A Lesson in Lock Out Tag Out from Phillips 66 Disaster

An Online Continuing Education Course for Engineers

Course Number: ED-1002

Credit: 1 Hour / 1 PDH / 1 CPD

A Lesson in Lock Out Tag Out from Phillips 66 Disaster

Jeffrey S. Caudill, P.E.

Prologue

On October 23rd, 1989, a catastrophic process release occurred at the Phillips 66 Houston Chemical Complex (HCC). The plant is located along the Houston Ship Channel in Pasadena, Texas. A reactor was released that was holding more than 85,000 lbs. of the highly flammable process materials, known as high-density polyethylene (HDPE). A flammable vapor cloud of ethylene gas formed as a result, and within minutes, the cloud found an ignition source, exploding shortly after 1:00 PM. The force of the blast was reported to be equivalent to 2.4 tons of TNT, registering as high as a 3.5-magnitude earthquake on the Richter scale. First responders were not able to immediately respond due to a series of explosions occurring after the initial blast. Twenty-three workers lost their lives, and over 300 were injured.

This incident has been a pillar in the formation of what is now OSHA's fourteen elements of process safety found in 29 CFR 1910.119. This code was published around three years after Phillips 66 incident.

Lock Out Tag Out (LoTo), or Controlling Hazardous Energy, was released on September 1st, 1989, before the disaster, but an extension was granted to require companies like Phillips 66 to be in compliance by January 2nd, 1990. Because this regulation was belated, no one knows if it could have prevented this incident. The incident, however, provided urgency in the Chemical and Refining industries to move faster on adopting the regulation. Further discussions on delaying compliance were dampened as well.

An entire generation has retired from the workforce since the 1989 incident in Pasadena. Further, this incident has been overshadowed by more modern incidents like the BP explosion in 2005 and Deep-Water Horizon in 2010. Professional Engineering societies rarely discuss Pasadena, yet many failures applying LoTo still occur today. The difference is, they are confined to a few persons and do not garner national media attention because the impacts are localized.

Control of hazardous energy ranked in the top five on OSHA's top ten most violated standards over the last few years. It is estimated that between 150 and 200 fatalities and some 50,000 injuries occur worldwide annually due to failure to control the release of hazardous energy. In the United States annually, over 3,000 injuries occur due to reported LoTo issues, with about a dozen resulting in fatalities. The injuries range from minor shocks and lacerations to severe burns and amputations.

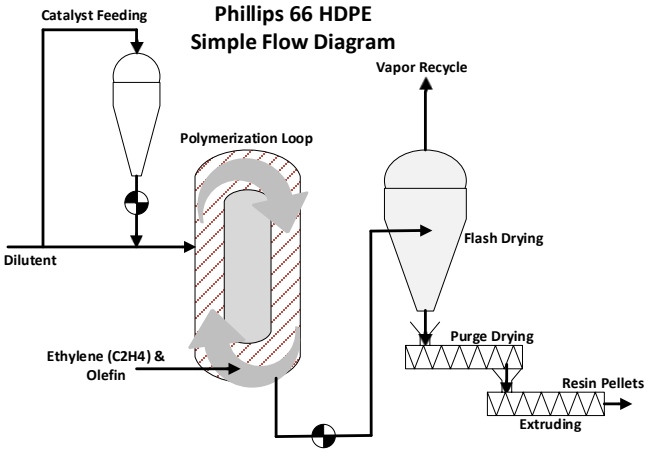
The Phillips 66 incident was by far one of the deadliest single LoTo failures in the last thirty-plus years. However, failure to learn from history makes us all vulnerable to repeating it. On October 23rd, 2009, a fire and explosion rocked the Caribbean Petroleum Refinery in Bayamón, PR. Even though this was an unrelated incident, as it pertains to LoTo, this explosion occurred 20 years later on the same day due to a tank overfill.

These non-related incidents highlight the fact that even though we have made many improvements

in process safety over the last thirty years, we have room to improve. With the ever-increasing pressure on the chemical and refining industries, corners cannot be cut, and compromises cannot be made. The impacts and scrutiny on the industry as a whole cannot absorb an intolerant media and public. Professional Engineers employed in these industries must do more to provide confidence to the public that these manufacturing plants can continue to operate safely.

Phillips 66, Houston Chemical Complex Incident Overview

HDPE is the base product in plastic piping and many other products. Many companies like Phillips and Chevron have their own patented processes for making HDPE. The HDPE pellets that they produce are then sold to other manufacturers who produce containers, bottles, toys, piping, and many other products we enjoy.



