Environment, Safety and Health Advisory

Explosion and Fire at Texas Chemical Plant Result from Faulty Welds

DOE/EH-0699 2006-03 June 2006

***Special Operations Reports** are issued to initiate management actions in response to events whose subject matter represents significant Departmental safety concerns.*

***Environment, Safety and Health Alerts** are issued to initiate immediate action on potentially significant safety issues.*

***Environment, Safety and Health Bulletins** are issued to share information and recommend actions on potential safety issues.*

***Safety Advisories** are issued to provide information to the DOE Complex on potentially significant safety or health issues.*

PURPOSE

The Office of Environment, Safety and Health is issuing this Environment, Safety and Health Advisory to provide external operating experience regarding an explosion and fire that occurred at the Marcus Oil facility in Houston, Texas in December 2004. Investigators determined that the explosion resulted from faulty welds in a steel process pressure vessel.

DISCUSSION

In its final investigation report on the explosion, the U.S. Chemical Safety Board (CSB) describes the violent explosion of a 50,000-pound steel pressure vessel at the Marcus Oil and Chemical facility. The explosion was felt over a wide area in Houston and ignited a fire that burned for seven hours. Several residents were cut by flying glass, and steel fragments from the explosion were thrown up to a quarter-mile from the plant. Building and car windows were shattered, and nearby buildings experienced significant structural and interior damage.

The Marcus Oil facility refines polyethylene waxes for industrial use. The crude waxes, which are obtained as a byproduct from the petrochemical industry, contain flammable hydrocarbons such as hexane. The waxes are processed and purified inside a variety of steel process vessels. The vessel that exploded was a horizontal tank 12 feet in diameter, 50 feet long, and operated at a pressure of approximately 67 pounds per square inch.

The case study report and accompanying safety recommendations have been posted to the CSB web site (http://www.csb.gov).

WELDING ISSUES

CSB investigators determined that the failed vessel, known as Tank 7, had been modified by Marcus Oil to install internal heating coils, as were several other pressure vessels at the facility. Following coil installation, each vessel was resealed by welding a steel plate over the 2-foot-diameter temporary opening. The repair welds did not meet accepted industry quality standards for pressure vessels. Marcus Oil did not use a qualified welder or proper welding procedure to reseal the vessels and did not pressure-test the vessels after the welding was completed.

The weld used to close the temporary opening on Tank 7 failed during the incident because the repair weld (Figure 1) did not meet generally accepted industry quality standards for pressure vessel fabrication. The original, flame-cut surface was not ground off the plate edges before the joint was re-welded, and the weld did not penetrate the full thickness of the vessel head. Furthermore, the welds contained excessive porosity (holes from gas bubbles in the weld). These defects significantly degraded the strength of the weld.

Marcus Oil did not use a qualified welder or proper welding procedure to re-weld the plate on the vessel heads and install the steam pipe nozzles in the shells.

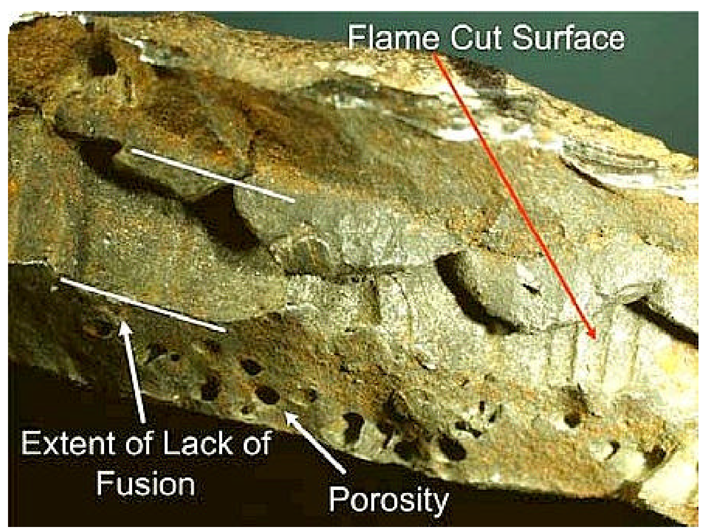

Figure 1. Recovered patch plate weld from failed Tank 7

The CSB estimated that the defective welds had decreased the strength of the vessels by more than 75 percent. It is likely that the welds were further weakened by metal fatigue from hundreds of operating cycles over many years. The weld on Tank 7 finally failed catastrophically during a routine production run.

Design Issues – Relief Valves

The CSB found that Tanks 5, 6, 7, and 8, the nitrogen storage vessels, and the compressed-air storage vessel were not equipped with pressure-relief devices, as required by the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. However, this was not a factor in causing the incident.

