Lecture 1

Safety Practices in Chemical and Nuclear Industries

Review of Industrial Accidents

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Definitions

Safety

The condition of being safe; freedom from danger, risk or injury.

Reliability

The probability that a component part, equipment, or system will satisfactorily perform its intended function under the given circumstances for a specified period of time.

Major Oil Industry Accidents

- **July 6, 1988:** Piper Alpha disaster. An explosion and resulting fire on a North Sea oil production platform.

- Total insured loss is about US$ 3.4 billion. Rated as the world's worst offshore oil disaster in terms both of lives lost and impact to industry.

- 167 men were confirmed dead.

Major Oil Industry Accidents

- **March 23, 2005:** Texas City Refinery explosion. An explosion occurred at a British Petroleum refinery in Texas.
- It is the third largest refinery in the United States and one of the largest in the world, processing 433,000 barrels of crude oil per day and accounting for 3% of that nation's gasoline supply.
- Over 100 were injured, and 15 were confirmed dead.
- Several level indicators failed, leading to overfilling of a drum, and light hydrocarbons concentrated at ground level throughout the area. A nearby running diesel truck set off the explosion.

Major Oil Industry Accidents

- **December 11, 2005:** Hertfordshire Oil Storage Terminal fire.
- A series of explosions at the Buncefield oil storage depot, described as the largest peacetime explosion in Europe, devastated the terminal and many surrounding properties.
- There were no fatalities. Total damages have been forecast as £750 million.

Major Oil Industry Accidents

- **April 20, 2010:** The Deepwater Horizon oil spill (BP oil spill) in the Gulf of Mexico flowed for three months.
- It is the largest accidental marine oil spill in the history of the petroleum industry.
- The explosion killed 11 men working on the platform and injured 17 others. About 4.9 million barrels of crude oil was released into the sea.

BP Oil Spill Gulf Mexico

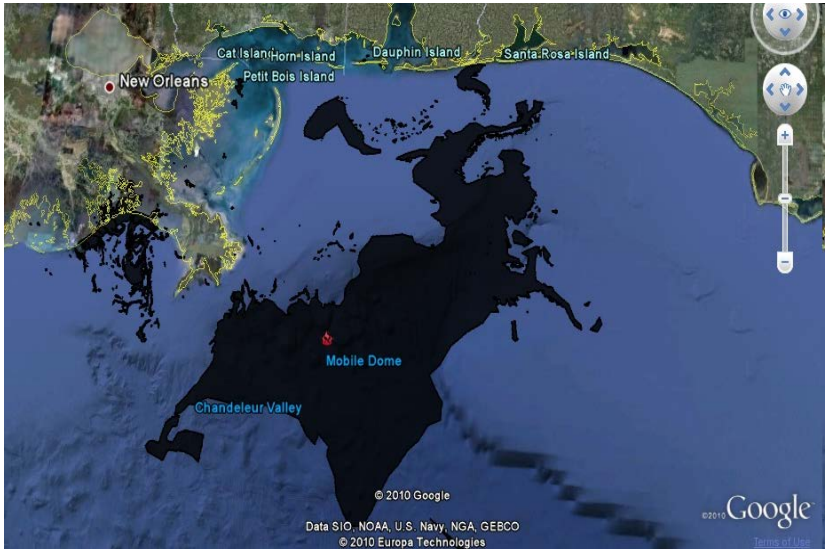

Image courtesy: Google Images

12 Killed in IOCL October 29, 2009.

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12 killed in Jaipur IOC depot fire, Army called

TNN 30 October 2009, 01:41am IST

JAIPUR & NEW DELHI: A devastating fire swept through an Indian Oil fuel storage and distribution terminal on the outskirts of Jaipur on Thursday, killing at least a dozen people and injuring more than 100. The toll is likely to go up as the blaze is still raging. At the time of going to press, all 12 tankers at the terminal were aflame.

Preliminary reports said the fire broke out after a pipeline valve failed when petrol was being transferred from the IoC terminal to Bharat Petroleum's storage nearby. D C Daga, director marketing of IoC, said the fire began with a leak in one of the tankers.

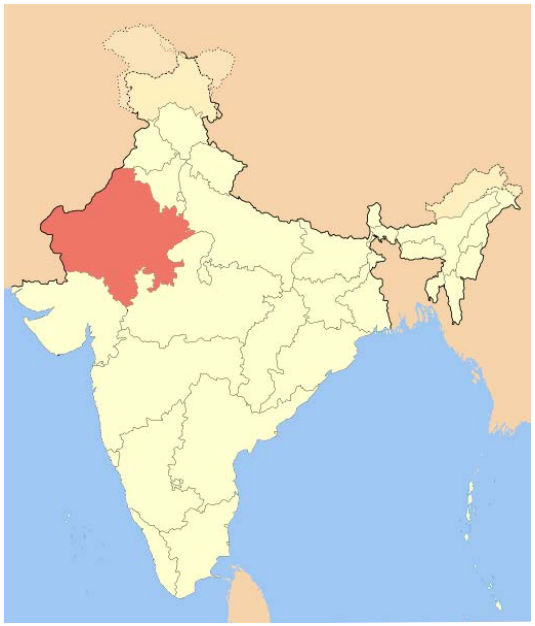
The Met department recorded a tremor measuring 2.3 on the Richter scale around the time the first explosion was heard at 7.36pm. Such was the impact of the explosions that windows of houses even 3km away were damaged. The capacity of the terminal is 80 lakh litres of fuel.

There were at least 40 IoC employees at the terminal, which is close to the Sanganer airport, and it isn't known how many of them have managed to escape. About 300 tourists from nearby Chowkidhani resorts were evacuated. Electricity lines in surrounding areas have snapped. Students living in nearby hostels have been taken to safer places.

All 31 fire tenders in Jaipur have been rushed to the spot and an expert from Mumbai has been contacted to fly down and help douse the fire. The terminal gets its supplies from IoC's Mathura refinery through pipeline and feeds part of the Rajasthan market.

