Operating Experience Summary

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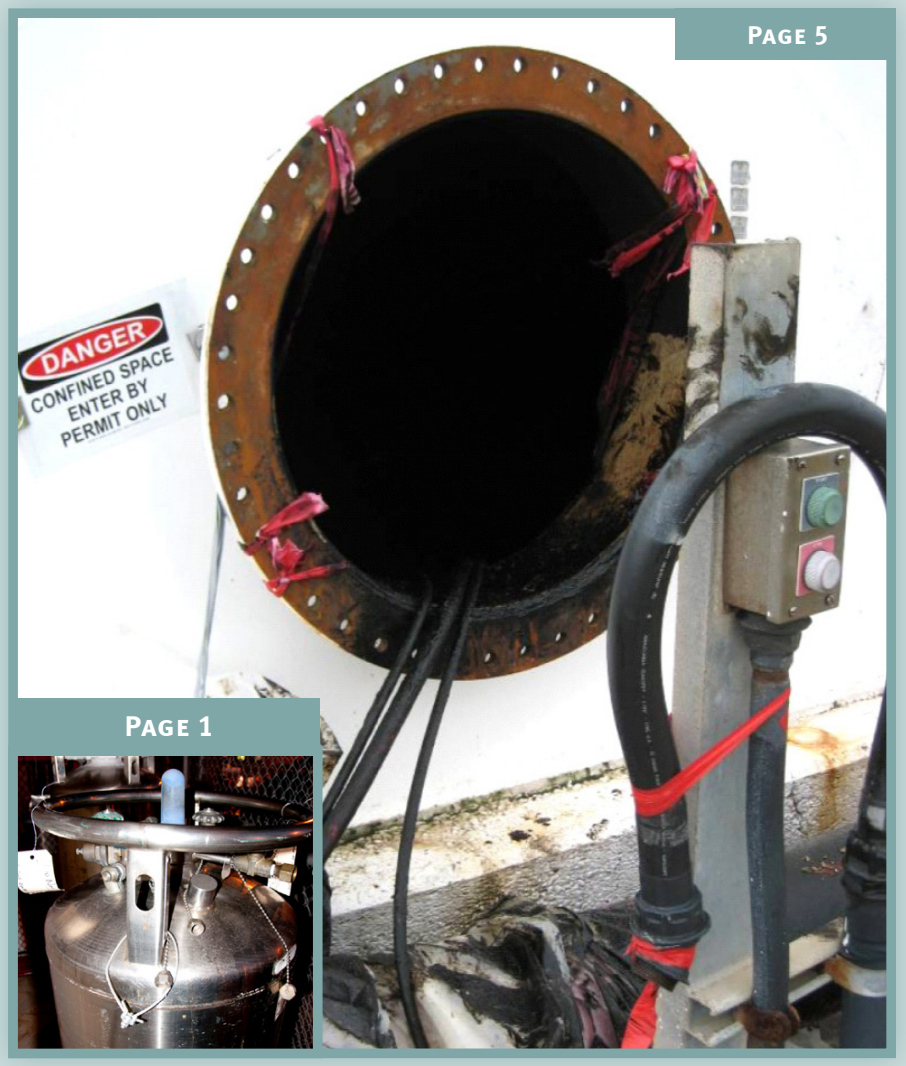

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Improper Use of Dewar Carts Results in Serious Hand Injuries

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The following article provides a summary of four incidents in which Department of Energy workers suffered serious hand injuries when moving Dewars on Dewar transport carts. The injuries occurred from January to August 2011. Post-event investigations were conducted. This article provides good practices for handling large cryogenic containers.

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In 2011, there were four incidents in which Department of Energy workers suffered serious hand injuries when large Dewars (cryogenic vacuum flasks) they were moving slipped from the Dewar transport carts. During the 8-month period from January to August 2011, workers who transport such containers on a regular basis received injuries ranging from fingertip avulsions to hand fractures that resulted in more than 260 lost or restricted work days. Post-event investigations determined that improved work instructions, enhanced on-the-job training, worker awareness of the hazards, and use of safer models of Dewar transport carts could prevent recurrence.

