Incident Title	**Methyl Isocyanate Storage Tank Temperature Runaway**	
Incident Type	Toxic Gas Release	
Date	3rd December 1984	
Country	India	
Location	Bhopal, MP	
Fatalities	**Injuries**	**Cost**
2153 (minimum)	> 200,000	Unknown

Incident Description

Credit: D. Hendershot/CCPS Staff Cons

Carbaryl (an insecticide) was being manufactured by reacting methylamine with phosgene to make a methyl isocyanate intermediate product which was then reacted with 1-naphthol. On the morning of the incident, an exothermic reaction occurred in the nitrogen-purged stainless steel methyl isocyanate intermediate storage tank. The temperature and pressure in the tank continued to rise until 40 tonnes of highly toxic vapours, including methyl isocyanate (MIC) and hydrogen cyanide (HCN) were released to atmosphere via the pressure relief system. The official death toll was 2153 but some unofficial estimates were > 16,000 (uncertain due to unknown population of shanty town adjacent to the plant). The plant never restarted.

Incident Analysis

Basic cause was a runaway chemical reaction caused by water ingress to the MIC intermediate storage tank (isolation error or sabotage?).

Critical factors included: 1) The refrigeration system, vent gas scrubber and flare stack were not in service, 2) MIC was routinely pressured out of the tank with nitrogen because the MIC transfer pump was unreliable (seal leaks), 3) The carbon steel vent headers were routinely water flushed to clear fouling deposits, 4) The tank high temperature alarm was disconnected when the refrigeration system was taken out of service, 5) The emergency water spray was only capable of knocking down vapour clouds at low elevation (e.g. MIC pump seal leak), 6) The presence of a shanty town near the plant boundary.

Root causes included: 1) Inadequate preventative maintenance (instruments and safety-critical equipment), 2) Inadequate risk assessment (MIC inventory during plant outages), 3) Inadequate management of change (refrigeration, vent gas and flare system outages), 4) Inadequate training (plant operators), 5) Inadequate leadership (operational oversight), 6) Inadequate emergency response planning (due to inadequate risk assessment), 7) Failure to apply inherently safer design principles (MIC intermediate storage), 8) Inadequate land use planning (close proximity of shanty town to high hazard plant).

Lessons Learned

1) Carbon steel process piping and equipment is incompatible with MIC in atmospheres containing oxygen because rust (Fe_2O_3) catalyses an MIC trimerisation (polymerisation) reaction which can cause heavy fouling.
2) An inherently safer process for carbaryl manufacture which avoids production of MIC intermediate (but has higher operating costs) uses the same reactants in a different sequence (phosgene reacts with 1-naphthol to produce 1-napthylchloroformate which is then reacted with methylamine).
3) Regulators should ensure that manufacturing companies are made fully accountable for contaminated land clean-up costs in the event of a spill or release and site remediation costs when production is finally terminated.
4) The Public Liability Insurance Act 1991 was introduced in India to provide for public liability insurance for providing immediate relief to anyone affected by an accident while handling any hazardous substance.

More Information

1) "Union Carbide: Disaster at Bhopal", P. Cullinan, S. Acquilla and V. Ramana Dhara (1993).
2) "Remembering Bhopal" IChemE Loss Prevention Bulletin 240 (2014): https://www.icheme.org/media/1277/lpb240_digimag.pdf.
3) "What Went Wrong? Case Histories of Process Plant Disasters and How They Could Have Been Avoided", 4th Edition (1999), Trevor Kletz, Elsevier, ISBN-10: 0-88415-920-5, ISBN-13: 978-0-88415-920-9.

Industry Sector	Process Type	Incident Type
Agrochemicals (Manufacture)	Pesticide	Toxic Gas Release
Equipment Category	**Equipment Class**	**Equipment Type**
Not equipment-related	Not applicable	Not applicable

Peter Marsh
Director – XBP Refining Consultants Ltd.