

CASE STUDY

Fire at Formosa Plastics Corporation: Evaluating Process Hazards



2006-01-I-TX



Introduction

This case study describes a fire and series of explosions in an olefins production unit located in Point Comfort, Texas. Sixteen employees were injured, one seriously. A shelter-in-place order was issued for the Point Comfort community, and the local elementary school was evacuated. The fire burned for 5 days. CSB makes recommendations to Formosa Plastics Corporation; Kellogg, Brown, and Root; and the Center for Chemical Process Safety.

Formosa Plastics Corporation

Point Comfort, Texas
October 6, 2005

Key Issues:

- Hazard Reviews
- Flame Resistant Clothing
- Use of Current Standards

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1.0 Incident Description

This case study examines a hydrocarbon release and subsequent fire and explosions that occurred in the Olefins II unit at the Formosa Plastics Corporation, USA, (Formosa) Point Comfort, TX, complex.¹ At about 3:05 PM on October 6, 2005, a trailer being towed by a forklift snagged and pulled a small drain valve out of a strainer in a liquid propylene system. Escaping propylene rapidly vaporized, forming a large flammable vapor cloud.

Operators immediately began to shut the plant down and attempt to isolate the leak. They tried to reach and close manual valves that could stop the release; however, the advancing vapor cloud forced them to retreat. At the same time, control room operators shut off pumps, closed control valves, and vented equipment to the flare stack to direct flammable gases away from the fire.

At about 3:07 PM, the vapor ignited, creating an explosion.² The explosion knocked down several and burned two (one seriously) operators exiting the unit. Flames from the fire reached more than 500 feet in the air (Figure 1).

Because of the size of the fire, Formosa initiated a site-wide evacuation. Fourteen workers sustained minor injuries including scrapes and smoke inhalation. The extensive damage shut down Olefins II unit for 5 months.



Picture courtesy of Bill Harvey

Figure 1. Point Comfort fire.

1.1 Plant Emergency Response

Formosa's Point Comfort complex has a large trained and equipped Emergency Response Team (ERT) that includes 120 members and two fire trucks. On the day of the incident, two of the off-shift crews were on site for training; as a result, 90 trained emergency responders were immediately available. Firefighters from the surrounding communities also supplemented the Formosa ERT by providing and staffing a fire fighter health monitoring station.

The Formosa emergency response strategy was to prevent the fire from spreading to other units and to isolate fuel sources where possible. Ultimately, the fires burned for five days and about seven million gallons of water were used to cool vessels and contain the fire.

¹ The CSB previously investigated an unrelated incident at Formosa Plastics Corporation Illiopolis, Illinois which killed five and injured three.

² The explosion could be characterized as an unconfined low-speed deflagration

1.2 Community Response

Within minutes of the initial explosion, local officials ordered a shelter-in-place for the Point Comfort community and closed Highway 35 that runs adjacent to the Formosa complex and through Point Comfort (Figure 2). Students and staff at the Point Comfort Elementary School evacuated to Port Lavaca, about five miles away. Local officials rescinded these measures by 9:00 PM that night.

The Red Cross assisted employees and contractors at the Port Lavaca Community Center. More than 20 local residents sought medical evaluation at local hospitals, but none were admitted.



Figure 2. View of the Damaged Plant from Highway 35.

2.0 Formosa Operations

Formosa manufactures plastic resins and petrochemicals at four wholly owned chemical manufacturing subsidiaries in Delaware City, DE; Illiopolis, IL; Baton Rouge, LA; and Point Comfort, TX.

operations in 1983. The complex employs 1400 full-time workers and 400 contractors and covers 1,800 acres. The fire and explosions occurred in the Olefins II unit, one of 17 units at the complex (Figure 3).

2.1 Point Comfort, TX, Complex

The Point Comfort complex, the largest Formosa facility in the United States, began



Picture courtesy of Formosa

Figure 3. Formosa Point Comfort complex.

