineering design factors that contributed to the incident include the following.

- The design process failed to verify proper implementation of required DSA and TSR safety significant design features for the retrieval pump system and the associated dilution and sparge lines.
- The dilution and sparge lines were not classified as safety significant; specifically, the portions of the lines within the pump housing to the incorrectly located backflow preventers were not classified as safety significant.
- The retrieval pump system design specifications were not fully incorporated into operating procedures.

The following JONs address these engineering design factors.

1. Improve incorporation of the design features, testing, and operating limits and specifications into operating procedures associated with the tank and the pump to ensure its ability to move waste without becoming fouled.
2. Revise the design review processes, procedures, and implementation to ensure approved designs are technically correct and satisfy the requirements of the DSA.
3. Perform an engineering analysis to determine whether the pump can continue to be operated safely following the deformation that occurred when excessive shaft torquing was applied during maintenance.
4. Change the safety basis to require that new primary pressure boundaries for the tank be classified as safety significant, and treat existing installed systems, structures, and components as if they were safety significant to the extent practical.

The Accident Investigation Board concluded that this accident could have been prevented if a backflow prevention device had been installed, as required by the DSA and TSRs for the tank farms. They also concluded that, although several workers reported symptoms, it is unlikely that the accident resulted in significant radiation or chemical exposures to workers. However, the event could have been significantly worse if individuals had been in the immediate vicinity of the spill at the time of the release.

The detailed two-volume Accident Board report is available on the DOE Office of Health, Safety and Security website. An upcoming issue of the Summary will address the work control factors that contributed to the event.

This event illustrates the importance of conducting detailed design reviews and engineering analyses of equipment and systems in order to guarantee that their design, installation, and function meet the requirements set forth in the Documented Safety Analysis and the Technical Safety Requirements.

KEYWORDS: *Type A accident, hazardous waste, spill, transfer pump, isolation device*

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

NRC Operating Experience on Electrical Circuit Breaker Problems

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On October 22, 2007, the Nuclear Regulatory Commission (NRC) issued Information Notice 2007-34, *Operating Experience Regarding Electrical Circuit Breakers*, to inform operating license holders about problems associated with maintenance and operation of low-, medium-, and high-voltage circuit breakers. Circuit breakers are relied upon to provide electrical power to equipment credited in nuclear plant accident analysis. Because licensees often use circuit breakers of the same type and from the same manufacturer in their redundant safety systems, certain breaker problems raise the possibility of a common-mode failure. In particular, several licensees have experienced problems following installation of replacement breakers of a different manufacturer into their existing switchgear. (NRC Information Notice 2007-34)

The Office of Nuclear Reactor Regulation reviewed circuit breaker operating experience and found that the following often were the cause of problems.

- Deficient fit of replacement circuit breakers within cubicles
- Inadequate or excessive tolerances and gaps
- Worn or misadjusted operating linkages
- Inadequate or inappropriate maintenance practices
- Configuration control errors
- Deficiencies from original design and refurbishment
- Design changes

The following are representative examples of electrical circuit breaker problems at five nuclear power plants.

1. At River Bend Station, Unit 1, a 4,160-volt circuit breaker, which is required for offsite power to standby switchgear, was found to be inoperable because it was not fully racked in. The racking mechanism was found to be difficult to operate. There was an outstanding maintenance work order that addressed a non-illuminated control power light for a breaker in the main control room. The light was not illuminated because the breaker was not fully racked in. In addition, a permissive signal required to close the breaker was not present because an upstream breaker was not closed. Surveillance test procedures for verifying the alignment of offsite power supplies were also less than adequate. The Operations procedure for breaker racking will be revised to verify indication of control power and to require a functional test of breakers that support a safety function. Surveillance test procedures will be revised to verify the circuit breaker alignments.

2. At Crystal River, Unit 3, an emergency diesel generator was declared inoperable because a circuit breaker closing spring was not charged, preventing the breaker from operating. The control switch for the charging motor was found in the off position. The switch is located inside a closed cubicle, and operations and maintenance personnel failed to verify its position following post-maintenance testing. The problem was revealed during the next periodic surveillance test.

