Operating Experience Summary

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1 Heat Exchanger Rupture at Goodyear Plant Results in Injuries and a Fatality

The following article provides a summary of the Chemical Safety Board's investigation into a rupture of a pressure vessel in a heat exchanger at the Goodyear Tire and Rubber Plant in Houston, Texas, in June 2008. As a result of this event, one worker died, five workers suffered ammonia exposure injuries, and another worker was injured. Identified causes included procedures, communications, and emergency response preparedness and response. Similar problems, including during shift turnovers, have been seen at Department of Energy (DOE) sites, so the information below should be useful for DOE facilities Complex-wide.

After reading the article, we encourage you to visit the Operating Experience Summary *Blog at http://oesummary.wordpress.com and rate the article in terms of value to you and provide a comment on the article and/or identify topics that would be of interest to you for future articles.*

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On June 11, 2008, at the Goodyear Tire and Rubber plant in Houston, Texas, a pressure vessel in a heat exchanger ruptured, hurling debris and spewing anhydrous ammonia into an active process area. As a result of the rupture, five workers suffered ammonia exposure injuries, and a sixth worker was injured as he tried to escape the area. Hours after an "all clear" was issued, a supervisor found the body of an emergency response team member, who died when she was struck by debris. Figure 1-1 shows some of the damage caused by the accident, and Figure 1-2 shows the area where the supervisor discovered the fatally injured emergency response team member.

Figure 1-1. Damage caused by the rupture

Figure 1-2. Area where the fatality was discovered

The Chemical Safety Investigation Board (CSB) investigated the accident and issued a final report in January 2011. The CSB report is available at http://www.csb.gov/assets/document/Case_Study.pdf?idevd=3273EF46CAE811DD8ECCD75256D89593&idevm=83413cad33334b2d808c3a8247757be0&idevmid=402969.

Anhydrous Ammonia

Anhydrous ammonia, a commonly used industrial coolant, is a colorless, toxic, and flammable vapor at room temperatures. It has a pungent odor and is hazardous when inhaled, ingested, or when in contact with eyes and skin.

Ammonia vapor is an eye and respiratory system irritant that compromises breathing.

In liquefied form, ammonia causes frostbite on contact.

The Event

When making synthetic rubber, pressurized anhydrous ammonia is frequently used as a chemical coolant, flowing through tubes around a cylindrical steel shell where chemicals are processed.

On the day before the accident, operators replacing a burst rupture disk closed an isolation valve between the heat exchanger shell and an overpressure relief valve; however, they did not re-open the valve as the procedure specified. Figure 1-3 shows the heat exchanger configuration and the valve locations.

On the morning of June 11, a dayshift operator began steam-cleaning the process piping. He was unaware that the isolation valve was still closed because that information had not been properly communicated at shift turnover, so he closed a block valve, inadvertently isolating the ammonia side of the heat exchanger from overpressure protection. When the operator connected the steam line to the process line, steam flowing through the heat exchanger increased ammonia temperature and pressure in the isolated heat exchanger, and internal pressure increased until the heat exchanger ruptured.

