CHEF Guide - A Summary of Historical Process Safety Incidents

"Those who cannot remember the past are condemned to repeat it."

- George Santayana

A brief summary of significant Process Safety incidents which have occurred in the past 50 years is summarized. Studying historical incidents is an excellent way to learn about process safety and how to prevent similar incidents from happening again. Several of these incidents were drivers in creating process safety regulation and industry guidance and are referenced throughout this document. Included are:

- Nypro Facility flammable release and explosion, Flixborough, UK – 1974
- ICMESA Facility uncontrolled reaction and environmental release, Seveso, Italy – 1976
- Union Carbide uncontrolled reaction and toxic release, Bhopal, India – 1984
- PEMEX LPG Facility flammable release and explosion, San Juanico, Mexico – 1984
- Phillips Petroleum Refinery flammable release and explosion, Pasadena, Texas – 1989
- BP Refinery flammable release and explosion, Texas City, Texas – 2005
- T2 Laboratories uncontrolled reaction and explosion, Jacksonville, FL – 2007
- Imperial Sugar dust explosion, Port Wentworth, GA – 2008
- DuPont Facility toxic release, Belle, WV – 2010
- West Fertilizer Facility explosion, West, TX – 2013

Nypro Facility, Flixborough, UK - 1974

[6, pp. 202-208]

In 1974, in a caprolactam (intermediate in the manufacture of nylon) production plant, a temporary bypass line ruptured, resulting in the leak of almost 40 tons of cyclohexane that caused a huge vapor-cloud explosion. The tragic disaster caused 28 fatalities including all the employees working in the control room. There was the alarming possibility of more than 500 fatalities had it been a normal working day instead of the weekend. Also, widespread damage to property within a 6-mile radius around the plant was another major consequence.

One of the reactors developed a six-foot crack. Management decided to remove the vessel and replace it with a temporary pipe designed in the maintenance shop without drawings or engineering review. The pipe was held in place by scaffolding.

The temporary piping worked for about two months. However, unknown to the operators, it was causing enormous stress to the reactor bellows joints. Finally, the bellows failed, releasing hot cyclohexane which ignited.

The Flixborough explosion was a critical driver in moving process safety issues forward in the UK. As a result of the Flixborough incident, at the end of 1974, the Advisory Committee on Major Hazards (ACMH) was formed. The lessons learned from this disaster highlight the importance of Management of Change with thorough evaluation prior to any modification in process plants.

ICMESA Facility, Seveso, Italy - 1976

[6, pp. 295-299]

The Seveso disaster was an industrial incident that occurred in 1976, in a small chemical manufacturing plant approximately 25 km north of Milan. During preparation for a weekend shut down, steam temperature used for heating the reactor was greater than normal. A slow runaway decomposition began, releasing more heat and leading to the onset of a rapid runaway reaction. The reactor relief valve eventually opened, causing the airborne release of 6 tons of chemicals containing high levels of 2,3,7,8-tetrachlorodibenzodioxin (TCDD).

Within days a total of 3,300 animals were found dead, mostly poultry and rabbits. Emergency slaughtering commenced to prevent TCDD from entering the food chain, and by 1978 over 80,000 animals had been slaughtered. Industrial safety regulations were passed in the European Community in 1982 called the Seveso Directive which imposed much harsher industrial regulations.

Because of local law, the process had to be shut down for the weekend with reactant inventory remaining in the vessel, an unusual situation. The exhaust steam pressurizing the heating coils was left on. Additionally, due to low weekend load, it reached a temperature of 300 degrees Celsius, well above its normal 190 degrees Celsius.

The reactor had no automatic cooling system; it had to be activated manually and only weekend maintenance personnel were on hand. Vessel contents reached 450 to 500 degrees Celsius, greatly increasing the formation of dioxin.

The decomposition reaction and utility operations were not known to have been covered in a Process Hazards Analysis (or PHA). Deficiencies in process design, hazard identification, and emergency response were significant (but not exclusive) contributors to the events that took place.