2.2 Olefins II Unit Operation

The Point Comfort Olefins³ II unit uses furnaces to convert either naphtha,⁴ or natural gas derived feedstock, into a hydrocarbon mixture containing:

- Methane
- Ethane
- Ethylene
- Propane
- Propylene
- Various higher hydrocarbons.

Distillation columns⁵ then separate the hydrocarbon mixture. Some of the separated gases are liquefied and sent to storage, while others are used as fuel for the furnaces or recycled into the feedstock.

Relief valves protect the distillation columns, heat exchangers, and other large vessels in the unit from overpressure. These valves discharge into a flare header system where the hydrocarbon gases can be safely burned.

³ An olefin is unsaturated hydrocarbon, such as ethylene, propylene, or butylene.

⁴ Naphtha is a highly volatile flammable liquid distilled from crude oil.

⁵ A distillation column separates liquids based on differences in their boiling points.

3.0 Incident Analysis

3.1 Incident Sequence

The CSB used physical evidence, electronic data, video recordings, and interviews to establish the likely failure sequence. The events are listed in the order in which they are believed to have occurred, although an exact timeline could not be established:

- A worker driving a fork truck towing a trailer under a pipe rack backed into an opening between two columns to turn around.
- When the worker drove forward, the trailer caught on a valve protruding from a strainer in a propylene piping system.
- The trailer pulled the valve and associated pipe (Figure 4) out of the strainer, leaving a 1.9-inch diameter opening.⁶



Figure 4. Valve and pipe.

- Pressurized liquid propylene (216 psig) rapidly escaped through the opening and

⁶ The valve was attached to a pipe that was threaded into the strainer cover.

partially vaporized creating both a pool of propylene liquid and a rapidly expanding vapor cloud.

- The fork truck driver and other contractors saw the release and evacuated.
- An operator also heard and saw the escaping propylene and immediately notified the control room.
- Control room operators saw the vapor cloud on a closed circuit television and began to shut down the unit.
- Outside operators tried unsuccessfully to reach and close manual valves that could stop the release.
- Outside operators turned on fixed fire monitors.⁷
- Control room operators shut off pumps from the motor control center and closed control valves to slow the leak.
- The vapor cloud ignited.
- Outside operators left the unit.
- Control room operators declared a site-wide emergency.
- Control room operators smelled propylene vapors and evacuated.
- A large pool fire burned under the pipe rack⁸ and the side of an elevated structure that supported a number of vessels, heat exchangers, and relief valves.

⁷ A fire monitor is an unattended device that can direct a spray of water on a fire.

⁸ The pipe rack supports piping, as well as instrument and power cables to and from columns, vessels, pumps, and valves in the unit.

- The Formosa ERT arrived and took command of the incident response (Figure 5).



Figure 5. Formosa ERT equipment.

- About 30 minutes into the event, the side of the elevated structure collapsed, crimping emergency vent lines to the flare header.
- Crimped pipes and steel, softened from fire exposure, led to multiple ruptures of piping and equipment and the loss of integrity of the flare header.
- The Formosa ERT isolated fuel sources where possible, and allowed small fires to burn the uncontained hydrocarbons.
- The fire was extinguished about five days after the start of the incident.

3.2 Vehicle Impact Protection

The propylene piping involved in this incident protruded into an open space, yet had no impact protection (Figure 6).

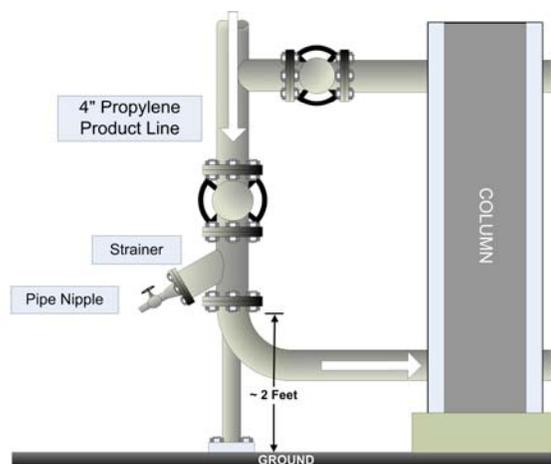


Figure 6. Pipe and valve arrangement.

