REFINERY FIRE INCIDENT:
A CASE STUDY OF A MULTIPLE FATALITY INCIDENT AT THE TOSCO AVON REFINERY, MARTINEZ, CALIFORNIA[1]

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On February 23, 1999, a fire occurred at the Tosco Avon Refinery in Martinez, California. Workers were attempting to replace piping attached to a 150-foot-tall crude fractionator while the process unit was in operation. The piping, which had developed a pinhole leak, contained flammable naphtha liquid that was not successfully drained or isolated during the thirteen-day period before the removal work began. During the removal of the piping, naphtha was released onto the hot fractionator tower where it ignited. Four workers were killed and one sustained serious injuries. The U.S. Chemical Safety and Hazard Investigation Board (CSB) initiated an incident investigation.

The CSB examined the following safety issues in the Tosco case:

1. Control of hazardous nonroutine maintenance
2. Management oversight and accountability
3. Management of change
4. Corrosion control program

This paper summarizes the results of the investigation, including a review of the incident, causes identified by CSB, and recommendations to prevent future similar incidents.

Keywords: oversight and accountability, management of change, corrosion, maintenance.

INTRODUCTION

On February 23, 1999, a fire occurred in the crude unit at Tosco Corporation's Avon oil refinery in Martinez, California. Workers were attempting to replace piping attached to a 150-foot-tall fractionator[2] tower while the process unit was in operation. During removal of the piping, naphtha[3] was released onto the hot fractionator and ignited. The flames engulfed five workers located at different heights on the tower. Four men were killed, and one sustained serious injuries.

Ultramar Diamond Shamrock Corporation (UDS) purchased the facility in September 2000 and renamed it the Golden Eagle refinery.

Because of the serious nature of this incident, and the fact that another fatality had occurred at the Avon facility in 1997, the U.S. Chemical Safety and Hazard Investigation Board (CSB) initiated an investigation to determine the root and contributing causes of the incident and to issue recommendations to help prevent similar occurrences.

INCIDENT

On February 10, 1999, a pinhole leak was discovered in the crude unit on the inside of the top elbow of the naphtha piping, near where it was attached to the fractionator (Figure 1) at 112 feet above grade.[4] Tosco personnel responded immediately, closing four valves in an attempt to isolate the piping. The unit remained in operation.

Subsequent inspection of the naphtha piping showed that it was extensively thinned and corroded. A decision was made to replace a large section of the naphtha line.[5] Over the 13 days between the discovery of the leak and the fire, workers made numerous unsuccessful

attempts to isolate and drain the naphtha piping. The pinhole leak reoccurred three times, and the isolation valves were retightened in unsuccessful efforts to isolate the piping. Nonetheless, Tosco supervisors proceeded with scheduling the line replacement while the unit was in operation.

On the day of the incident, the piping contained approximately 90 gallons of naphtha, which was being pressurized from the running process unit through a leaking isolation valve. A work permit authorized maintenance employees to drain and remove the piping. After several unsuccessful attempts to drain the line, a Tosco maintenance supervisor directed workers to make two cuts into the piping using a pneumatic saw[6]. After a second cut began to leak naphtha, the supervisor directed the workers to open a flange[7] to drain the line. As the line was being drained, naphtha was suddenly released from the open end of the piping that had been cut first. The naphtha ignited, most likely from contacting the nearby hot surfaces of the fractionator, and quickly engulfed the tower structure and personnel.

KEY FINDINGS

1. The removal of the naphtha piping with the process unit in operation involved significant hazards. This nonroutine[8] work required removing 100 feet of 6-inch pipe containing naphtha, a highly flammable liquid. Workers conducting the removal were positioned as high as 112 feet above ground, with limited means of escape. The hot process unit provided multiple sources of ignition, some as close as 3 feet from the pipe removal work. One isolation valve could not be fully closed, which indicated possible plugging.

   On three occasions prior to the incident, the naphtha pipe resumed leaking from the original pinhole and felt warm to the touch, indicating that one or more isolation valves were leaking. Numerous attempts to drain the piping were unsuccessful; a failed attempt to ream out the drain lines and the removal of a small section of pipe confirmed that the line was extensively plugged. On seven occasions, the downstream naphtha stripper vessel filled–indicating probable isolation valve leakage.

2. The naphtha pipe that was cut open during the repair work was known by workers and the maintenance supervisor to contain flammable liquid. Although Tosco procedures required piping to be drained, depressured, and flushed prior to opening[9] this was not accomplished because extensive plugging prevented removal of the naphtha. The procedures did not specify an alternative course of action if safety preconditions, such as draining, could not be met. Although the hot process equipment was close to the removal work, Tosco's procedures and safe work permit did not identify ignition sources as a potential hazard. The permit also failed to identify the presence of hazardous amounts of benzene in the naphtha.