Fermi National Accelerator Laboratory

On August 23, 2011, a worker's fingertip was amputated when he attempted to move a 160 L liquid nitrogen Dewar using a Harper Series 600 Universal Liquid Gas Cylinder Truck (Dewar transport cart). The worker had inserted the cart's lifting hook into the Dewar's lifting slot (shown in Figures 1-1 and 1-2), placed his left hand on the Dewar handling (halo) ring, and placed his right hand on the cart handle. He then began tilting the cart down onto its wheels. As he pulled back on the cart and Dewar, the cart lifting hook disengaged from the lifting slot of the Dewar and the Dewar rapidly slid down the cart. His left middle finger was caught between the handling ring and a horizontal steel support on the cart, resulting in an avulsion of the fingertip. Emergency response personnel transported the worker to the local emergency room, where the

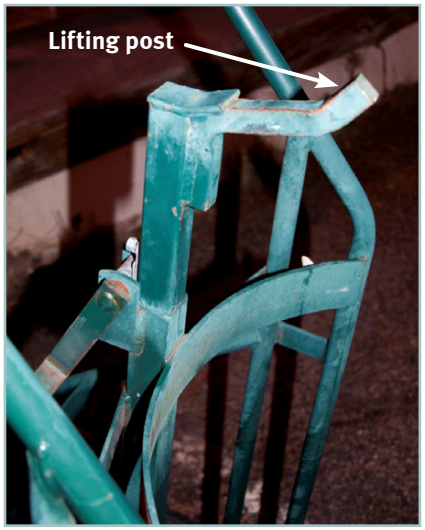

Figure 1-1. Lifting post that fits into Dewar

Figure 1-2. Dewar lifting slot

fingertip was reattached. He lost 5 work days and, although he returned to work, had job-limiting restrictions for an additional 9 weeks. (Lesson Learned ID: 2011-FSO-FNAL-001)

A preliminary investigation identified the direct cause of the incident as the improper adjustment of the cart lifting hook. In addition, the placement of the worker's hand on the handling ring while tilting the cart back placed the hand in a vulnerable position when the Dewar disengaged from the lifting hook. Management of the divisions utilizing Dewar carts was made aware of the incident, and management curtailed Dewar movements until supervisory personnel could inform affected personnel about the incident and the identified causes. In addition, the Laboratory Cryogenic and Mechanical Safety Subcommittees were contacted and a panel of members from those committees, along with Environment, Safety & Health personnel from affected divisions, was convened to assist in further investigation of the incident and in the development of corrective actions.

The panel inventoried the carts and evaluated them for hazard potential. One style of cart (not the same style as the one involved in the incident) was judged to have an unacceptably high risk associated with its use and was removed from service. All of the other carts of different styles were determined to be fit for use, including the style of cart used during the specific incident. However, the evaluation made it clear that personnel needed training on the proper means to adjust each style of tilt-back cart, since each style has the potential to be inadvertently misadjusted, potentially resulting in loss of control of the Dewar. Dewar and cart vendor materials were reviewed to ascertain the proper procedures for use of the carts.

The panel's cart evaluation and follow-up discussions indicated that cart users lacked clear understanding of the proper steps to use when adjusting the carts to fit a given Dewar. The panel learned that cart users had developed a common practice of placing one hand on the Dewar handling ring when tilting back a cart with the Dewar attached, but they did not understand that this practice placed their hands in a hazardous position where an injury could occur. This widespread misunderstanding led the panel to decide that the past practice of treating Dewar cart use as a skill-of-the-craft task was inadequate and that specialized, formal training was required for personnel to safely use Dewar carts to move large liquefied gas Dewars.

