Incident Title	Temporary Reactor Bypass Line Rupture	
Incident Type	Explosion and Fire	
Date	1st Jun 1974	
Country	UK (England)	
Location	Flixborough (Lincolnshire)	
Fatalities	**Injuries**	**Cost**
28	53	US$ 359 m (2021) – Ref. 3

Incident Description

Credit: The National Archives

Caprolactam (an intermediate product in the production of nylon) was being manufactured by oxidation of cyclohexane with air in a series of 6 mild steel, inter-connected reactors. A temporary 20" NS (DN 500) bypass pipe assembly incorporating expansion joints (bellows units) had been installed around one of the reactors to enable it to be taken off-line to repair a large crack. On the day of the incident (Saturday), while the plant was on hot circulation pending restart, the bypass line ruptured releasing 30 tonnes of hot cyclohexane that formed a flammable cloud and subsequently found an ignition source. A huge unconfined vapour cloud explosion (UVCE) occurred and 28 employees were killed instantly (18 of them in the control room). The entire plant was destroyed and 1821 homes and 167 business premises suffered significant damage. The resulting fire burned for 3 days. The loss of life would have been greater if the explosion had occurred on a weekday.

Incident Analysis

Basic cause was a hot cyclohexane release to atmosphere due to squirm and rupture of a bellows unit in the temporary reactor bypass pipe assembly.

Critical factors included: 1) The process was inefficient and required a large amount of recycle (hence large inventory), 2) One of the six reactors had developed a crack (hence taken out of service), 3) The Works Engineer post at the plant was vacant (consequently the temporary bypass pipe assembly was designed by unqualified staff without reference to design standards or bellows unit manufacturer), 4) The bypass pipe assembly was not properly supported (rested on scaffold), 5) Bellows unit was exposed to transverse loads (due to inadequate support), 6) Proximity of control room to the plant.

Root causes included: 1) Lack of hazard awareness (limited data available on potential consequences of UVCEs at the time), 2) Inadequate design (bypass piping assembly including re-use of existing bellows units), 3) Inadequate risk assessment (absence of bellows unit failure modes and effects analysis), 4) Inadequate quality assurance (no inspection and testing of bypass piping assembly), 5) Inappropriate plant layout (control room too close to plant), 6) Inadequate management of change (to plant and organisation), 7) Inadequate leadership (failure to investigate cause of cracking in bypassed reactor - later found to be external nitrate stress corrosion cracking - and to inspect remaining reactors for similar cracks), 8) Inadequate emergency response planning (major loss of plant inventory), 9) Inadequate land use planning (close proximity of local housing).

Lessons Learned

1) All plant modifications should undergo a rigorous safety, engineering and technical (management of change) review, 2) The positioning and structural design of occupied buildings and control rooms close to process plant require careful consideration, 3) Management should provide role clarity and training for staff to avoid unconscious incompetence (staff unaware of their own limitations), 4) New legislation was developed (UK Health & Safety At Work Act, UK Pressure Systems Regulations, EU Seveso Directive, etc).

More Information

1) “The Flixborough Disaster: Report of the Court of Inquiry”, Her Majesty's Stationery Office, London (1975), ISBN 011-361075-0.
2) “Flixborough: Lessons Which Are Still Relevant Today”, R. Turney, IChemE Loss Prevention Bulletin 237 (2014).
3) “100 Largest Losses in the Hydrocarbon Industry”, Marsh Property Risk Consulting Practice, 27th Edition (2022).

Industry Sector	Process Type	Incident Type
Petrochemicals	Caprolactam	Explosion & Fire
Equipment Category	**Equipment Class**	**Equipment Type**
Mechanical	Piping	Expansion Joint