The massive spillage of highly inflammable petrol being pumped at high pressure has resulted in heavy destruction. A team of IoC officials has rushed to Jaipur. Petroleum minister Murli Deora is expected to reach the spot on Friday morning. IoC officials said oil supply in the state would not be affected, and that another terminal at Jodhpur would be pressed into service.

The Burning Indian Oil Corporation depot



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IOCL fire due to negligence

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THE TIMES OF INDIA

Jaipur fire: Indian Oil Corporation faces negligence charge

IANS 3 November 2009, 01:24pm IST

JAIPUR: An executive of a private company has filed a complaint against Indian Oil Corporation (IOC) after a fire broke out at its oil depot here October 29 killing 11 people and injuring over 150. With four of the 11 tanks in the depot still ablaze on the sixth day, the IOC has been charged with criminal negligence.

The blaze broke out in the depot in Sitapura industrial area about 20 km from the Jaipur city centre at 7.15 pm October 29.

"The FIR (first information report), was filed on Monday by Pratipal Singh, an employee of Genus Power Infrastructure Limited, a factory that is situated near the IOC depot," a police officer said on Tuesday.

"We have lodged a case under Section 304 A, which relates to causing death by negligence, and other appropriate sections of the Indian Penal Code," he said.

According to the management at Genus, the factory has suffered massive damages because of the fire.

"There were three casualties in our factory and 15 others were injured. It is difficult for us to assess the damage to the industrial unit as of now. We would only be able to do it once the fire is controlled in the depot," an official of the factory said.

Meanwhile the district administration has decided to shut educational institutes in Sitapura for the next eight days. The decision was taken as some of the buildings at the institutes were damaged.

The district administration said that the fire is still blazing in four of the 11 tanks situated in the depot. These tanks contain petrol and diesel. In the remaining seven tanks the fire has almost come to an end and black smoke is coming out, which has formed dark clouds in a two to three km radius around the premises.

A union petroleum ministry team has already visited the site and started its probe into the fire. The team is to submit its report in 60 days.

IOC officials say it will take over a year to rebuild the depot which has been completely damaged.

Major Chemical Industry Accidents

- **June 1, 1974:** Flixborough disaster, England. An explosion at a chemical plant near the village of Flixborough kills 28 people and seriously injures another 36.

- **July 10, 1976:** Seveso disaster, in Seveso, Italy, in a small chemical manufacturing plant, due to the release of dioxins into the atmosphere, 3,000 pets and farm animals died and, later, 70,000 animals were slaughtered to prevent dioxins from entering the food chain.

Major Chemical Industry Accidents

- In addition, 193 people in the affected areas suffered from chloracne and other symptoms. The disaster lead to the Seveso directive, which was issued by the European Community and imposed much harsher industrial regulations.
- **November 19, 1984**: San Juanico, Mexico LPG Disaster, a gas leak in stored LPG set off a gas cloud which drifted towards houses, ignited and caused BLEVE, rupturing large spheres and many cylinders 500 deaths, unknown number of burn victims

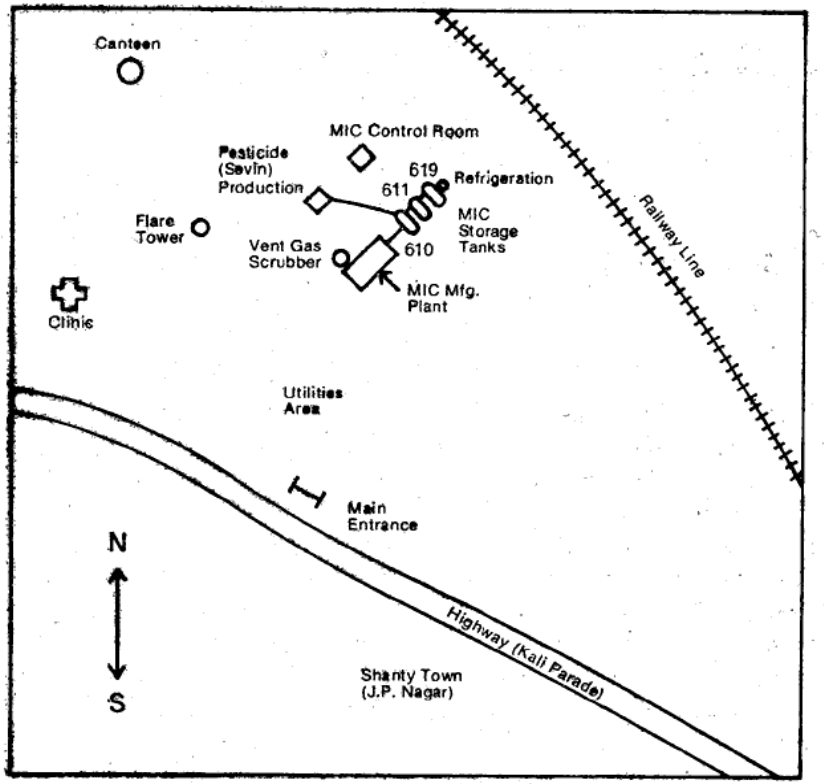
Major Chemical Industry Accidents

- **December 3, 1984:** The **Bhopal disaster** in India is the Worst and Largest industrial disaster on record. A faulty tank containing poisonous methyl isocyanate leaked at a Union Carbide plant and left nearly 4,000 people dead on the first night of the gas leak and at least 15,000 later from related illnesses. The disaster caused the region's human and animal populations severe health problems to the present.
- **October 23, 1989:** Phillips Disaster. Explosion and fire killed 23 and injured 314 in Pasadena, Texas. Capital losses over $715 million.