Los Alamos National Laboratory

On January 28, 2011, an experienced worker attempted to stabilize a 160 L argon Dewar that began to dislodge from a commercial transport cart. The worker's right hand was caught between the Dewar and the cart, and the ends of his right ring finger and little finger were severed. The worker had intended to move the recently-filled Dewar a few feet to connect it to the building's gas manifold for laboratory use. Gas plant personnel had recently delivered filled Dewars and had left the argon Dewar attached to the transport cart for movement to the manifold. When the worker pulled back on the cart, either the pin in the adjustable assembly gave way or the lifting stem became dislodged from the Dewar and caused the injury. A coworker immediately took the injured worker to the Laboratory's occupational medicine facility, and then to the Los Alamos Medical Center for treatment. The worker lost 2 centimeters from the end of his right ring finger and 1 centimeter from the end of his right little finger. (ORPS Report NA--LASO-LANL-ESH-SUPT-2011-0001 and Lesson Learned ID: 2011-LANL-LL-ESHSUPT-0001)

According to the operating procedure posted on the commercial transport cart, the hook height must be adjusted so that the hook is fully engaged through the lifting eye of the cylinder and is in contact with the top of the eye before tipping the cylinder. Figure 1-3 shows a cylinder loaded onto a cart before being tipped. Immediate post-event actions included pausing Dewar movements, instructing gas plant personnel to bring their own carts with them on deliveries to minimize movements by programmatic personnel, outfitting stationary carts

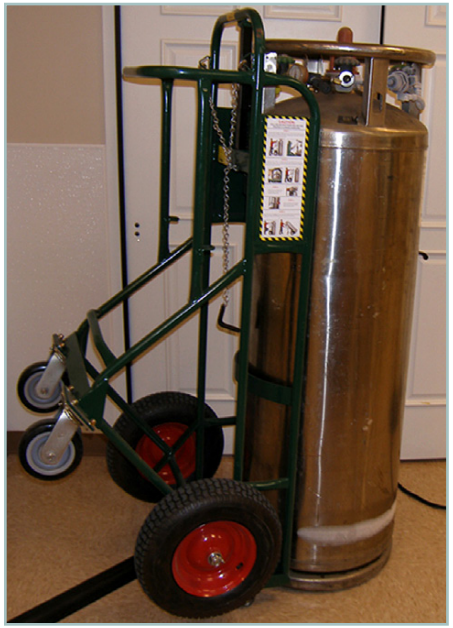

Figure 1-3. Non-DOE Dewar and cart in pre-tipped configuration

with a wheeled base where appropriate, procuring new carts to replace inferior units, reviewing and revising work control documents as appropriate, adopting a two-person rule for cart movement, and reviewing and revising cryogenic safety training course content.

Argonne National Laboratory

On April 27, 2011, a senior technician injured his ring finger when he tipped a Dewar cart back to move a recently-filled Dewar, gripping the top of the Dewar to steady it. The cart's spring-loaded retaining hook/bar did not seat correctly into the Dewar's retaining/lifting slot, and the tipping motion allowed the Dewar to slip and pin the worker's finger. He was immediately treated by medical staff and referred to a hand surgeon, who diagnosed a compound fracture requiring surgery.

Post-event examination of the cart showed that a user cannot see whether or not the hook is properly engaged with the Dewar opening when standing behind the cart and therefore must move to the side to see the point of contact. If a user holds both cart handles while tilting, the hands will be out of harm's way. However, if a user holds one handle and steadies the Dewar with the other hand while tilting (an instinctive precaution that the technician took), the hand will be in a vulnerable position.

A subsequent extent-of-condition review found 26 carts of this model and 6 were removed from service. In July 2011, a safety notice was issued describing how to properly use the cart, and in August, a formal lesson learned was issued to inform users of potential dangers and correct handling methods for the cart. (ORPS Report SC--ASO-ANLE-ANLEAPS-2011-0001)