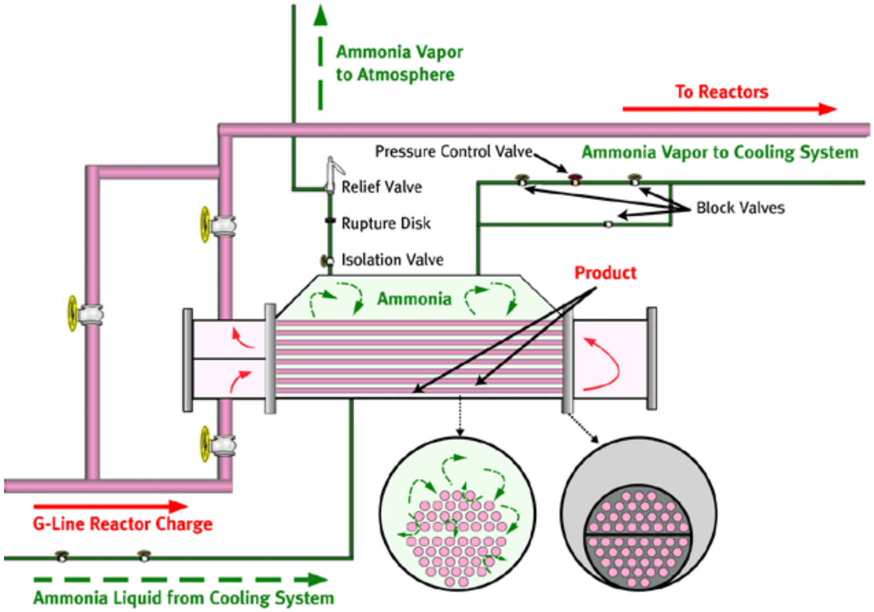

Figure 1-3. Heat exchanger configuration showing the valve locations

Post-Accident Events

Facility procedures required supervisors to account for their employees following an evacuation using a master list generated from a computerized electronic badge-in/badge-out system. However, a system malfunction delayed production of the personnel lists. Instead, supervisors developed handwritten lists as they identified workers who congregated at the muster points or sheltered in place. As a result, plant management erroneously believed that all workers had been accounted for and had safely evacuated. They issued an "all clear," and workers returned to all work areas except for the accident scene. Several hours after the all clear was issued, an operations supervisor, assessing the damage in the accident area, discovered the fatally injured worker, buried in debris, in a dimly lit area next to the heat exchanger.

Findings

CSB investigators identified violations of overpressure protection requirements, insufficient communication, and inadequate maintenance documentation and procedures as causal factors in this accident. They also identified the following deficiencies in Goodyear's emergency preparedness and response.

- **Failure to Follow Procedures/Insufficient Communication**
  Although work order procedures required a signature from production operators, both before work began and after it had been completed, maintenance personnel did not always obtain those signatures as required. In addition, work order documentation was not kept at the production control stations. Operators used the lockout/tagout procedures to manage the work on the heat exchanger rupture disk, but they did not clearly document the maintenance progress and status when replacing the rupture disc valve. As stated earlier, the operators who replaced the burst rupture disk failed to open the isolation valve between the heat exchanger shell and the overpressure relief valve as the procedure required. In addition, communication between the work groups was insufficient, since there was only a handwritten note on the work order to indicate that the isolation valve on the safety relief vent remained in the closed position (locked out) following the maintenance. Goodyear was unable to produce a signed copy of the work order for the work activities of June 10.

- **Inadequate Procedures**
  Occupational Safety and Health Administration (OSHA) regulations in Title 29 of the Code of Federal Regulations (29 CFR), Section 1910.119, *Process Safety Management Standard*, required the use of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII (ASME Code), for operations at the Goodyear plant. However, plant maintenance procedures did not address overpressurization when the relief line was blocked and did not require posting a worker at the vessel to open the isolation valve if the pressure increased above the operating limit, both of which are required by the ASME Code. Investigators also determined that inadequate lockout/tagout procedures were an ongoing concern at the Goodyear plant.

> ASME Code requires that when a pressure vessel relief device is temporarily blocked and there is a possibility of vessel pressurization above the design limit, a worker capable of releasing the pressure must continuously monitor the vessel.

- **Deficiencies in Emergency Preparedness and Response**
  Although Goodyear procedures required plant-wide evacuation and shelter-in-place drills at least four times a year, workers told investigators that no drills had been conducted in 4 years. Plant standard operating procedures also required clearly identified emergency muster points for both partial and plant-wide evacuations, but investigators determined that some workers did not understand these procedures. Some workers told investigators that they were not immediately notified of the vessel rupture and ammonia release, but learned of the accident only by radio or word-of-mouth. Although Goodyear had installed a plant-wide alarm system, a number of workers told investigators that the system was unreliable. In addition, investigators learned that the emergency alert system included location-specific alarm pull-boxes throughout the production unit areas, but the ammonia release and the automatic water deluge system prevented responders from accessing the pull-boxes in the rupture area.