Union Carbide, Bhopal, India – 1984

[6, pp. 25-30]

In 1984, at the Union Carbide plant in India, a storage tank containing methyl isocyanate (MIC) was contaminated with water leading to a runaway reaction causing the release of more than 40 tons of toxic MIC gas through a relief valve. The incident caused more than 3,000 fatalities and injured hundreds of thousands more. This was arguably the worst chemical industry incident in terms of people affected.

After investigation, the prevailing conclusion is that water was deliberately introduced to an MIC storage vessel through an instrument connection. MIC is extremely water reactive, and a runaway reaction ensued.

There were a number of confounding factors that led to the Bhopal disaster:

- The vessel refrigeration system was down for six months to save money; its Freon was being used elsewhere.
- A relief effluent system caustic scrubber was inactive (said to be down for maintenance).
- The downstream flare for a scrubber was also shut down (said to be awaiting replacement of corroded pipe work).
- A fixed water curtain used to absorb MIC vapors was insufficient to reach the cloud.
- Supervision was slow to react to initial reports of MIC odor in the area; this was coffee break time (up to an hour may have been lost here).
- A shanty town had been allowed to form along the plant perimeter over a number of years.
- An effective emergency communication/response system was not in place.

In most of Bhopal's causal factors, you can see glaring deficiencies in the major process safety management elements of hazard analysis, mechanical integrity, operating procedures, and management of change.

As a direct response to Bhopal, many regulatory initiatives were implemented worldwide. In India, this event led to the Environment Protection Act (1986), the Air Act (1987), the Hazardous Waste (Management and Handling) Rules (1989), the Public Liability Insurance Act (1991) and the

Environmental Protection (Second Amendment) Rules (1992). In the US, the Emergency Planning and Community Right-to-Know Act (EPCRA) was promulgated in 1986, and the Clean Air Act Amendments (CAAA) were signed into law in 1990.

PEMEX LPG Facility, San Juanico, Mexico – 1984

[6, pp. 58-63]

The PEMEX Mexico City liquefied petroleum gas (LPG) facility had six spherical storage tanks and 48 smaller horizontal cylindrical tanks. In 1984, a leak occurred at this LPG terminal.

The LPG leak continued for five to ten minutes; a cloud of LPG vapor estimated to be 200 meters by 150 meters by two meters high formed. The cloud ignited. The explosion knocked storage tanks off their supports and ruptured piping, causing more LPG to be released.

Fire impinging on the LPG tanks resulted in a series of boiling liquid expanding vapor explosions (BLEVEs), which destroyed the site. Large fragments of the tanks traveled up to 1200 meters. In addition to destroying the facility, the fire and explosions caused 600 fatalities and injured nearly 7000 others.

Thermal radiation from the BLEVE fireball was a major cause of loss of life. Most of the casualties were members of the public living in surrounding communities that were outside the facility boundary watching the incident unfold.

The exact cause of the leak could not be determined with certainty after the event because of the extent of damage to the site. However, two important lessons were learned from this event:

- The emergency response was inadequate to remove the local population from hazards inherent to the facility.
- Improved fire protection and greater spacing between storage tanks could have reduced the consequences of the event.

Phillips Petroleum Refinery, Pasadena, Texas – 1989

[6, pp. 272-276] [7]

In 1989, in the Phillips Petroleum plant in Pasadena, Texas, the rupture of a seal on a polyethylene reactor caused the release of highly flammable ethylene and isobutene gas, forming a gas cloud and leading to a massive explosion. There were 23 fatalities and more than 300 injured.

Information from witnesses indicates that a vapor cloud developed very quickly and that workers had approximately 60 to 90 seconds to evacuate. The exact ignition source may never be known. Metal and concrete debris was found as far as six miles away following the explosion.

The day before the incident, a maintenance procedure had been performed by contractor personnel. This incident underscored the importance of rigid adherence to operating procedures and the implementation of an appropriate management system for contract workers. This incident also underscored the value of a thorough Emergency Plan.