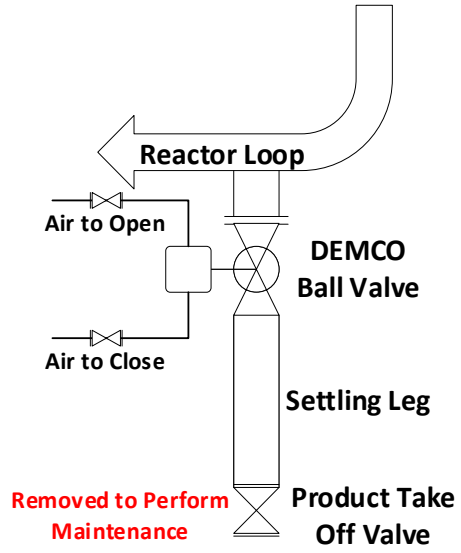
This incident began days earlier due to a common issue with the process design. What is the process of making HDPE? The process begins with ethylene, which is a gas before polymerization. One of the main ways that a manufacturer can get ethylene gas is by isolating a substance called ethane from natural gas.

Ethane becomes the feedstock material for a process called steam cracking, where steam and extreme heat are applied to the ethane to rearrange intramolecular bonds in the ethane and create ethylene. Next, those ethylene molecules are combined with olefins and chromium catalysts into chains of polyethylene, which combine in a high-density arrangement polymerizing the mixture. The HDPE is now a viscous resin that can be molded into whatever solid product it is needed for.

The Spontaneous Transfer Equation looks something like this using Phillips Chromium catalyst:

$$Cr - CH_2 - CH_2 - polymer \rightarrow Cr - H + CH_2 = CH - polymer$$

The Phillips process utilized six settling legs on each reactor. These settling legs routinely plugged off, requiring contractor maintenance crews to isolate the legs and clear the blockage.



Operations personnel were in responsible charge of isolating the settling legs according to the site's alternative isolation procedure. This procedure involves closing valves by LoTo and disconnecting the actuator air hoses. Operations would then allow the maintenance contractor to remove the blockage from each of the plugged settling legs.

The first of six plugged settling legs was disassembled and unplugged without difficulty on October 22nd, while the reactor continued operating at normal pressure and temperature (600 psi, 180F-230F). On October 23rd, the maintenance contractor began the day by removing the blockage in the second of the six plugged settling legs.

A small portion of the blockage was removed with difficulty. The remaining blockage proved to be out of reach for the contractor.

The maintenance contractor paused work and contacted Phillips 66 operations. Jointly, they returned to the settling leg. A short time later, a catastrophic process release occurred. Information on these few moments is not known.

Workers from both the contractor (Fish Contracting) and Phillips 66 perished, so many people have made educated guesses and assumptions on what took place in those remaining minutes. “Our hearts and souls should take a moment of silence to remember those that were killed or injured on this day.”

Post-incident, it was discovered that the air to the DEMCO valve had been reconnected in reverse. This reversal meant that the valve would open instead of closing. It is thought that the valve was actuated for some reason and opened. They may have been attempting to cycle the valve to loosen the blockage or move it where it could be accessed. This placed pressure (600 psi) behind the blockage that eventually gave way, blowing out and releasing an Ethylene gas and Olefin mixture.

Over 85,000 lbs. of the highly flammable process material were released. A flammable vapor cloud formed as a result, and within minutes, the cloud found an ignition source exploding shortly after 1:00 PM. The force of the blast was reported to be equivalent to 2.4 tons of TNT, registering as high as a 3.5-magnitude earthquake on the Richter scale.

The fire took six hours to contain; however, residual fires burned throughout the evening. The incident resulted in 23 fatalities and over 300 injuries. Property damage was estimated at the time to be in the range of $750M ($1.52B in today’s dollars). The explosion spread debris up to a 6-mi radius from the blast location. Lastly, the plant was down for months after the blast.

What Was Missed?

There were a number of items that Professional Engineers would have recognized today that were not covered in 1989. To discuss these, we need to identify the findings from the 1989 Phillips 66 incident. The major findings for this incident were determined by most accounts to be:

- Inadequate valve LoTo process
    a. Phillips' existing safe operating procedures for opening lines in hydrocarbon service were not prohibited during maintenance of the polyethylene plant settling legs
    b. Written maintenance procedures at the Phillips HCC facility did not incorporate the required double block and bleed valves or a block and blind flange inserted when a line in a chemical or hydrocarbon service was opened. However, this was still a common practice when possible, even in 1989
    c. Management had denied a workaround (alternate procedure) to remove the LoTo, hook up the air to the DEMCO valve, and cycle it to push out the plug. This is known to have been ignored, as the DEMCO valve was found in the open position, air hoses connected, and LoTo removed post-incident inspection. It is not known who allowed or performed this operation
    d. The DEMCO valve actuator mechanism was not locked out
    e. Air supply hoses could easily be connected during maintenance
    f. Identical air hose connectors for open and closed sides of the valve
    g. Air supply valves for actuator hoses found in the open position
- No process hazard analysis had been utilized in the Phillips polyethylene plants. These were not required in 1989 but were available
- An effective safety permit system was not enforced with regard to Phillips or contractor employees to ensure proper safety precautions during maintenance. An effective system has Plan-Do-Check-Adjust qualities
- Gas testing or continuous monitoring for leaks was not utilized at this time
- Facilities siting requirements utilized today did not exist in 1989
    a. Ignition sources were located near to or downwind from large hydrocarbon inventories
    b. There was inadequate separation between occupied locations and/or vital control equipment process units

There are other findings that can be derived from modern techniques like those used in "**F-4007: Advanced Incident Troubleshooting Guide**" that would have pointed to other findings.

