

Incident Title		LNG Peak Shaving Plant Explosions	
Incident Type		Explosion and Fire	
Date		31 st March 2014	
Country		USA	
Location		Plymouth, WA	
Fatalities		Injuries	Cost
0		5	US\$ 72 m (2014) – Ref. 2
Incident Description		<p>The Plymouth liquified natural gas (LNG) peak shaving plant takes natural gas from the Northwest Pipeline (NWPL) interstate transmission system, purifies it by removing carbon dioxide (CO₂) and water vapour, then liquefies and stores the purified LNG for future vapourisation and compression back into the NWPL system during periods of peak demand. The purification system comprises 2 molecular sieve adsorbers (1 operating, 1 regenerating), a regeneration gas compressor, a salt bath heater (SBH) for heating the regeneration gas, hot and cold dust filters and associated piping and valves.</p> <p>On 31-Mar-14, the peak shaving plant was undergoing its annual startup. After bringing the SBH up to full operating temperature, the purification and regeneration (P&R) system was rapidly pressured up, the compressor was started and the automated P&R system was initiated. As the sequential logic-controlled valves aligned, flow through the P&R system commenced. Almost immediately, a series of internal explosions occurred in the regeneration gas piping between the SBH and the connected adsorber, causing the pipe to fail catastrophically at the SBH inlet. The adsorber also suffered a catastrophic failure, ejecting shrapnel in all directions and damaging the outer shell of a large LNG storage tank. The plant emergency shutdown (ESD) was initiated and everyone within a 3.2 km (2 mile) radius of the plant was evacuated.</p>	
 <p>Credit: US Dept. of Transportation</p>			
Incident Analysis		<p>Basic cause of the initiating pipe failure was auto-ignition of a flammable gas/air mixture as the it flowed to the inlet of the salt bath heater (SBH) during startup. The adsorber then failed due to rapid over-pressurisation caused by a rolling detonation against the flow of gas through the flammable zone.</p> <p>Critical factors included: 1) Open ends created when valves were removed from the hot dust filter (HDF) on 01-Nov-13 were covered in plastic and tape instead of blind flanges (allowing air to enter the P&R system), 2) Air-freeing of the system after the HDF valves were replaced on 18-Mar-14 involved 3 pressure and purge cycles using natural gas as the purge medium, 3) The adsorber piping configuration and the valve alignment specified in the purge procedure (single blowdown point) created a dead leg at the SBH (incomplete purge), 4) The P&R system was left at ~ 35 kPag (5 psig) after the final purge but a passing valve caused the system pressure to slowly rise to 365 kPag (53 psig), 5) The SBH was fired up before the P&R system had been pressurised, 6) The adsorber metallurgy was code-compliant but had low toughness and was susceptible to brittle fracture (fragmentation).</p> <p>Root causes included: 1) Inadequate purge procedure (too few purge points, blowdown target 35 kPag [5 psig] exceeded industry guidance of < 6.9 kPag [1 psig]), 2) Inadequate maintenance (passing valve), 3) Inadequate process monitoring (valve leak), 4) Inadequate materials of construction (adsorbers).</p>	
Lessons Learned		<p>1) Blind flanges should be used to seal open ends and prevent air ingress. 2) Piping layout, vent points and purge procedures should be designed to prevent the possibility of flammable mixtures accumulating in dead legs. 3) Use of an inert gas medium (e.g. nitrogen) for air-freeing is inherently safer.</p>	
More Information		<p>1) "Failure Investigation Report – Liquified Natural Gas Peak Shaving Plant, Plymouth, WA", US Dept. of Transportation (DoT) Pipeline and Hazardous Materials Safety Administration (PHMSA), 2016: Investigation Report. 2) "Pipeline Safety Violation Report", US DoT PHMSA, 2016: Violation Report.</p>	
Industry Sector		Process Type	Incident Type
Oil & Gas		LNG Purification	Explosion & Fire
Equipment Category		Equipment Class	Equipment Type
Mechanical		Piping	Pipe