Bhopal - India

- Bhopal is the capital of a less developed Madhya Pradesh
- 70’s period of green revolution – large scale use of fertilizers & pesticides
- Import of pesticides costly, indigenous production encouraged
- Incentives for industrial development
- 1969 - UCIL subsidiary of UCC set up pesticide plant to make Carbaryl in using imported raw materials
- 1979 – granted licence to make MIC based pesticides
- 1980 – production started

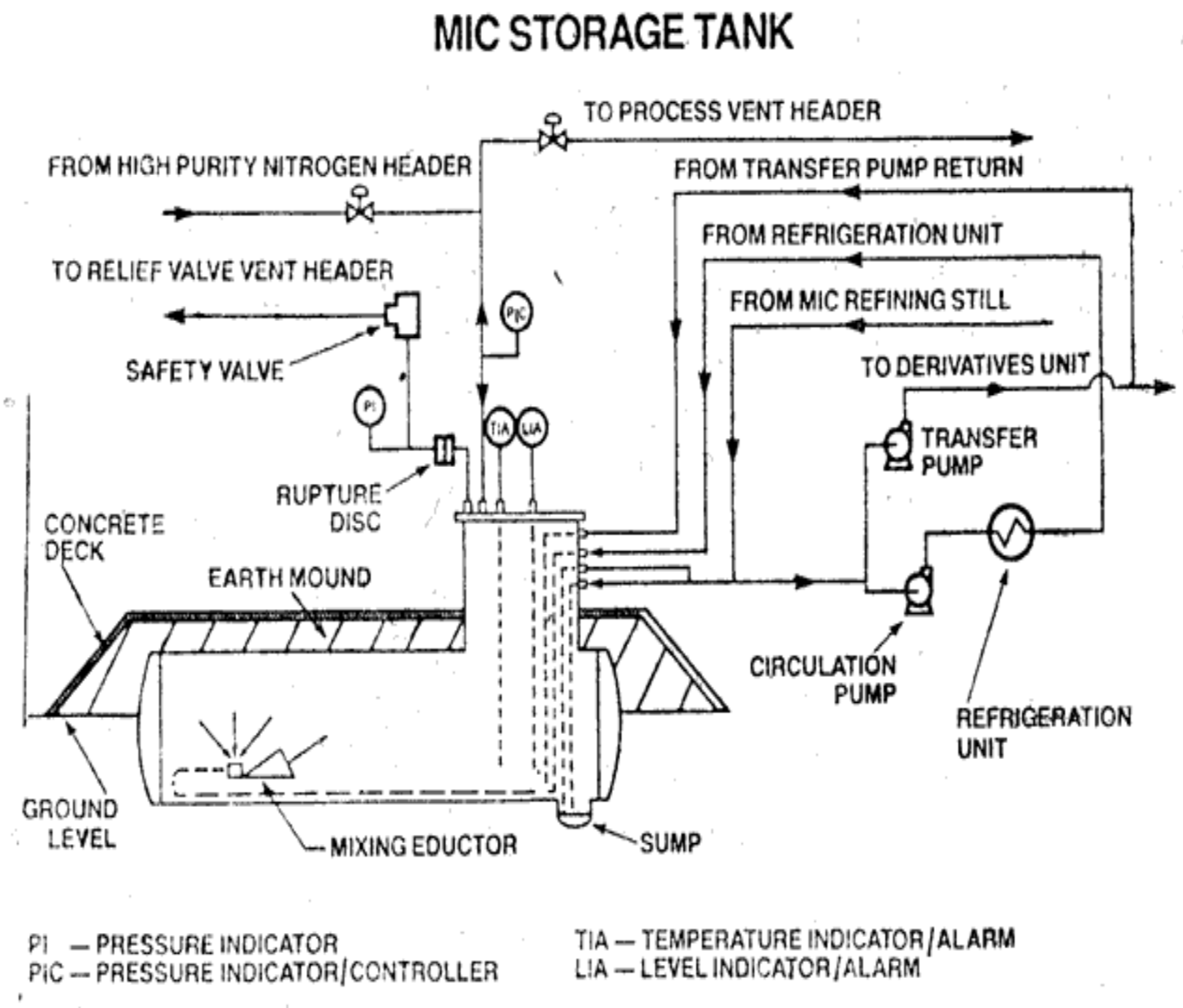
Union Carbide



THE MIC SETUP AT BHOPAL UC

Refrigeration Unit
Vent Gas Scrubber
Flare Tower
Water Curtain
Alarm Siren

Methyl Isocyanate Storage Tank



Bhopal - the World's Worst Industrial Disaster

- The Bhopal disaster, also known as the Union Carbide disaster or the Bhopal gas tragedy, was an industrial catastrophe that took place at a Union Carbide pesticide plant in Bhopal on December 3, 1984.

- Around 12 a.m. the plant released 40 tons of methyl isocyanate (MIC) gas and other toxins, resulting in the exposure of over 500,000 people.

Bhopal - the World's Worst Industrial Disaster

- Estimates vary on the death toll. The government has confirmed a total of 4000 deaths related to the gas release.

- Other government agencies estimate 15,000 deaths. Others estimate 8000 to 10,000 died within 72 hours and 25,000 have since died from gas-related diseases.

Bhopal - the World's Worst Industrial Disaster

- 25 years after the gas leak, 390 tonnes of toxic chemicals abandoned at the Union Carbide plant continue to leak and pollute the groundwater.

- There are currently civil and criminal cases related to the disaster ongoing in the United States District Court, the District Court of Bhopal, against Union Carbide, now owned by Dow Chemical Company, with an Indian arrest warrant pending against Warren Anderson, CEO of Union Carbide at the time of the disaster.