3. The naphtha stripper vessel level control bypass valve was leaking, which prevented isolation of the line from the operating process unit. As a result, the running unit pressurized the naphtha piping. Excessive levels of corrosive material and water in the naphtha line and operation of the bypass valve in the partially open position for prolonged periods led to erosion/corrosion of the valve seat and disk. Excessive levels of corrosives and water also plugged the piping and led to the initial leak.

4. Tosco's job planning procedures did not require a formal evaluation of the hazards of replacing the naphtha piping. The pipe repair work was classified as low risk maintenance. Despite serious hazards caused by the inability to drain and isolate the

line–known to supervisors and workers during the week prior to the incident–the low risk classification was not reevaluated, nor did management formulate a plan to control the known hazards.

5. Tosco's permit for the hazardous nonroutine work was authorized solely by a unit operator on the day of the incident. Operations supervisors were not involved in inspecting the job site or reviewing the permit.

6. Operations supervisors and refinery safety personnel were seldom present in the unit to oversee work activities. On the morning of the incident, prior to the fire, one operations supervisor briefly visited the unit, but he did not oversee the work in progress and no safety personnel visited the unit. The maintenance supervisor was the only management representative present during the piping removal work.

The U.S. Environmental Protection Agency (EPA) similarly determined that a lack of operations supervisory oversight during safety critical activities was one of the causes of a previous Avon refinery incident, a 1997 explosion and fire at the hydrocracker, which resulted in one fatality (USEPA, 1998; pp. viii, 65). [10]

7. In the 3 years prior to the incident, neither Tosco's corporate safety group nor Avon facility management conducted documented audits of the refinery's line breaking,[11] lockout/tagout,[12]or blinding[13] procedures and practices.

8. Tosco did not perform a management of change (MOC)[14] review to examine potential hazards related to process changes, including operating the crude desalter[15] beyond its design parameters, excessive water in the crude feedstock,[16] and prolonged operation of the bypass valve in the partially open position. Tosco memos and incident reports revealed that management recognized these operational problems and the increased rate of corrosion. However, corrective actions were not implemented in time to prevent plugging and excessive corrosion in the naphtha piping.

ROOT CAUSES

1. **Tosco Avon refinery's maintenance management system did not recognize or control serious hazards posed by performing nonroutine repair work while the crude processing unit remained in operation.**

   - Tosco Avon management did not recognize the hazards presented by sources of ignition, valve leakage, line plugging, and inability to drain the naphtha piping. Management did not conduct a hazard evaluation[17] of the piping repair during the job planning stage. This allowed the execution of the job without proper control of hazards.

   - Management did not have a planning and authorization process to ensure that the job received appropriate management and safety personnel review and approval. The involvement of a multidisciplinary team in job planning and execution, along with the participation of higher level management, would have likely ensured that the process unit was shut down to safely make repairs once it was known that the naphtha piping could not be drained or isolated.

   - Tosco did not ensure that supervisory and safety personnel maintained a sufficient presence in the unit during the execution of this job. Tosco's reliance on individual workers to detect and stop unsafe work was an ineffective substitute for management oversight of hazardous work activities.

   - Tosco's procedures and work permit program did not require that sources of ignition be controlled prior to opening equipment that might contain flammables, nor did it specify what actions should be taken when safety requirements such as draining could not be accomplished.

2. **Tosco's safety management oversight system did not detect or correct serious deficiencies in the execution of maintenance and review of process changes at its Avon refinery.**

   Neither the parent Tosco Corporation nor the Avon facility management audited the refinery's line breaking, lockout/tagout, or blinding procedures in the 3 years prior to the incident. Periodic audits would have likely detected and corrected the pattern of serious deviations from safe work practices governing repair work and operational changes in process units. These deviations included practices such as:

   - Opening of piping containing flammable liquids prior to draining
   - Transfer of flammable liquids to open containers
   - Inconsistent use of blind lists
   - Lack of supervisory oversight of hazardous work activities
   - Inconsistent use of MOC reviews for process changes.

CONTRIBUTING CAUSES

1. **Tosco Avon refinery management did not conduct an MOC review of operational changes that led to excessive corrosion rates in the naphtha piping.**

   Management did not consider the safety implications of process changes prior to their implementation, such as:

   - Running the crude desalter beyond its design parameters.
   - Excessive water in the crude feed.

- Prolonged operation of the naphtha stripper level control bypass valve in the partially open position.

These changes led to excessive corrosion rates in the naphtha piping and bypass valve, which prevented isolation and draining of the naphtha pipe.

2. The crude unit corrosion control program was inadequate.

Although Avon refinery management was aware that operational problems would increase corrosion rates in the naphtha line, they did not take timely corrective actions to prevent plugging and excessive corrosion in the piping.

