Process safety essentials: Preparation for maintenance

Explosion at the Phillips' Houston chemical complex, Pasadena, 23 October 1989

Dr J Bond

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The plant

High density polythene is manufactured in Plant IV and V from ethylene gas dissolved in isobutane and reacted in long pipes under elevated pressure and temperature. Various chemicals are added to modify the polyethylene to meet the desired product characteristics. The polyethylene forms particles which settle out in legs of the reactor pipe and are drawn out of the legs through valves.

At the top of each leg is a ball valve (Demco brand) where it joins the reactor pipe loop. This ball valve is kept open during normal operation. Clogging of the settling legs occurs periodically and on these occasions the top Demco ball valve is closed and the leg removed to clear the blockage. The reaction is continued during this operation as the product is able to settle out in adjacent settling legs.

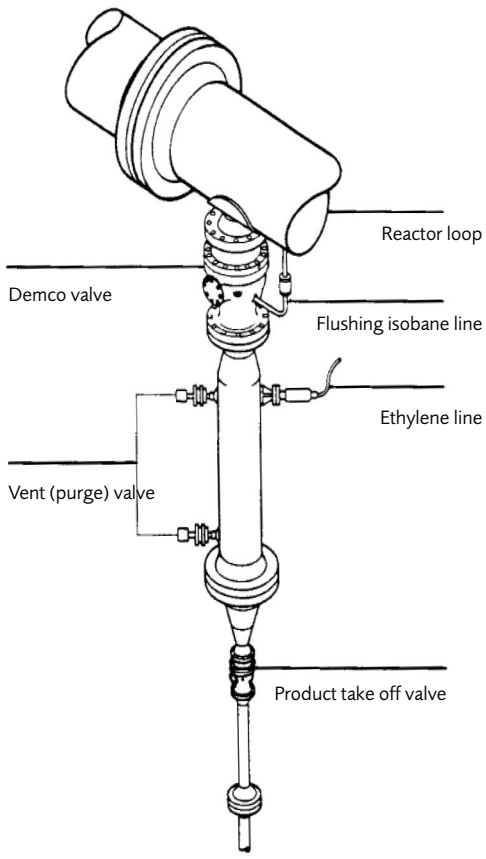

Figure 1: Typical piping settling leg arrangement

The accident

On Sunday 22 October, a contractor's crew began work to unplug three of the six settling legs on reactor 6. All three legs were prepared by an operator according to procedure with the Demco valve shut and their air operating lines disconnected. The maintenance crew dismantled the first leg and removed the blockage without incident. On Monday 23 October, work began to remove the second leg. Part of the blockage was removed but there remained a further blockage 30cm to 45cm below the Demco valve. A contractor went to the control room to seek the assistance of an operator when vapour was seen to be coming from the open pipe. 38,690kg of hydrocarbon came out in a very short space of time and formed a large semi-confined vapour cloud.

Within about two minutes the cloud was ignited by an unidentified source. Two other major explosions occurred after the first, one 10 to 15 minutes later when two 90,920 litre isobutane storage tanks exploded, and the other when a further reactor loop failed catastrophically about 25 to 45 minutes after the initial event.

Twenty three workers on the site were killed and more than 130 injured. All those who died at the scene were within 75m of the initial release.

Missiles from the explosion were thrown up to 9.5km into the neighbouring area. Two production units were completely destroyed causing $750 million of damage. The initial explosion had the force of 2.4 tonnes of TNT and measured 3.5 on the Richter Scale.

The response

The Phillips fire brigade provided the initial response with fire fighting equipment and first aid. Additional help was provided by the local emergency response units and by the Channel Industries Mutual Aid organisation which included municipal fire brigades, US Coast Guards and County Fire Departments.

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There was no dedicated water system for fighting the fire, only that which was tied into the process. Fire hydrants were sheared off by the explosion and the water system became ineffective. Water supplies had to be established from remote places including a neighbouring plant. Of the three diesel driven pumps on the site for fire purposes, one was out of service and one ran out of fuel. Electric cables supplying power to fire service pumps were damaged by the fire and could not be used. The fire was put out in 10 hours.

More than 100 employees escaped from the administration building by being ferried across the Houston Ship Channel by the US Coast Guard. Their normal route would have been through the area of the explosions.

The environment

Environmental tests were carried out during the fire by a mobile Air Control Board unit. There were no significant increase above normal levels and airborne levels of asbestos did not exceed the exposure limits.

24 sealed radiation sources were removed. It was determined that no employee or member of the public was at risk from radiation.

The investigation

The investigation was carried out by OSHA and established that the Demco valve was open at the time of the release. The air hoses which supplied air pressure to actuate the ball valve were found to be connected in a reverse manner such that the air pressure would open the valve even though the actuator switch called for the valve to be closed. The established procedure for carrying out maintenance work did not call for a backup isolation system.