3. During quarterly surveillance testing at Indian Point, Unit 2, a residual heat removal pump failed to start when a control power fuse blew in the 480-volt supply breaker for the pump. The inertia latch, which prevents breaker re-closure caused by contact bounce on a breaker trip, was binding and did not reset. This kept the closing coil energized until protective fuses opened. Foreign material was found embedded on the surface of the inertia latch bushing, creating a rough, uneven surface. Corrective actions included cleaning and lubricating the inertia latch and changing the breaker preventive maintenance procedure to emphasize the importance of ensuring freedom of movement and smooth operation of the inertia latch.

4. On two occasions at the Fort Calhoun Station, the mechanical-operated contact (MOC) switch in a 4,160-volt circuit breaker for a pump did not actuate the auxiliary contacts that provide breaker position indication and an open signal to the pump discharge valve. The switch failed because the MOC offset rod, which transfers the motion of the circuit breaker to operate the auxiliary contacts, was broken. In 1995, all 4,160-volt General Electric (GE) Magna-Blast circuit breakers were replaced with breakers from Asea Brown Boveri that were designed to fit in the GE switchgear. However, the design process failed to recognize, and properly evaluate, the additional stresses placed on the MOC offset rod by a metal "test flag" device used during circuit breaker testing. The MOC offset rods had to be replaced.

5. At Farley, Unit 1, a fit discrepancy occurred during installation of new Cutler Hammer breakers in Allis Chalmers switchgear because the procedural guidance on how to set up the replacement circuit breakers for initial installation and testing was inadequate. The problem was discovered during a test of the emergency diesel generator when the MOC switch in the generator output breaker, which provides breaker status indication and other control functions, failed to rotate sufficiently to fully engage the normally open contacts.

The NRC review of operating experience also revealed the following circuit breaker issues caused by inadequate maintenance practices.

- Gaps and clearances in circuit breaker operating mechanisms were not corrected, preventing proper circuit breaker operation.
- Trip mechanisms were not properly cleared and reset once the circuit breaker was fully racked into the connect position, preventing the circuit breaker from closing on demand.
- Excessive wear developed on circuit breaker main stabs, causing misalignment of the stabs while racking the circuit breaker into the cubicle. Electrical faults resulted when the high-resistance stab connections failed.
- Circuit breakers were racked in while misaligned to the cubicle, preventing control power contacts from connecting properly. In addition, relay and switch contacts were not adequately assessed, cleaned, and tested, resulting in circuit breakers not operating as designed.

- Control power lead lugs were not properly crimped, causing loss of control power. Loose connections were not always identified and corrected.
- Failing to properly clean (including removal of hardened grease) and grease circuit breaker mechanisms prevented the mechanisms and auxiliary switches from operating as designed.
- Relays mounted on circuit breaker cubicle doors were inadvertently actuated during circuit breaker maintenance.

The NRC archive of information notices can be obtained at http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/.

This information notice identifies deficiencies and issues that could be applicable throughout the DOE complex. A review of DOE Lessons Learned and the ORPS database for electrical circuit breaker problems identified similar issues, many of which occurred in the 1990s, as aging circuit breakers were starting to fail and replacements were being installed in existing switchgear.

The electrical circuit breaker problems identified in the NRC information notice underscore the importance of a strong circuit breaker maintenance program. Preventive and corrective maintenance can quickly identify and resolve electrical circuit breaker problems to ensure safe and reliable power delivery and equipment operation.

KEYWORDS: *Circuit breaker, switchgear, maintenance, modification, aging*

ISM CORE FUNCTION: *Provide Feedback and Continuous Improvement*

The Office of Health, Safety and Security (HSS), Office of Analysis publishes the Operating Experience Summary to promote safety throughout the Department of Energy (DOE) complex by encouraging the exchange of lessons-learned information among DOE facilities.

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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