Lethal Dose Comparison

Lethal Dose, ppm	Chemical
50.0	Carbon Monoxide
25.0	Chloroform
10.0	Methyl amine
10.0	Benzene
10.0	Acetic acid
10.0	Cyanogen
0.10	Phosgene
0.02	**MIC**

Bhopal Industrial Disaster

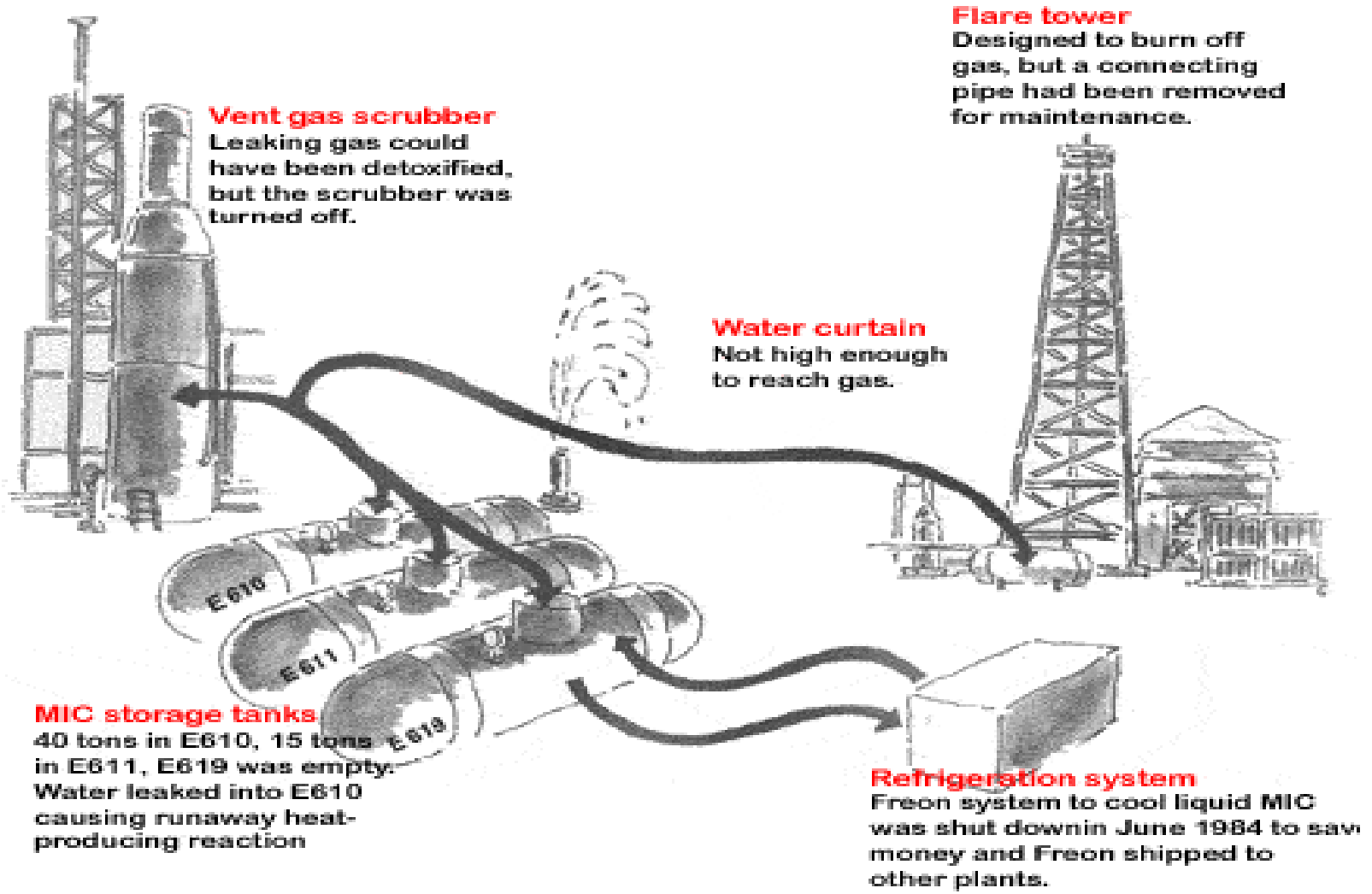


Image courtesy: Google Images

Bhopal Disaster

Areas affected by MIC release

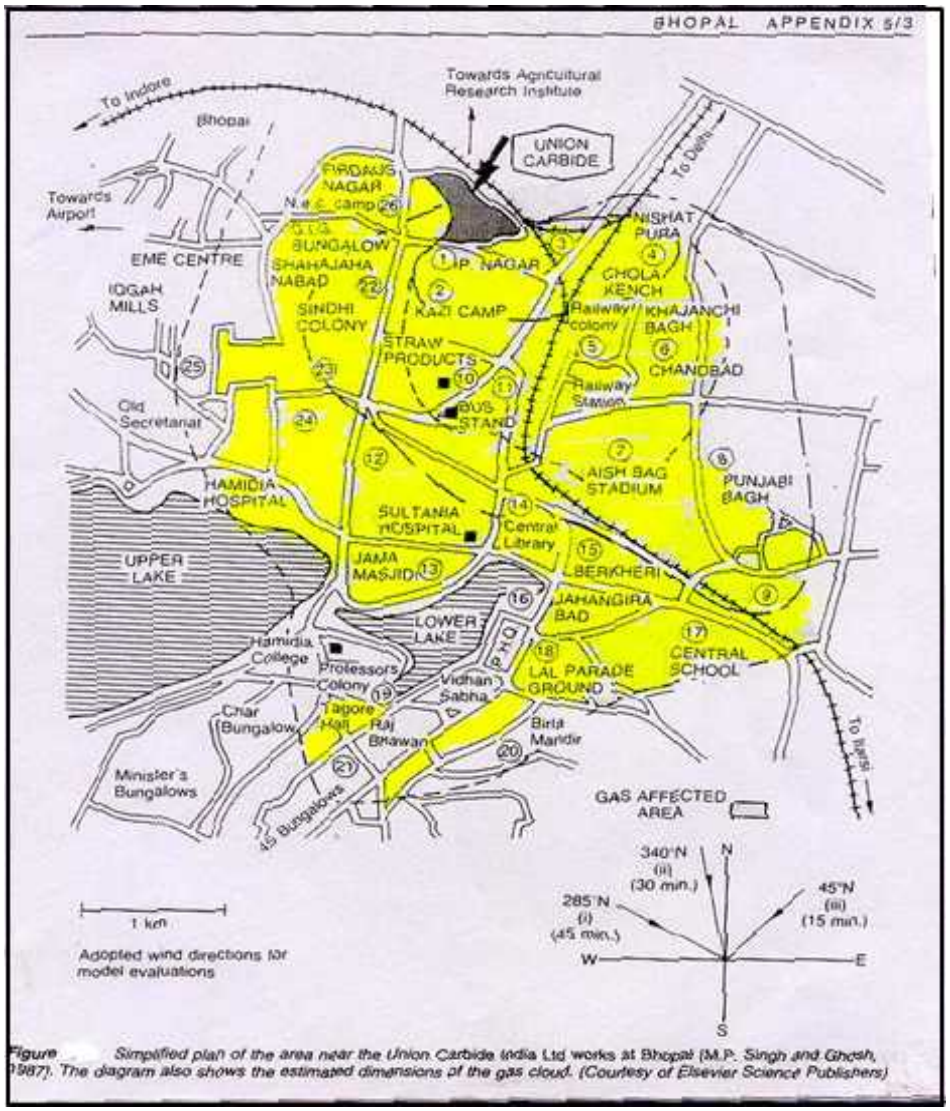


Figure Simplified plan of the area near the Union Carbide India Ltd works at Bhopal (M.P. Singh and Ghosh, 1987). The diagram also shows the estimated dimensions of the gas cloud. (Courtesy of Elsevier Science Publishers)

A vast stock of MIC provoked by ingress of water unleashed a furious gas cloud on unsuspecting people, at midnight

"A Sleeping community outside as the gas began its spread. Bodies roused, coughing, crying out, eyes burning and watering. Thousands running, staggering through alleys, many clutching their babies, not knowing where to run, which way to escape. Death by the thousands, injuries by the tens of thousands. Pandemonium in the hospital. By daybreak the scene of silence around those left behind: Fathers, mothers, children, cows, bulls, goats, dogs – all in final repose. A peace in its eeriness never before more heart wrenching. Mass cremations, mass burials".