Formosa has administrative safeguards for vehicle operation in the unit, including a plant-wide speed limit, a vehicle permitting process, and a crane use procedure. However, these safeguards do not specifically address where vehicles may operate within the unit.

The plant design drawings designate specific access ways for vehicles; these are not physically marked in the unit. The area where the impact occurred was not a designated access way but was large enough for a vehicle to easily pass.

Guidance about protecting control stations, pipelines, and other grade-level plant equipment, although not specific, states that protective measures should be in place to prevent impact.

The ASME B31.3 “Process Piping Code” states, “Impact forces caused by external or internal conditions shall be taken into account in the design of piping.”

Loss Prevention in the Process Industries (Lees, 2001) states:

- “Incidents are numerous in which lift trucks are driven into and damage buildings and plant; including process

plant; pipe work is particularly at risk.”

- “Particular attention should be paid to plant layout with specific regard to traffic and impact.”
- “Every precaution should be taken to prevent damage by vehicles, particularly cranes and forklift trucks.”

Safety in Process Plant Design (Wells, 1980) provides a safety checklist that includes “protection of equipment and pipe work from vehicles.”

3.3 Structural Steel Fire Protection

During the fire, part of a structure supporting the relief valves and emergency piping to the flare header collapsed. The collapse caused several pipes to crimp, likely preventing flow through the pipes and leading to the rupture of major equipment and piping that added fuel to the fire.

Passive fire protection (fireproofing⁹) was installed on only three of four support column rows and the columns that supported the pressure relief valves and emergency vent piping had no fireproofing (Figure 7). The bare steel columns bent over, while the fireproofed columns remained straight.



Figure 7. Fireproofed and bare steel support columns.

Formosa contracted M. W. Kellogg (Kellogg) to design the Olefins II unit in 1996. The Olefins II unit is an identical copy of the Olefins I unit, which Formosa contracted Kellogg for in late 1988. Olefins I unit is a nearly identical copy of an ethylene plant that Kellogg sold to another company in the mid 1980s. American Petroleum Institute (API) Publication 2218, “Fireproofing Practices in Petroleum and Petrochemical Processing Plants” (July 1988) recommends that steel supporting important piping such as relief and flare lines be fireproofed. This API publication was issued after Kellogg was contracted for the earlier design; however, the designs sold to Formosa were never updated to incorporate this guidance.

Had the steel been fireproofed as API recommends, the consequences of this incident would likely have been less severe.

⁹ The fireproofing was a concrete coating applied over the steel to insulate it from a fire and slow its failure.

3.4 Remote Equipment Isolation

Figure 8 shows the general arrangement of the piping and valves around the leak point. The leak occurred between manual block valves and a remotely operated control valve. While a check valve and remotely operated isolation valve downstream of the leak prevented the backflow of propylene from product storage, operators were unable to reach the manual valves capable of stopping the flow from the distillation column. The operators were also unable to reach the local control station to turn off the pumps supplying propylene, although they eventually turned off the pumps at the motor control center located in the control room building, slowing the rate of propylene feeding the fire.

Had a remotely actuated valve been installed upstream of the pumps, this incident would likely have ended quickly, possibly even before ignition occurred. Additionally, had

remote control of the pumps been possible from the control room, the propylene flow could have been quickly reduced, potentially reducing the severity of the incident.

Plant designers specify where remote operation of isolation valves and equipment should be used. Kellogg, the designer of Formosa's Olefins II unit, specified remotely actuated valves for raw material supply and final product lines, but only local manual valves pump controls for equipment within the unit that contained large hydrocarbon inventories.

Limited information is available in consensus standards on the degree of isolation designers should incorporate into the design, guidance is available. Kletz (1998) and Health & Safety Executive (HSE) (1999) both recommend that large vessels and columns with hazardous inventories be equipped with a rapid isolation capability.