On July 27, 2011, a worker injured the second finger of his right hand while transporting a filled liquid nitrogen Dewar when the cylinder moved slightly, allowing the cart's locking mechanism to disengage and come down on the worker's finger. The force fractured his finger and resulted in amputation of the fingertip. Although the worker had successfully disengaged the locking mechanism in the past, he had never been trained in the proper method of disengaging the Dewar from a cart and instead relied on intuition and past experience to perform the task. The Laboratory did not provide training since the manufacturer's general guidance on the proper use of the carts did not emphasize the hazards of the locking mechanism. Based on lessons learned from this incident, the Laboratory immediately issued a Safety Alert, and then identified personnel who handle Dewars, started mandatory training for them, enhanced existing procedures, and completed a hazard analysis and work control documentation for Dewar movement. (ORPS Report SC--ASO-ANLE-ANLE-2011-0002)

Lessons Learned

Specialized, formal training should be required for all personnel who use carts to move large portable Dewars. The objectives of the training should be to inform personnel about how to recognize the hazards associated with handling and moving large portable Dewars; to provide information on the carts and safe methods for their use; and to provide hands-on training on moving a Dewar with the type(s) of cart(s) that individuals will be expected to use.

At most sites, using commercial Dewar carts had been treated as a skill-of-the-craft task. As a result, technicians received only minimal, informal on-the-job training which did not include detailed vendor information on cart handling. Because current practices may diverge from cart and Dewar vendor-recommended methods, personnel may be unaware of critical steps in the process of safely securing a Dewar to a cart. Personnel who move Dewars should keep in mind safe practices such as those listed in the textbox on the right. For example, Los Alamos National Laboratory revised its handling documents to include the two-person rule.

Site management should review engineering controls related to Dewar carts and the carts currently in use. If needed, carts should be replaced with safer models. Los Alamos National Laboratory has replaced some carts and can provide recommendations; please contact Bob Stuewe at (505) 665-1392.

KEYWORDS: Dewar, cart, handling, hand injury, training, hazards

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

Good Practices for Handling Large Cryogenic Containers

- Ensure that handlers are properly trained.
- Use only carts specifically designed for moving Dewars.
- Ensure that the lifting post/bar is fully engaged with the Dewar's lifting slot.
- Keep hands and fingers clear of any potential pinch points.
- Use safe handling techniques such as both hands on the handles.
- Keep Dewars upright at all times.
- Always consider the movement of liquid inside the container and its effect on the container's center of gravity.
- Consider adopting a two-person rule for cylinder movement.

Strategic Petroleum Reserve Investigation Results — Fatality at the Bryan Mound Site 2

The following article provides a summary of the accident investigations into an event that took place at the Department of Energy's Strategic Petroleum Reserve Bryan Mound Site on July 8, 2010, resulting in the fatality of a subcontractor tank technician cleaning the floor of a crude oil storage tank. The worker was using supplied air to protect against the possibility of inhaling hazardous material. The autopsy report stated that the cause of death was asphyxiation due to lack of oxygen. A three-tiered accident investigation was conducted, finding gaps in work control and emergency response.

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On July 8, 2010, at the Department of Energy's (DOE) Strategic Petroleum Reserve (SPR) Bryan Mound Site, a subcontractor tank technician (Technician 1) suddenly collapsed while cleaning the floor of a 32-foot-high, 222-foot-diameter crude oil storage tank. The SPR Bryan Mound Site and the tank that was being cleaned are shown in Figures 2-1 and 2-2. The worker was using supplied air to protect against the possibility of inhaling hazardous materials (e.g., benzene in oil vapors) that could be stirred up by cleaning operations. Another tank

Figure 2-1. Aerial photo of Strategic Petroleum Reserve Bryan Mound Site showing four crude oil storage tanks (bottom center)

Figure 2-2. Crude oil tank that was being cleaned

technician (Technician 2) was working inside the tank and, as he was approaching Technician 1 to discuss the task, he saw Technician 1 pulling on his air line and heard a "pop," indicating that the air line had disconnected. He then saw Technician 1 take a few steps in one direction, shift direction, and fall forward without attempting to break his fall. Technician 2 and a nearby attendant, who was not wearing Personal Protective Equipment (PPE), immediately rendered aid, turning on Technician 1's five-minute air supply, removing him from the tank, and administering cardiopulmonary resuscitation (CPR). When emergency responders arrived, they continued CPR and used an automated external defibrillator while preparing him for transport to the hospital. Emergency Room medical staff pronounced Technician 1 dead shortly after his arrival at the hospital. On January 4, 2011, the Galveston County Medical Examiner's Office stated in its autopsy report that the cause of death was asphyxiation due to a lack of oxygen. (ORPS Report FE--SPRO-SPR-BM-2010-0001)