-Wil Lepkowski, *C & EN News*,1985.

Flixborough Disaster, England

- The chemical plant in operation since 1967, produced caprolactam, a precursor chemical used in the manufacture of nylon.
- The process involved oxidation of cyclohexane with air in a series of six reactors to produce a mixture of cyclohexanol and cyclohexanone.
- Two months prior to the explosion, a crack was discovered in the number 5 reactor. It was decided to install a temporary 50 cm diameter pipe to bypass the leaking reactor to allow continued operation of the plant while repairs were made.

Flixborough Disaster, England

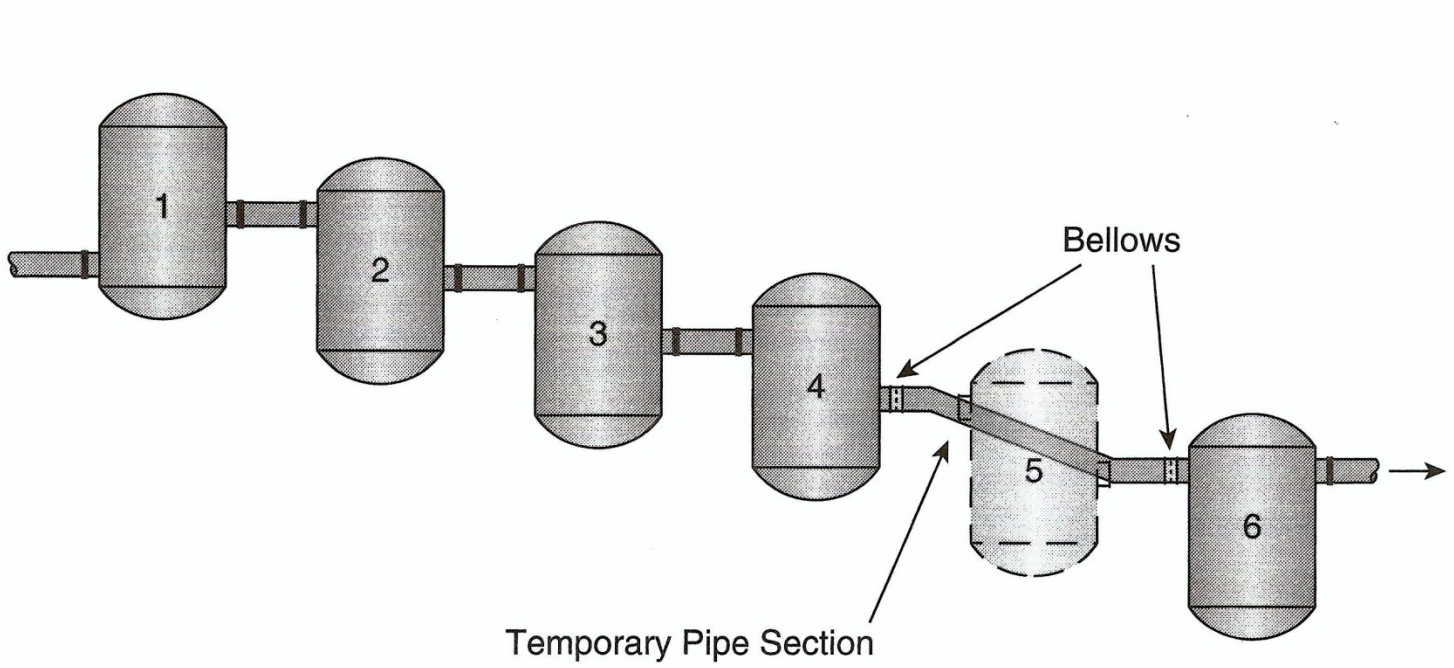
- At 17:00 hrs on Saturday 1 June 1974, the temporary bypass pipe (containing cyclohexane at 150°C and 1 MPa (10 Bar)) ruptured, possibly as a result of a fire on a nearby pipe which had been burning for nearly an hour. Within a minute, about 40 tons of the plant's 400 tons store of cyclohexane leaked from the pipe and formed a vapour cloud 100–200 meters in diameter. The cloud, on coming in contact with an ignition source (probably a furnace at a nearby hydrogen production plant) exploded, completely destroying the plant.

