Lessons Learned Database
Individual Incident Summary Report

IChemE
Safety & Loss Prevention
Special Interest Group

Incident Title	**Hydrogenation Reactor Catastrophic Failure**	
Incident Type	Explosion and Fire	
Date	3rd June 2014	
Country	Netherlands	
Location	Moerdijk, NB	
Fatalities	**Injuries**	**Cost**
0	2	Unknown

Incident Description

Credit: Dutch Safety Board (OVV)

A styrene monomer and propylene oxide (MSPO) chemical intermediate manufacturing plant was being restarted after a routine catalyst changeout. The hydrogenation reaction section of the plant had been successfully air-freed, leak-tested, flushed with ethyl benzene (EB), placed on circulation with a fresh charge of EB, and allowed to "line out" to ensure the catalyst bed was wetted and heated homogeneously. The next step of the startup procedure was heat up ("reheat") of the trickle-bed reactors in preparation for reduction of the active metals on the catalyst. The Control Board Operator decided the reheat step was proceeding too slowly and manually increased the heat up rate. An unexpected exothermic (heat-liberating) runaway chemical reaction occurred which generated gases and rapidly increased the reactor pressure. This was not recognised as flows and levels were fluctuating widely and alarms were sounding regularly (as expected from previous restarts). Two explosions occurred in rapid succession and a major fire followed.

Incident Analysis

Basic cause was overpressure of the reactor due to presence of hot spots created by an exothermic EB dehydrogenation reaction catalysed by the fresh (un-reduced) catalyst during the reheat step of the startup procedure.

Critical factors included: 1) The new catalyst contained more active metals in oxidised form than the original catalyst (tests on the original catalyst in 1977 showed it to be inert to EB), 2) Inadequate wetting of the catalyst pellets during the reheat step (due to EB flow instability), 3) The product separator gas vent to flare system tripped closed on high level (to prevent liquid discharge to flare) but was not reset by the Control Board Operator when the level returned to normal (this had the unintended consequence of preventing venting of gases generated by the runaway reaction), 4) The remote-operated emergency block valves (EBVs) were disabled by the explosion.

Root causes included: 1) Inadequate communication between catalyst supplier and operator (new formulation not explicitly reported), 2) Inadequate management of change (new catalyst formulation not re-tested and changes to startup procedure not reviewed), 3) Inadequate instrumentation (reactor thermometry), 4) Inadequate design (absence of automatic controls for heat up during reheat step, product separator high level trip closing gas vent to flare, pressure relief system undersized for the unexpected chemical reaction), 5) Failure to adequately investigate similar incident at sister plant.

Lessons Learned

1) Quantitative reaction hazard assessment data (thermal stability tests, calorimetry, etc) should be used to inform design of appropriate safeguards,
2) A rigorous management of change (MoC) review should be carried out before any changes are made to process plant or operating procedures,
3) Operating procedures should clearly identify safety-critical steps and any relevant limits on key operating variables.
4) Control systems should be designed to provide stable process control under transient (e.g. startup) as well as steady-state conditions.

More Information

1) "Explosions MSPO2 Shell Moerdijk", Dutch Safety Board (OVV), The Hague, July 2015.
2) "CAST Analysis of the Shell Moerdijk Accident", N.G. Leveson, Massachusetts Institute of Technology (MIT) for the E.U. Major Accident Hazards Bureau (2016): http://sunnyday.mit.edu/shell-moerdijk-cast.pdf.

Industry Sector	Process Type	Incident Type
Petrochemicals	Styrene Monomer	Explosion & Fire
Equipment Category	**Equipment Class**	**Equipment Type**
Mechanical	Vessel	Reactor

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