Having completed thousands of incident investigations in almost thirty-years, there are some common truths that the author has gleaned. Take an employee and provide them with the right training, job plan, location, tools, and equipment, and they are successful 99% of the time. Remove any one of these, and you will draw improvisation. What does that mean?

An employee wants to do a good job. They do not come into work and say, "I'm going to be a complete screw-up today and get hurt or blow myself up." With this in mind, they will improvise what they don't have or perceive they cannot easily obtain to perform the work safely. Many times, this behavior is driven by inexperienced or impatient frontline supervision.

These are a few of the bases for normalization of deviance (NOD). How was NOD a part of this incident? It is the author's opinion, having been well-read on this incident and spoken to three employees that were there that day and survived, that NOD did play a role.

Consider these:

- This task had been performed hundreds of times successfully, without incident, building confidence
- This task was required because there was a flaw or issue in the design that was not known when it was built. No process hazard review had ever been completed, so the continual plugging was accepted as normal operations after a while
- The company allowed contractors too much autonomy within a LoTo'd piece of equipment
- The contractors were not, we assume, as familiar with the process, hazards, and other conditions. They reconnected the air hoses backwards. This had probably been accomplished many times before by operations or a more experienced contractor. This type of visual learning behavior filters into a younger, less experienced worker who will eventually make a mistake in the workaround
- Oversight of the contractor was relaxed. This task had, in everyone's minds, been considered routine
- Frontline supervision is often aware that these types of workarounds exist. However, they either were trained in the NOD themselves coming up through the ranks or look the other way as long as the work is completed. This reinforces a culture of "silence is acceptance"; accepting this lower standard of safety until this lower standard becomes the normal way of operating

These NOD conditions were right under their noses. Like many disasters, the rug of no fatalities, low recordable rates, and thousands of man-hours without lost time can all be pulled away in less than two minutes.

Normalization of deviance occurs when small incremental deviations in safety standards are relaxed over time. These small deviations from safety, when summed up, provide almost no safety standard at some point in the future. Look at it as a downward trend.

Here is an example of NOD. The first time you LoTo this DEMCO valve, you hang tags, and LoTo the valve, actuator, airline valves, automatic controls, and even install a blind. Then, over time, you stop using the blind. No incidents occur. Then you stop LoTo'ing the automatic controls, then the airline valves, and finally, the LoTo is just an exercise in hanging a tag that really does not prevent any hazardous energy from being released. This is not to suggest that this is what happened in the Phillips 66 incident, but an example of how NOD can creep in.

What Modern Process Safety Measures May Have Prevented This Incident?

Professional Engineers employed at or associated with the chemical-refining manufacturing industry are very familiar with Process Safety Management (PSM). This course is not going to teach you how to be a process safety engineer and learn the OSHA Code, 29CFR 1910.119 Subpart H, fourteen elements of process safety. Below is a brief refresher of all fourteen process safety elements as defined by OSHA.

PSM/RMP Element	Element Description
Employee Participation	Requires that employees—including production, maintenance, and contractor staff—be involved in every aspect of the PSM programs at their respective worksites. Client contractor programs provide the avenue for contractors to participate in their PSM/RMP programs.
Process Safety Information	According to OSHA's PSM mandates, "PSM/RMP OSHA Regulated facilities shall complete a compilation of written process safety information before conducting any process safety hazard analysis required by the standard." In other words, all workers should be able to access and understand the technical data regarding the HHC (highly hazardous chemicals)-related risks they face on the job. This right to know is provided through company PSM/RMP site-specific training on the process hazards.
Process Hazard Review	Process Hazard Analysis requires that companies using HHCs analyze the consequences of safety failures. These analyses must be conducted in teams, and OSHA requires that each team must include one person who is "knowledgeable in the specific process hazard methodology being used." Findings must be shared and any deficiencies corrected.
Operating Procedures	There are plenty of potential chemical hazards fo… …rnarounds and emergency shutdowns. OSHA inspector… …ve plans for keeping everyone s… …through Startup, Emergency, Shu…
Training	Wo… …well-trained, and their trair… …source, first-party or othe… …nted. Training management softw… …a test of knowledge that is docu…
Contractors	Regul… …d of the hazards they face. Under… …all inform contract emplo… …hazards related to the contrac… …g through client site-specifi…
Pre-Startup Safety Review (PSSR)	OSHA … …or both new and modifie… …s only affect a single compon…