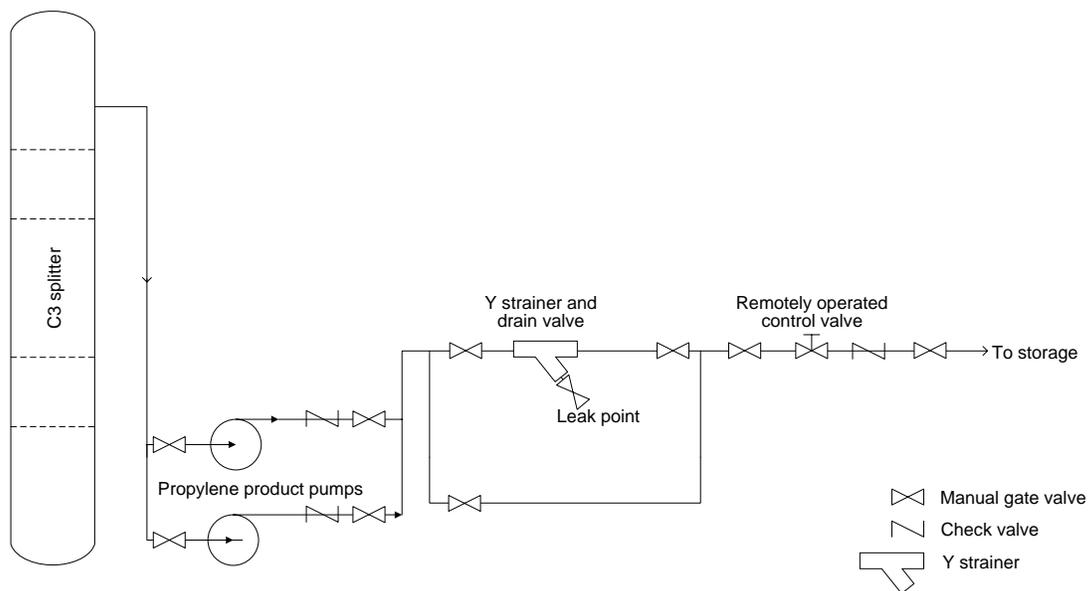


Figure 8. Propylene product flow.

Had Formosa been able to isolate the major hazard inventories in the unit as recommended in industry guidance, the consequences of this incident would likely have been lessened.

3.5 Flame Resistant Clothing

Flame resistant clothing (FRC) can limit the severity of burn injuries to workers in plants where flash fires may result from uncontained flammable liquids and gases. Neither of the two operators burned in this incident was wearing FRC. Had they been, their injuries would likely have been less severe.

The OSHA personal protective equipment standard, 29 CFR 1910.132, requires companies to complete a hazard assessment to determine the protective equipment appropriate for all of the workplace hazards. This includes protective clothing, such as FRC, when the hazards include the potential for fires.

The National Fire Protection Association (NFPA) (2001) suggests considering the following in determining FRC needs:

- Proximity of the work to a potential flash fire hazard;
- Potential for a flammable release that could result from a mechanical failure such as a line breaking;
- Potential for flammable vapors in the work environment;
- Presence of engineering controls designed to reduce exposure to flammable materials;
- Accident history.

Formosa Point Comfort evaluated requiring FRC following two incidents where static electricity was suspected of igniting hydrocarbon releases. Formosa decided to require FRC for specific high-risk assignments, but decided not to require FRC for operators in the Olefins II unit except for those involved in emergency response.¹⁰

¹⁰ Following the October 6, 2005 incident OSHA cited Formosa for not requiring FRC for workers in the unit. Formosa has contested the citation.

4.0 Process Hazard Analysis

Formosa performed a series of hazard reviews including a hazard and operability study (HAZOP); facility siting analysis; and a pre-startup safety review (PSSR) prior to the operation of the Olefins II unit. The following sections describe how Formosa addressed vehicle impact protection and remote isolation in these reviews.

4.1 Vehicle Impact Protection

Formosa considered how to protect equipment from vehicle impact damage in both the facility siting analysis and the PSSR. The PSSR, used to identify safety issues prior to operating the Olefins II unit, looked only at protecting emergency equipment (such as firewater equipment). The PSSR team verified that traffic protection around emergency equipment had been installed, but did not look at specific process equipment.