Process Changes

Marcus Oil installed a connection between the nitrogen and compressed-air systems to provide rapid pressurization of the nitrogen system when the nitrogen pressure was too low to move molten wax from the tanks to the process unit. The company assumed that compressed air was an acceptable substitute for nitrogen during processing. However, CSB investigators determined that management did not evaluate the hazards that resulted from this process change. Pressurizing the nitrogen system with compressed air contaminated the nitrogen gas with as much as 18 percent oxygen — a level sufficient to support combustion of the hydrocarbon vapor and wax inside the tanks.

Marcus Oil used air instead of nitrogen to boost the pressure of the vessel, and the oxygen inside the tank allowed the ignition of the flammable material, most likely by sparks from the metal fragments. The fire spread back into the damaged tank and caused a violent explosion, which propelled the 25-ton vessel more than 150 feet, where it came to rest against a warehouse on an adjacent property (Figure 2). CSB investigators later found a variety of large metal fragments in the surrounding community, including a 120-pound steel plate located in a field 900 feet away.

Figure 2. The scene following the explosion

Pressure Vessel Codes

The CSB report pointed out that Texas is one of 11 states that have not adopted national safety standards for pressure vessels.

The ASME Boiler and Pressure Vessel Code provides rules for pressure vessel design, fabrication, weld procedures, welder qualifications, and pressure testing. In addition, the National Board of Boiler and Pressure Vessel Inspectors has established the National Board Inspection Code for pressure vessel repairs and alterations. However, Texas is one of 17 states that do not require adherence to the National Board Inspection Code. The code requires alterations to pressure vessels to be inspected, tested, certified, and stamped.

"If the provisions of internationally recognized pressure vessel safety codes had been required and enforced, this accident would almost certainly not have occurred," CSB Board Member John S. Bresland said. "Pressure vessels potentially contain huge amounts of stored energy, and if they fail they can pose a grave danger to lives and property, as clearly demonstrated by the accident at Marcus Oil. The presence of unregulated, uninspected, and improperly maintained pressure vessels within an urban area like Houston is a serious concern."

The Board called on the City of Houston to expand the current building ordinance to require mandatory compliance with the ASME Code for all new pressure vessels and with the National Board Inspection Code for all pressure vessel repairs and alterations. The Board separately recommended that Marcus Oil repair all modified pressure vessels to conform to the National Board Inspection Code requirements, install relief devices on all pressure vessels, and keep air from contaminating its nitrogen supply to prevent fires.

Implications

The incident at the Marcus Oil facility underscores the importance of compliance with pressure vessel and inspection codes and the use of qualified welders. Equally important is understanding the potential hazards introduced with process changes.

Acknowledgement

Richard Higgins of CH2M Hill Hanford Group, Inc. is the principal author of this Advisory.

Questions regarding this Environment, Safety and Health Advisory should be directed to Tom Williams of the Office of Corporate Performance Assessment (EH-3) by telephone at 301-903-4859 or by e-mail at thomas.e.williams@eh.doe.gov.

PREVENT EVENTS
Learning from Industry Experience

PREVENT EVENTS is intended for use by personnel during morning meetings, pre-job briefings, and work unit meetings to communicate key industry experience.

Management

1. Do we have any inerting systems? If so, do these inerting systems provide an oxygen-deficient gas that is unable to support combustion?
2. Do our engineering and operating procedures ensure inerting systems are never connected to any system that can contaminate the inerting gas with oxygen?
3. Are all our pressure vessels operated above 15 psig equipped with a correctly sized and certified pressure relief device, as required by the ASME Boiler and Pressure Vessel Code?

Maintenance

1. Do our maintenance processes ensure any repairs or alterations we make are performed only by qualified personnel in accordance with a generally recognized and accepted good practice such as the ASME Boiler and Pressure Vessel Code and the National Board Inspection Code (NB-23)?
2. Do we maintain a list of our code-stamped vessels?

Procurement

1. Do our procurement processes ensure that any pressure vessels purchased are designed and constructed only by qualified personnel in accordance with a generally recognized and accepted good practice such as the ASME Boiler and Pressure Vessel Code and the National Board Inspection Code (NB-23)?
2. Do our procurement processes ensure that any repairs or alteration services purchased under contract are performed only by qualified personnel in accordance with a generally recognized and accepted good practice such as the ASME Boiler and Pressure Vessel Code and the National Board Inspection Code (NB-23)?

Training

1. Are operators and maintenance personnel trained on the hazards of adding air to inerting systems?

Individual Worker

1. Do I work with any inerting systems? If so, do I know the system limits? Are there any cross-ties where valving or temporary connections could allow oxygen into the system?
2. Do I know where the pressure relief devices are on my systems? Do I know what to do if a pressure relief device activates during operation?
3. Do I know what to do if I lose pressure in an inerting system?