Flixborough Disaster, England

- Around 1,800 buildings within a mile radius of the site were damaged.

- Observers have said that had the explosion occurred on a weekday, more than 500 plant employees would likely have been killed. Resulting fires raged in the area for over 10 days.

Flixborough Disaster, England



A failure of a temporary pipe section replacing reactor 5 caused the Flixborough accident

Flixborough Disaster

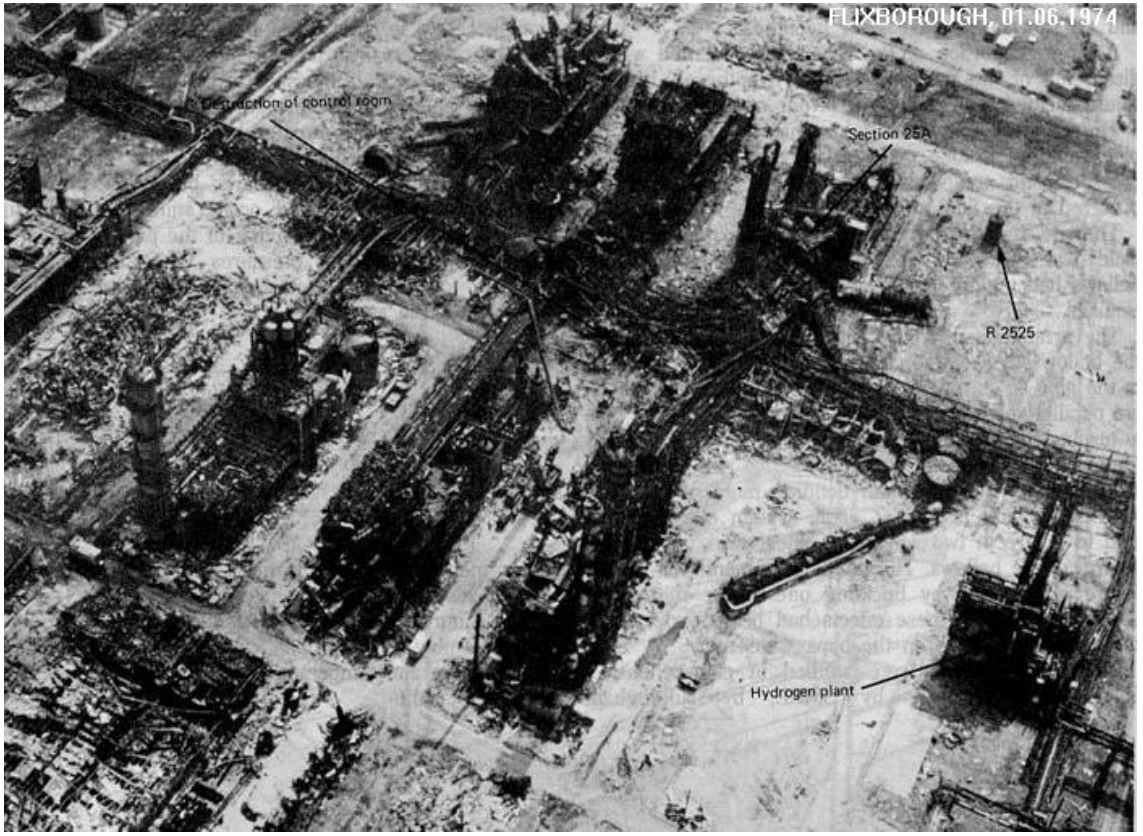
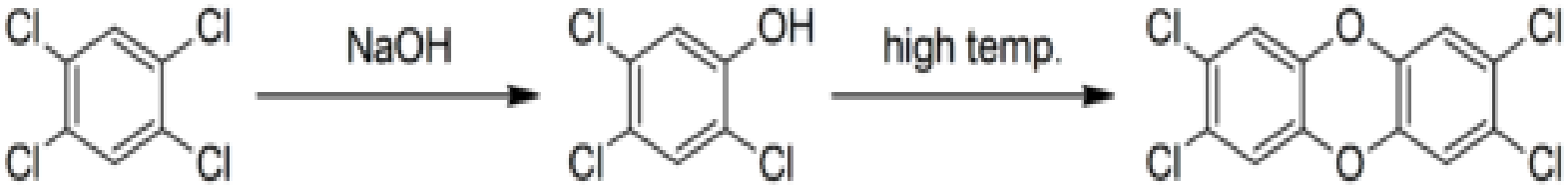


Image courtesy:
Google Images

Seveso disaster, Italy

- The Seveso disaster was an industrial accident that occurred on July 10, 1976, in a small chemical manufacturing plant (ICMESA) near Milan in Italy. It resulted in the highest known exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in residential populations.



Seveso disaster, Italy

- Trichlorophenol was intended as an intermediate for the herbicide 2,4,5-T (2,4,5-trichlorophenoxyacetic acid).

- This reaction must be carried at a temperature above that of the normal process utilities that were available, so the exhaust steam from onsite the electricity turbine was passed around an external heating coil of the reactor. The exhaust steam was at 12 bar and 190°C, resulting in a reaction mixture at 158°C.

Seveso disaster, Italy

- The plant was supposed to shutdown over the weekend, and parts of the site started to close down as batches finished. This caused the load on the turbine to fall dramatically, resulting in the exhaust steam temperature rising to around 300°C, heating the reactor wall to the same temperature.