RECOMMENDATIONS

Tosco Corporation:

Conduct periodic safety audits of your oil refinery facilities in light of the findings of this report. At a minimum, ensure that:

- Audits assess the following:
  - Safe conduct of hazardous nonroutine maintenance
  - Management oversight and accountability for safety
  - Management of change program
  - Corrosion control program.

- Audits are documented in a written report that contains findings and recommendations and is shared with the workforce at the facility.

- Audit recommendations are tracked and implemented.

Ultramar Diamond Shamrock Golden Eagle Refinery

1. Implement a program to ensure the safe conduct of hazardous nonroutine maintenance. At a minimum, require that:
   - A written hazard evaluation is performed by a multidisciplinary team and, where feasible, conducted during the job planning process prior to the day of job execution.
   - Work authorizations for jobs with higher levels of hazards receive higher levels of management review, approval, and oversight.
   - A written decision-making protocol is used to determine when it is necessary to shut down a process unit to safely conduct repairs.
   - Management and safety personnel are present at the job site at a frequency sufficient to ensure the safe conduct of work.
   - Procedures and permits identify the specific hazards present and specify a course of action to be taken if safety requirements–such as controlling ignition sources, draining flammables, and verifying isolation–are not met.
   - The program is periodically audited, generates written findings and recommendations, and implements corrective actions.

2. Ensure that MOC reviews are conducted for changes in operating conditions, such as altering feedstock composition, increasing process unit throughput, or prolonged diversion of process flow through manual bypass valves.
3. Ensure that your corrosion management program effectively controls corrosion rates prior to the loss of containment or plugging of process equipment, which may affect safety.

American Petroleum Institute (API)
Paper, Allied-Industrial, Chemical & Energy Workers International Union (PACE)
National Petrochemical & Refiners Association (NPRA)

Communicate the findings of this report to your membership.

REFERENCES

[1] This paper is the Executive Summary of the U.S. Chemical Safety and Hazard Investigation Board's Investigation Report of the February 23, 1999, Tosco Avon Refinery fire incident (Report No. 99-014-I-CA, Issue Date: March 2001). The full report is available on the World Wide Web at http://www.chemsafety.gov/.
[2] A fractionator is an oil refinery processing vessel that separates preheated hydrocarbon mixtures into various components based on boiling point. The separated components are referred to as fractions or cuts. Inside the fractionator, some trays draw off the fractions as liquid hydrocarbon products (such as naphtha), and piping transports them to storage or for further processing.
[3] Petroleum naphtha is a highly flammable mixture of liquid hydrocarbons drawn off as a cut from the fractionator tower.
[4] "Above grade" refers to the vertical distance from ground level at the point upon which equipment rests.
[5] The term "naphtha line" is synonymous with naphtha piping. "Naphtha draw line" was also used at the facility to refer to the naphtha piping. The draw line takes or "draws" naphtha product from the 38th tray of the fractionator, where it flows through a level control valve to the naphtha stripper vessel.
[6] A pneumatic saw is a cutting device that is energized by air pressure rather than electrical energy
[7] A flange is a rim on the end of a section of piping or equipment used for attachment to other piping and equipment.
[8]The Center for Chemical Process Safety (CCPS) defines "nonroutine work" as unscheduled maintenance work that necessitates immediate repair and may introduce additional hazards (CCPS, 1995b; p. 212). One example is "breakdown maintenance," where equipment is operated until it fails. In this incident, the February 10 naphtha draw line leak is an example of breakdown maintenance.
[9]Tosco Avon Safety Procedure S-5, Safety Orders, Departmental Safe Work Permits, October 19, 1998.
[10] The EPA report states: "Supervision was not present at the unit even though there had been a succession of operating problems just prior to the final temperature excursion that led to the explosion and fire."
[11]" Line breaking" refers to equipment opening.
[12]" Lockout/tagout" refers to a program to control hazardous energy during the servicing and maintenance of machinery and equipment. Lockout refers to the placement of a locking mechanism on an energy isolating device, such as a valve, so that the equipment cannot be operated until the mechanism is removed. Tagout refers to the secure placement of a tag on an energy-isolating device to indicate that the equipment cannot be operated until the tag is removed.
[13] A blind is a piping component consisting of a solid metal plate inserted to secure isolation.
[14] Management of change is a systematic method for reviewing the safety implications of modifications to process facilities, process material, organizations, and standard operating practices.
[15] The desalter vessel removes inorganic salts, water, and suspended solids to reduce corrosion, plugging, and fouling of piping and equipment.
[16] Feedstock is material of varying constituents that is processed in a refinery.
[17] A hazard evaluation is a formal analytical tool used to identify and examine potential hazards connected with a process or activity (CCPS, 1992; p. 7).