Similar Events

A similar event occurred on January 23, 2009, at the Rye House Power Station, north of London, England, where two workers sustained serious burns when they were engulfed by hot condensate while repairing a leaking check valve on a high-pressure recirculation pump for a heat recovery boiler. The most severely burned worker was trapped against a scaffold 10 feet above the ground and unable to escape. A third worker, who was attempting to help the others, was also badly burned. As was the case in the Goodyear accident, work at the Rye House Power Station began on one shift and concluded on another. Investigators determined that information about drainage schedules and the status of the discharge lines was not adequately communicated during shift turnover. This event was detailed in OE Summary 2009-08, which can be accessed at http://www.hss.doe.gov/sesa/analysis/oesummary/oesummary2009/OES_2009-08.pdf.

A similar event at the Savannah River Site (SRS) on August 17, 2007, also involved miscommunication between shifts. Workers loosened a connection before evacuating and backfilling a line, resulting in a tritium release inside a glovebox. Investigators determined that the workers misunderstood the status given during shift turnover. Miscommunication between a manager and a control room operator led to the manager initialing three critical steps in the process as "completed" without verifying whether the steps had actually been performed. (ORPS Report NA--SRSO-WSRC-TRIT-2007-0006; final report issued October 4, 2007)

DOE Directives

DOE Order 422.1, *Conduct of Operations*, requires thorough, accurate transfer of information and responsibilities at shift or operator relief, including "the turnover of equipment/facility status, duties, and responsibilities that results in the safe and effective transfer of equipment status and in-progress or planned activities from one shift or workgroup to the next." In addition, DOE Standard 1038-93, *Guide to Good Practices for Operations Turnover*, states that during shift turnover "a discussion of all information concerning the work station must be accomplished, and the oncoming and off-going personnel must be confident that an appropriate information exchange has taken place prior to transferring responsibility." Section 4, "Good Practices," of the Standard discusses the information that should be provided in turnover checklists (e.g., equipment problems; maintenance, testing, and evolution status; and any documents to be reviewed). A sample turnover checklist is included in Appendix B of the Standard. The Standard can be accessed at http://www.hss.doe.gov/nuclearsafety/ns/techstds/docs/standard/s1038cn1.pdf.

Rules for pressure vessel design, use, and maintenance are found in American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section VIII (the ASME Code). Part 9 of the Code is applicable to overpressure protection.

Recommendations

This event demonstrates the importance of effective communications during shift turnover and the need to provide the follow-on shift with formal, written turnover documents that detail the status of operations. It also demonstrates the need for thorough and accurate procedures that address all aspects of the job, including emergency response.

It is important to encourage a worker mindset that the job is not finished until the last step—formal paperwork *verifying* that the task has been completed—is completed. It is also important that employees, who are assigned to perform a work task that spans more than one shift, understand the additional hazards that such work entails and confirm that those hazards have been controlled. Workers should always verify that the work order is understood and that any handwritten annotations receive special scrutiny.

When work is running smoothly, it is difficult to imagine a time when it will not, but emergencies can occur at any time. All workers should understand their roles and responsibilities in the event of an emergency and should be trained and current in emergency response procedures. Managers should conduct worker headcount drills that implement emergency response plans on a facility-wide basis. In addition, in case key personnel are absent or automated systems fail, operating procedures should include plans for redundancy in accounting for workers to ensure that all workers can be quickly accounted for during an emergency. Drills that simulate tracking system malfunctions should be conducted to ensure that alternate verification techniques will account for workers in a real situation. Conducting both scheduled periodic reviews and unscheduled reviews of alert procedures, processes, and responsibilities is also important for ensuring the workforce is prepared for emergency situations.

Periodic reviews should include identifying plant layout deficiencies and factoring them into site and facility hazard analysis plans. As the Goodyear accident demonstrates, manually-activated emergency alarms should be strategically located so they are accessible regardless of where an accident occurs.

KEYWORDS: Goodyear Tire and Rubber, Chemical Safety Board, CSB, heat exchanger rupture, pressure vessel, anhydrous ammonia, overpressure, evacuation, shift turnover, emergency response, injuries, fatality, procedures, communication, conduct of operations

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

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