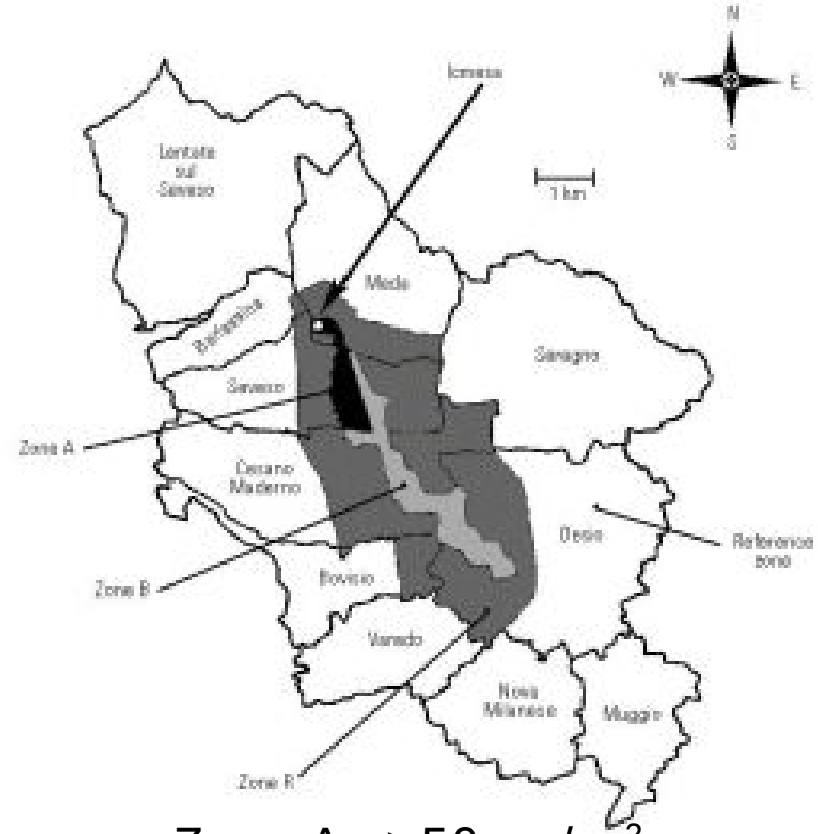
- The relief valve eventually opened, and about 6 tonnes of chemicals were released into the air. The accident was not immediately noticed. No one was at the plant when it happened.

Seveso disaster, Italy

- The first sign of health problems, burn-like skin lesions, appeared on children a few hours after the accident. Latter a severe skin disorder usually associated with dioxin, broke out on some of the people most exposed to the cloud.

- Authorities began an investigation five days after the accident, when animals such as rabbits began to die en masse. Roughly 70,000 animals -- were killed to prevent contamination from filtering up the food chain.

Seveso disaster, Italy



Zone A: >50 μg/m²
Zone B: 5-50 μg/m²
Zone R: <5 μg/m²

Image courtesy: Google Images

The Mexico LPG Disaster

- LPG disaster in San Juanico, Mexico city
- 19 Nov 1984 (2 weeks before the Bhopal tragedy)

Image courtesy: Google Images

Storage Tanks

Image courtesy: Google Images

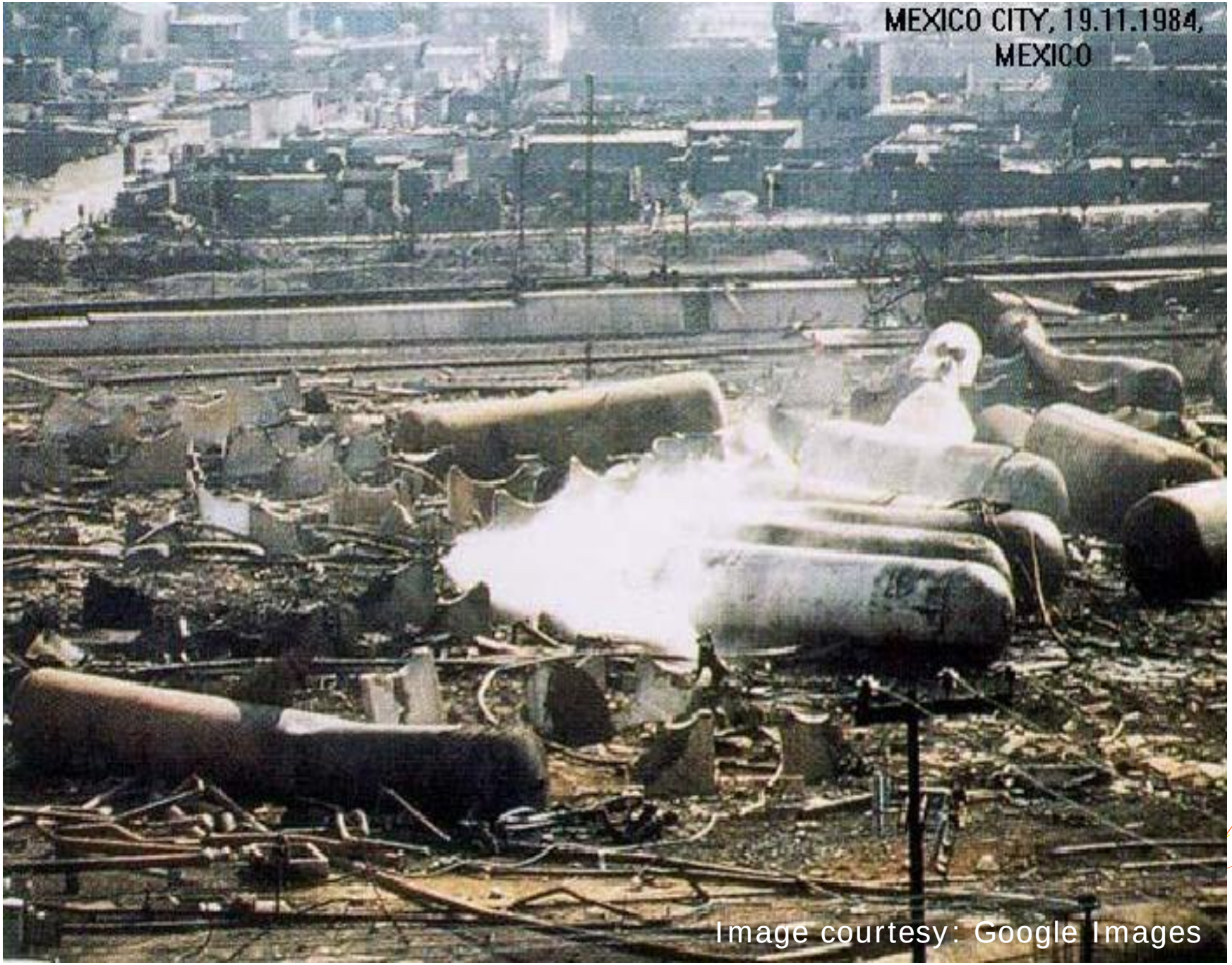

MEXICO CITY, 19.11.1984,
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Image courtesy: Google Images