BP Refinery, Texas City, Texas – 2005

[47]

In 2005, during the startup of an isomerization unit, the safety relief valves of a distillation tower opened due to overfilling, allowing hydrocarbon liquids to flow into a disposal blowdown drum with a stack, which were also overfilled, resulting in a liquid release.

The evaporation of the hydrocarbons produced a flammable vapor cloud that ignited and led to a series of fires and explosions. Fifteen workers died and about 180 were injured. This incident led to major investigations including the milestone Baker panel report headed by former US Secretary of State James Baker III.

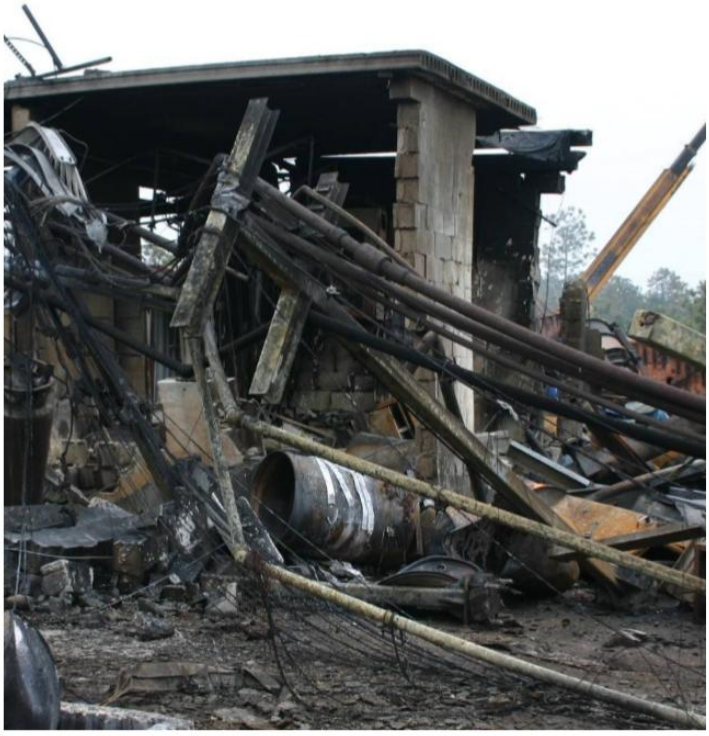
Trailers were used as temporary buildings by contractors at the site. Some of these trailers were located near the process. The trailers were not designed to be blast resistant. All of the fatalities occurred in or near the trailers located close to the blowdown drum.

At the time of the incident, wood frame trailers had been located 37 meters from the vent of a blowdown drum stack. The local rule for wood frame trailers was that they should be no closer than 107 meters from process equipment without an MOC review. This review had not been done.

This incident also resulted in significantly more interest in and attention to issues such as facility siting, atmospheric venting, leading and lagging process safety performance indicators and safety culture.

T2 Laboratories, Jacksonville, FL – 2007

[43]



In 2007, a runaway reaction resulted in a powerful explosion and subsequent chemical fire that caused four fatalities and destroyed T2 Laboratories, Inc. a chemical manufacturer in Jacksonville, Florida. 32 were injured, including the four employees and 28 members of the public who were working in surrounding businesses. Debris from the reactor was found up to one mile away, and the explosion damaged buildings within one quarter mile of the facility.

One of the most significant findings by the U.S. Chemical Safety Board (CSB) investigation was that neither the owners nor operators of the processing facility were aware of all of the potential hazards associated with the reactions in the facility. Other findings included:

- The cooling system employed was susceptible to single point failures due to a lack of design redundancy.
- The MCMT reactor relief system was incapable of relieving the pressure from a runaway reaction.

The CSB identified the root cause as "T2 did not recognize the runaway reaction hazard associated with the MCMT it was producing" and made recommendations to include process safety in the criteria that AIChE and the Accreditation Board for Engineering and Technology (ABET) uses for review and approval of chemical engineering programs.