Additionally, the following conditions were noted:

- The Demco valve actuator mechanism did not have its lock out device in place.
- The air hoses that supplied air to actuate the ball valve could be connected at any time even though the procedure required them to be disconnected during maintenance work.
- The connectors for the open and closed side of the valve were identical.
- The air supply valves for the actuators were in the open position so that on connection air would flow and cause the valve to rotate.
- The lockout mechanism for the valve was such that it could be locked in either position.
- The site layout with the proximity of normally high occupancy structures contributed to the severity of the event.

The findings

- The process hazards had not been identified nor the potential for malfunction established.
- The procedure for maintenance on the settling legs was inadequate.
- An effective safety permit system was not enforced for contractors or their own employees.
- There was no hydrocarbon detecting equipment to give early warning of release.
- Ignition sources were introduced into high hazard areas without testing for flammable gas.
- Buildings with people were not separated from process units in accordance with accepted engineering principles.
- Ventilation systems for buildings were not designed to prevent the ingress of gas.
- The fire protection system was not maintained in a state of readiness.

The citations

Citation for wilful violations with proposed penalties of $724,000 has been issued to the maintenance contractors for failing to obtain the necessary permits. Citations for serious violations for hazards involving inadequate respiratory protection and deficiencies in hazard communication programme were proposed.

Citations were made to the contracting company and to the Phillips 66 Company.

Pasadena and Flixborough compared

	Flixborough	Pasadena
Date	1/6/74	23/10/89
Substance	Cyclohexane	Ethylene/isobutane
TNT Equivalence	32 tonnes[1]	4 tonnes[2] 10 tonnes[3]
Fatalities	28	23
Injuries	89+	130
Lethal radius	125 metres[1]	75 metres[2]
Damage (trended)	$412 million[3]	$500 million + [3]

These two petrochemicals disasters seem to lie within the same severity bracket. Flixborough was probably the more violent explosion but property damage at Pasadena is likely to prove to be appreciably higher.

Pasadena would be a more sophisticated plant and a comparison of photographs suggests that the capital invested per unit area was higher than on the Flixborough site.

1. Marshall, V.C., *'Major Chemical Hazards'*, Ellis Horwood 1987
2. *Presidents' Report (OSHA Report on Phillips 66 Houston Explosion)*
3. *M&M Large Property Damage Losses in the Hydrocarbon Chemical Industries*, 13th Edition 1990.

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Loss Prevention Panel comment

There have been many major incidents where maintenance work was a contributing factor to the incident. The fire and explosion at the Phillips site in Pasadena, Texas[1] resulted in 23 fatalities, 130 injuries and caused $750 million of damage. Maintenance work was being undertaken on three settling legs on Reactor 6 to remove blockages. Whilst work on settling leg 2, a large release of hydrocarbon vapour occurred which subsequently ignited. A key finding of OSHA was that the procedure for maintenance on the settling legs was inadequate. This article also compares the Phillips explosion to another well-known major industry accident – Flixborough[2]. Whilst that incident is always remembered as a prime example of how not to manage plant modifications, poor maintenance management practices were also a factor.

Another Loss Prevention Bulletin article 'The implication of maintenance in major accident causation'[3] discusses how maintenance activities have contributed to six other major accidents including Piper Alpha[4] and Texas City[5]. In both these cases, key deficiencies in the maintenance programs, including the planning and execution phases, were identified during the incident investigations.

As early as Loss Prevention Bulletin 004 (1975) important lessons from incidents relating to maintenance activities were being shared. The article 'Engineering Maintenance'[6] included examples of poor lock-out practices and lack of identification of equipment prior to maintenance. Other examples of maintenance related accidents in the LPB we can learn from are: 'A Pump Explodes'[7], 'Acid Burns to Face..... During Preparation.... for Maintenance'[8], 'The fire at Hickson and Welch'[9] and 'Communication – in brief'[10].

There are also several LPB toolbox talks on the LPB website (www.icheme.org/lpb) with examples of accidents and of good practice relating to isolation of equipment before maintenance and identification of equipment for maintenance.

Maintenance on a chemical plant is undertaken for a range of reasons – regulatory compliance, to ensure mechanical integrity and to maintain production rates or quality. Whatever the reason for the maintenance activity it can introduce hazards during all the phases of the work – from planning and preparation, through the maintenance work itself and following the restart of the equipment. These hazards must be properly risk assessed and then managed. If not managed appropriately there is the potential for a major accident resulting in serious injury or loss of life and environmental damage in addition to reputational damage.

Doug Reid

References:

1. *Explosion at the Phillips' Houston chemical complex, Pasadena, 23 October 1989, LPB097, 1990*
2. *Flixborough: Lessons which are still relevant today, LPB237, 2014*
3. *The implication of maintenance in major accident causation, LPB236, 2014*
4. *Shared isolations, LPB261, 2018*
5. *Lessons from Texas City - a case history, LPB192, 2016*
6. *Engineering maintenance, LPB004, 1975*
7. *A pump explodes, LPB074, 1987*
8. *Acid burns to face, chest and legs during preparation of plant for maintenance, LPB098, 1991*
9. *The fire at Hickson & Welch, LPB227, 2012*
10. *Communication in brief, LPB218, 2011*

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