MEXICO CITY, 19.11.1984,
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MEXICO CITY, 19.11.1984,
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Damage Contours of Mexico

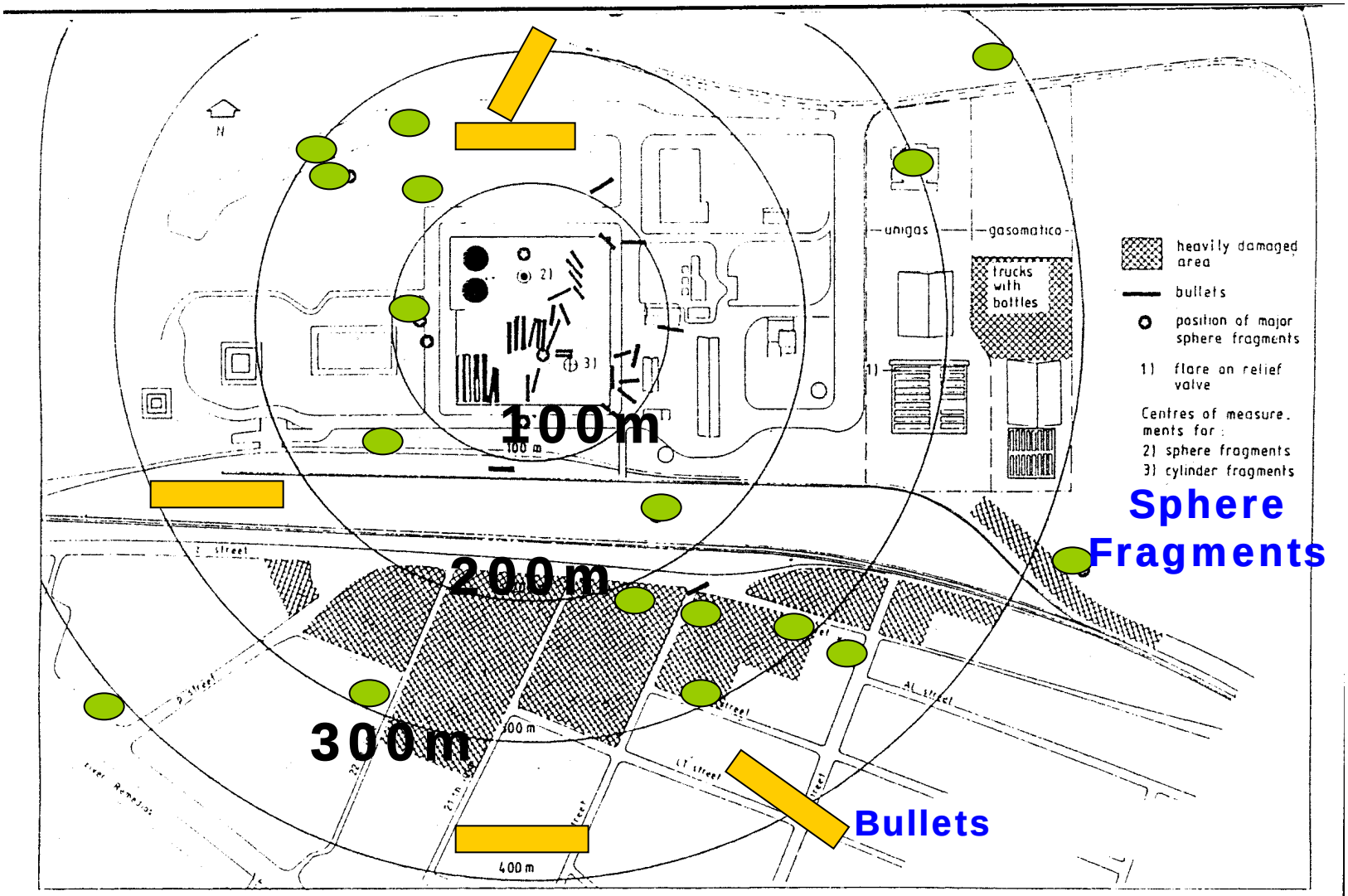

Figure *Area plan of the PEMEX site at Mexico City, showing damage to housing area and fall of missiles (Pietersen 1985) (Courtesy of TNO)*

Phillips Disaster, Texas

- The facility produced high-density polyethylene (HDPE), a plastic material used to make milk bottles and other containers.
- The Houston Chemical Complex (HCC) facility employed 905 company employees and approximately 600 daily contract employees, who were engaged primarily in regular maintenance activities and new plant construction.
- The incident started at approximately 1:00 PM local time on October 23, 1989, at Pasadena, Texas. A massive and devastating explosion and fire ripped through the Phillips HCC, killing 23 persons and injuring 314.

Phillips Disaster, Texas

- The explosion affected all facilities within the complex, causing $715.5 million worth of damage plus an additional business disruption loss estimated at $700 million.

- The initial explosion was equivalent to an earthquake registering 3.5 on the Richter Scale and threw debris as far away as six miles.

Phillips Disaster, Texas

- The accident resulted from a release of extremely flammable process gases that occurred during regular maintenance operations on one of the plant's polyethylene reactors.
- More than 85,000 pounds of highly flammable gases were released through an open valve. A vapor cloud formed and traveled rapidly through the polyethylene plant. Within 90-120 seconds, the vapor cloud came into contact with an ignition source and exploded with the force of 2.4 tons of TNT.

Phillips Disaster, 1989

Image courtesy: Google Images

SAFETY