Imperial Sugar, Port Wentworth, GA – 2008

[8]

In 2008, a series of sugar dust explosions occurred at the Imperial Sugar manufacturing facility in Port Wentworth, near Savannah, Georgia. The event resulted in 14 worker fatalities. Thirty-six workers were treated for serious burns and injuries.

The explosions and subsequent fires destroyed the sugar packing buildings, palletizer room, and silos, and severely damaged the bulk train car loading area and parts of the sugar refining process areas.

A system of screw and belt conveyors and bucket elevators transported granulated sugar from the refinery to three storage silos. The CSB determined that the first dust explosion initiated in the enclosed steel belt conveyor located below the sugar silos.

The recently installed steel cover panels on the belt conveyor allowed explosive concentrations of sugar dust to accumulate inside the enclosure. An undetermined source – perhaps an overheated equipment bearing – ignited the sugar dust, causing a violent explosion. The explosion lofted sugar dust that had accumulated on the floors and elevated horizontal surfaces, propagating more dust explosions through the buildings.

Secondary dust explosions occurred throughout the packing buildings, parts of the refinery, and the bulk sugar loading buildings. The pressure waves from the explosions heaved thick concrete floors and collapsed brick walls, blocking stairwell and other exit routes. The resulting fires destroyed the packing buildings, silos, palletizer building and heavily damaged parts of the refinery and bulk sugar loading area.

This incident underscored the need to raise awareness of dust explosion hazards. It also prompted process facilities to conduct a comprehensive review of all areas where dust might accumulate to ensure

they meet industry standards regarding dust hazard mitigation. Ultimately, this and other incidents resulted in the development of combustible dust standards [9] [10].

DuPont Facility, Belle, WV – 2010

[11]

In 2010, there was a release of highly toxic phosgene that caused a fatal exposure to a veteran operator at the DuPont facility in Belle, West Virginia. DuPont officials told the CSB that a braided steel hose connected to a one-ton capacity phosgene tank suddenly ruptured, releasing phosgene into the air.

The US Chemical Safety Board (CSB) determined that:

- DuPont's phosgene hazard awareness program was deficient in ensuring that operating personnel were aware of the hazards associated with trapped liquid phosgene in transfer hoses.
- DuPont relied on a maintenance program that was subject to changes without authorization or review, did not automatically initiate a change-out of phosgene hoses at the prescribed interval, and did not provide a back-up process to ensure timely change-out of hoses.
- DuPont Belle's near-miss reporting process was not rigorous enough to ensure that the near failure of a similar phosgene transfer hose, just hours prior to the exposure incident, would be immediately brought to the attention of plant supervisors and managers.
- DuPont lacked a dedicated radio/telephone system and emergency notification process to convey the nature of an emergency at the Belle plant, thereby restricting the ability of personnel to provide timely and quality information to emergency responders.

West Fertilizer Facility, West, TX – 2013

[12]

In 2013, a fire broke out in a fertilizer storage and distribution facility in the town of West, Texas. The facility stored large amounts of ammonium nitrate for use as a fertilizer. The fire caused approximately 27 metric tons of ammonium nitrate to detonate. The site itself and buildings near the site were destroyed.

The explosion caused extensive damage and destruction in the town of West. It resulted in 15 fatalities and many more injuries.

The CSB noted that the use of combustible materials next to the storage of ammonium nitrate at the site introduced the risk of a fire, which could then trigger an ammonium nitrate explosion. Twelve of the 15 people who died as a result of the incident were *volunteer firefighters* trying to evaluate the fire prior to the explosion.

One of the lessons learned from this incident is that the large volume of ammonium nitrate improperly stored at the facility created an increased risk that does not exist with an ordinary 10 or 20-kilogram bags of fertilizer.

Also, had the volunteer firefighters been better trained, managed, and informed of the quantity, proximity, and hazards of the ammonium nitrate stored at the facility, they likely would have been kept away from the fire.