During the facility siting analysis, the hazard analysis team discussed what might occur if a vehicle (e.g., fork truck, crane, man lift) impacted process piping. While the consequences of a truck impact were judged as “severe,” the frequency of occurrence was judged very low (i.e., not occurring within 20 years), resulting in a low overall risk rank.¹¹ Because of the low risk ranking, the team considered existing administrative safeguards adequate and did not recommend additional traffic protection.



Figure 9. Protection of fire fighting equipment.

The contrast between the physical protection for firefighting equipment and the administrative provisions for process piping and other equipment is striking. Figure 9 shows the protection afforded firefighting equipment, while Figure 10 shows the lack of protection where the impact and release occurred.



Figure 10. Vehicle impact point.

¹¹ The risk ranking methodology Formosa used considered both the potential consequences and likely frequency of an event.

4.2 Remote Equipment Isolation

Potential failure consequences greatly increase with large inventories, equipment congestion, and development near plants; remotely operated isolation valves can mitigate these consequences. Companies should address isolation philosophy as part of the hazard review process.

Formosa addressed isolating minor leaks in the hazard analysis and verified that operators could isolate minor leaks with local valves. However, the written hazard analysis did not consider a catastrophic loss of containment within the unit, and did not consider if local isolation valves would be accessible or if remotely operated isolation devices would be necessary.

5.0 Lessons Learned

5.1 Hazard Reviews

While Formosa conducted a preliminary hazard analysis, a process hazard analysis, a siting analysis, and a PSSR prior to operating the Olefins II unit, these reviews did not fully address protection of specific process equipment from vehicle impact or the use of remotely actuated valves to control a catastrophic release.

When performing a hazard analysis, facility siting analysis, or pre-startup safety review, vehicle impact and remote isolation of catastrophic releases should be investigated.

5.2 Flame resistant clothing

Formosa had prior incidents of flash fires from hydrocarbon leaks and evaluated the use of FRC. However, Formosa did not require FRC for operators working within the unit, even though the large flammable liquid and gas inventory may put operators at risk of injury from flash fires.

In process plants with large flammable liquid and/or gas inventories, mechanical failures can result in flash fires that endanger workers. The use of FRC may limit the severity of injury to employees who work in plants with large inventories of flammable gases and liquids.

5.3 Use of Current Standards

Kellogg sold the plant design used at Formosa multiple times between the mid-1980s and 2000. However, the design was not updated to incorporate improved recommended practices with respect to fireproofing structural steel that supports critical safety systems.

Evaluate the applicability and use of current consensus safety standards when designing and constructing a chemical or petrochemical process plant. This should include reviewing and updating earlier designs used for new facilities.

6.0 Recommendations

6.1 Formosa Plastics USA

2006-01-I-TX-R1

Revise policies and procedures for process hazard analysis and pre-startup safety review to more fully evaluate vehicle impact hazards, passive fire protection, and catastrophic releases.

2006-01-I-TX-R2

Require flame resistant clothing for workers in units at the Point Comfort complex where there is a risk of flash fires.

6.2 Kellogg, Brown, and Root

2006-01-I-TX-R3

Communicate the findings and recommendations of this report to all companies that contracted with either M. W. Kellogg or Kellogg, Brown, and Root (KBR) for plant designs similar to the Formosa Olefins II unit.

2006-01-I-TX-R4

Communicate the findings and recommendations of this report to your petrochemical process plant design engineers. Emphasize the importance of using current consensus safety standards when designing and constructing petrochemical process plants, including the earlier designs reused for new facilities.

2006-01-I-TX-R5

Revise KBR petrochemical process plant design procedures to ensure they address the use of current safety standards for new designs and earlier designs reused for new facilities.

6.3 Center for Chemical Process Safety (CCPS)

2006-01-I-TX-R6

Incorporate guidance for vehicular traffic protection and remote equipment isolation into the next revision of the Center for Chemical Process Safety's *Guidelines for Hazard Evaluation Procedures*.

7.0 References

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