There was a three-tiered approach to investigating the accident. An Occupational Safety and Health Administration (OSHA) investigation began immediately because OSHA has jurisdictional authority; DOE's SPR Project Management Office (PMO) began an internal investigation to determine the event's causes and corrective actions from an operations perspective; and the Office of the Assistant Secretary for Fossil Energy requested that DOE Headquarters (HQ) conduct an independent investigation of management system deficiencies. As a result, the Chief Health, Safety and Security Officer established an Independent Review Board (IRB) to review selected aspects of the broader safety management programs applicable to the incident and the effectiveness of the incident analysis performed by the SPR PMO, while recognizing that OSHA was investigating the event.

The IRB focused on determining what underlying factors (e.g., systemic weaknesses in procedures or maintenance and testing) needed to be addressed by DOE and contractor management to provide assurance that similar deficiencies were unlikely to recur. The IRB reviewed and identified opportunities for improvement in work controls, emergency response, and safety management systems. It also reviewed the SPR line management investigation of the event and its proposed corrective actions.

Work Safety Controls

The IRB determined that many work safety controls were in place for the tank cleaning activity. For example, daily safety briefings were used to communicate hazards and controls to workers, and lockout/tagout processes were implemented effectively and were sufficient to eliminate hazards associated with tank cleaning operations. In addition, appropriate work permitting processes were implemented effectively to formally authorize a variety of hazardous operations. However, the IRB also identified several areas where work safety controls were not adequately implemented for tank cleaning operations: couplings (testing); confined space; heat stress monitoring; respiratory protection; and air quality monitoring/sampling. In most of these cases, appropriate requirements were defined in site-specific or activity-specific safety documents but were not fully and effectively implemented for the activity.

Couplings – Several important aspects of the respiratory protection program were not implemented in accordance with applicable regulations and site-specific requirements. The Oilind brand air line couplings that were used matched those commonly used for air-powered tools, contrary to OSHA requirements. Title 29 of the Code of Federal Regulations (CFR), Section 1910.134(i)(8), *Occupational Safety and Health Standards — Respiratory Protection*, requires breathing air couplings to be incompatible with outlets for non-respirable work-site air or other gas systems. In addition, the Oilind air line hoses had not been tested and approved by the National Institute for Occupational Safety and Health (NIOSH) as

required by OSHA. NIOSH testing for hoses and couplings includes standard testing procedures for determining the strength of hoses and couplings, as well as their tightness. In addition, the IRB found that, although workers were required by the 2007 ES&H, LLC Policy and Procedures Manual, as well as the DOE stop-work policy, to report any problems or defects in equipment or inadequate elements of the respiratory protection program, hose couplings had failed three times during this job, but no one had reported the failures. The technicians were employees of ES&H, LLC, a subcontractor to Arctic Slope Regional Corporation Gulf States Constructors, LLC (AGSC).

Confined Space Safety Controls – Although the tank was appropriately designated and controlled as a confined space, the IRB identified deficient practices and conditions. The method for communicating between tank entrants and the confined space attendant was not sufficiently reliable for the working conditions present in the tank. Communications between tank entrants and the attendant were limited to hand signals and a bull horn, and the relatively dim artificial lighting inside the tank reduced visibility. (Figure 2-3 shows the Confined Space posting at one of the openings used for workers' ingress/egress.)