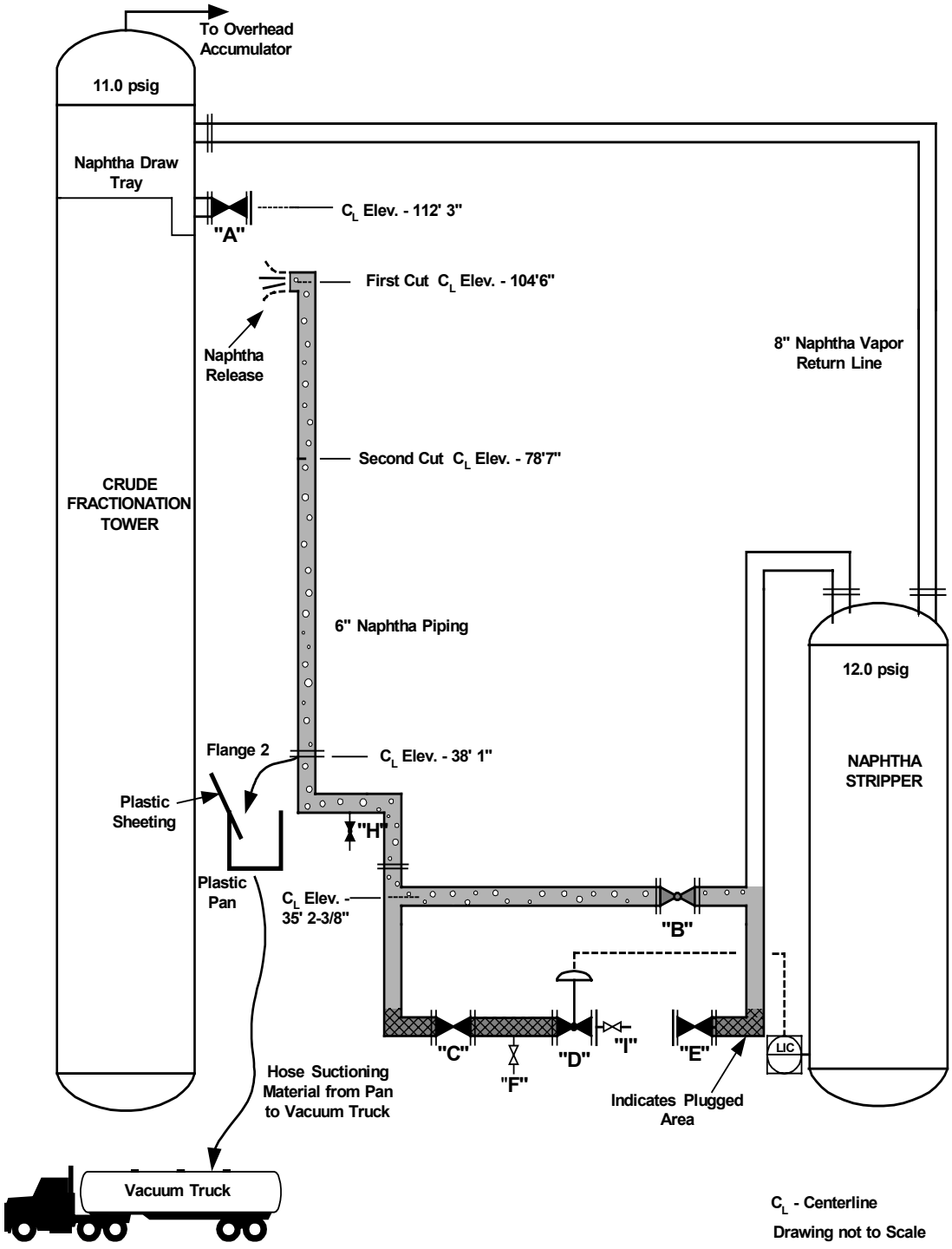
To Overhead Accumulator
11.0 psig
Naphtha Draw Tray
C_L Elev. - 112' 3"
"A"
First Cut C_L Elev. - 104'6"
Naphtha Release
8" Naphtha Vapor Return Line
Second Cut C_L Elev. - 78'7"
CRUDE FRACTIONATION TOWER
6" Naphtha Piping
12.0 psig
NAPHTHA STRIPPER
Flange 2
C_L Elev. - 38' 1"
Plastic Sheeting
"H"
Plastic Pan
C_L Elev. - 35' 2-3/8"
"B"
"C"
"F"
"D"
"I"
"E"
LIC
Hose Suctioning Material from Pan to Vacuum Truck
Indicates Plugged Area
Vacuum Truck
C_L - Centerline
Drawing not to Scale

Figure 1