Controlling and Monitoring for Heat Stress – The IRB determined that actions taken to monitor and control heat stress for tank entrants were not adequate and were not performed in accordance with the requirements established in the tank cleaning contract. For example, measures to protect workers against heat stress (e.g., using shade areas, rotating workers, using the buddy system, and providing water to maintain hydration) were not consistently implemented, and heat stress monitoring (e.g., heart rate, core body temperature) was not performed in accordance with American Conference of Governmental Industrial Hygienists recommendations. In a review of logs, the IRB also found that temperature measurements were not routinely taken and/or recorded while workers were in the tank and that equipment used during tank cleaning operations did not meet the applicable regulations and site-specific requirements.

Respiratory Protection – The IRB determined that there was no job-specific or contractor-specific respiratory program. It also determined that, although annual respirator fit-testing was required, it had not been maintained for all workers. Technician 1's fit test for the applicable respirator had lapsed in March 2010.

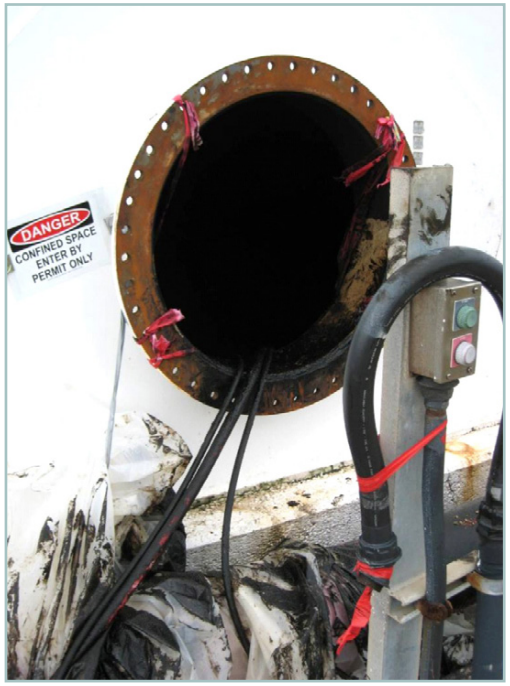

Figure 2-3. Tank opening for workers' ingress/egress (posted as Confined Space)

Air Quality Monitoring and Sampling – The IRB identified two inadequacies in this area. Continuous monitoring appears to have been conducted within the tank, but the measurements may not have been representative of the atmosphere inside the tank because the samples were collected just inside the tank entry point, with airflow being drawn into the tank. Considering the large size of the tank and the relatively low expected turnover of the atmosphere (e.g., small manway openings), the samples at the entry point may not have represented the breathing zone deeper inside the tank.

The IRB found that benzene concentrations at open manways were 1,299 parts per million (ppm) at 51 minutes before initial tank entry on the day of the event, but dropped to zero at 16 minutes before the entry. The IRB determined that the

ventilation method used did not have the capacity to reduce the concentration of benzene by that much across the volume of the tank, so apparently the measurement and monitoring methods were either in error or not sufficient to provide accurate information on the levels deeper inside the tank. Because of the combination of deficient monitoring and inadequate respiratory protection, the systems in place at the time of the incident did not provide sufficient assurance that worker exposures to benzene were less than the OSHA permissible exposure limit of 1 part per million time-weighted-average.

Emergency Response

The IRB determined that most aspects of the emergency response process appropriately reflected applicable regulations and DOE requirements and that the emergency response was rapid and effective. However, the sequence of events following the incident indicated that there were a number of deficiencies in implementing site requirements and that onsite personnel were not fully prepared to respond to an incident of this nature. Among the IRB's findings were that workers inside the tank were not wearing retrieval harnesses as required and that the tank cleaning team had not trained and practiced a physical rescue from a confined space in accordance with site and regulatory requirements. (Figure 2-4 shows the outside of the tank.)

The IRB also determined that site ES&H, LLC (a subcontractor to AGSC) personnel were not sufficiently prepared for an emergency entry. For example, a self-contained breathing apparatus was available at the work site, but it was not pre-positioned or ready for use at the tank; nor was the protective equipment (e.g., latex gloves, eye protection) needed for the protection of rescuers pre-positioned and readily available. In addition, because responders were understandably focused on assisting Technician 1 as rapidly as possible and believed that the air quality was safe, one responder entered the tank for a very short time without the required respiratory protection equipment.

Figure 2-4. Tank opening used by the subcontractor to feed air hoses to workers inside tank

Safety Management Systems

The IRB identified two aspects of safety management systems that were not fully effective: requirements management and oversight of subcontractor work activities.

Requirements Management – The IRB determined that several important safety requirements applicable to the tank cleaning task were not met (e.g., heat-stress monitoring, respiratory protection equipment, air monitoring, confined space work). In most cases, AGSC and ES&H, LLC program documents or contracts appropriately specify these requirements; however, AGSC and ES&H, LLC site management did not effectively convey them to the tank cleaning crew. Mechanisms were established to inform the tank cleaning crew of hazards and controls, but

they were not effectively implemented. Requirements for protective clothing and supplied breathing air, for example, were not incorporated into work-specific instructions to ensure that workers had a clear understanding of the controls and how to comply with them effectively. In some cases, requirements were not addressed in activity-specific hazard assessments and thus were not translated into work control requirements; in others, requirements were adequately addressed in activity-specific documents, but were not communicated to, or were not understood by, the workers.

Oversight – Although there was management oversight at the job site, there was insufficient industrial hygiene expertise to support special projects, such as periodic tank cleaning activities. Most of the industrial hygiene deficiencies identified after the event (e.g., poor lighting that impacted communications, noncompliance with requirements for heat exposure management, and poor tank air quality monitoring practices) were not identified in earlier oversight visits. The investigation determined that neither line managers nor safety representatives had expertise in industrial hygiene. In addition, weekly safety and health inspections did not identify significant safety deficiencies: "general housekeeping" was the only unsafe practice noted in inspection records for the 4 weeks preceding the fatality. An underlying factor in these breakdowns was an insufficient process for reviewing work instructions against requirements to ensure that all relevant requirements were clearly communicated to the working level.

Management Incident Analysis

The IRB determined that the SPR line management incident analysis overall identified an appropriate set of recommendations for addressing deficiencies at the Bryan Mound Site and those in SPR-wide safety programs. SPR line management recognizes that a number of issues warrant additional evaluation, and further analysis of the incident is being conducted to ensure that specific concerns and underlying causes are fully considered and addressed.

Conclusions and Opportunities for Improvement

The IRB concluded that there were gaps in work control, emergency response, and other areas identified as deficient that, in certain circumstances, could have contributed to an injury or exposure, delayed an effective emergency response, or resulted in gaps in the investigation of an event. Consequently, the IRB concluded that these deficiencies warrant timely management attention and appropriate corrective actions. Based on its findings, the IRB identified a number of opportunities for improvement, including the following.

- Perform comprehensive extent-of-condition reviews for the deficiencies identified by the IRB and SPR line management to ensure that activities at SPR can be performed safely.
- Ensure that members of the tank cleaning crew understand applicable health and safety requirements and the need for strict compliance.
- Evaluate and resolve deficiencies in communicating requirements to workers.
- Evaluate and enhance emergency response processes applicable to the Bryan Mound Site and to other potentially hazardous projects.
- Improve oversight programs, including oversight of tank cleaning activities.
- Add industrial hygiene expertise to oversee hazard analysis and controls associated with tank cleaning activities.
- Establish an industrial hygiene program at SPR.
- Maintain a cadre of safety specialists who can be temporarily located at sites commensurate with the risks of the work being performed.

More detailed information is available in the IRB report and the DOE-HQ Addendum, which can be accessed at http://www.hss.doe.gov/sesa/corporatesafety/aip/docs/accidents/typea/SPR_Fatality_Review_Report_FINAL_Rev_2.pdf and http://www.hss.doe.gov/sesa/corporatesafety/aip/docs/accidents/typea/SPR_6-2-11_signed.pdf.

KEYWORDS: Independent Review Board, IRB, storage tank, confined space, air line, couplings, fatality, poor lighting, communications, emergency management, oversight, heat stress, air quality, industrial hygiene

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

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