European Site #30 - Offsites (TKF)
Propane Storage Sphere Rupture

Safety Impact			Environmental Impact		Production Impact		Damage
Fatalities	Injuries	First Aid	Leak Volume	Reportable	Days	Cost	Cost
18	84	?	Large	Yes	?	$$$$$	$$$$

The Incident

An operator was draining water from a propane storage sphere via a DN 50 (2" NS) vertical drain leg below the sphere. The drain leg had 2 manual isolation valves in series. The lower valve was opened half-way first, then the upper valve was opened even further (contrary to procedure). When draining was almost complete, the upper valve was closed, then cracked open again. No flow was observed so it was opened fully. Propane suddenly started gushing out. The handle came off the upper valve and could not be reinstated. Attempts to close the lower valve failed as it had frozen in the half-open position. The liquid portion of the leaking propane was retained by the bund but a large vapour cloud formed and drifted in all directions. The emergency services were alerted and traffic was stopped on the nearby motorway. However, the vapour cloud found an ignition source at a car on a minor road which had not been closed in time and flashed back causing a fierce fire beneath the sphere. Around 60 minutes later, a boiling liquid expanding vapour explosion (BLEVE) occurred as the sphere ruptured. Flying shrapnel from the ruptured sphere struck the support legs of an adjacent sphere which then collapsed and toppled over. The PSV on the toppled sphere began discharging liquid which further fed the fire. Around 45 minutes later, this second sphere ruptured in another BLEVE. 3 other spheres collapsed and ruptured but did not explode. 2 bullets and 4 nearby floating roof fuel tanks were also destroyed. 18 people (including 11 firefighters) were killed and a further 84 were injured.

Background

The LPG storage area comprised 4 x 1200 m^3 propane storage spheres, 4 x 2000 m^3 butane storage spheres and 2 x 150 m^3 storage bullets (1 each for propane and butane). The 8 spheres were located inside a 0.5 m high rectangular bund with a central 0.25 m high dividing wall in the centre with each half section containing 4 spheres. The closest bund wall was less than 50 m away from a public motorway and about 300 m away from the nearest homes.

Causes

The immediate cause of the first fire was ignition of a vapour cloud formed by accidental release of a large quantity of propane from the open drain. The immediate cause of the first BLEVE was fire engulfment and overheating of the sphere. Critical factors included 1) the lower drain valve was erroneously opened before the upper drain valve (causing Joule-Thomson chilling and ice or hydrate formation), 2) the ground under the sphere was level (allowing pooling of leaked propane in the bund), 3) the firewater pump capacity was insufficient to protect all the spheres and 4) the local fire brigade did not try to cool the burning sphere, mistakenly believing it would be protected by its PSV (they directed their hoses to cool four adjacent spheres instead). Root causes included 1) failure to follow procedure (valve operating sequence), 2) inadequate drain system design (removable valve handles, open discharge in close proximity to valves), 3) inadequate sphere support leg design (not reinforced), 4) insufficient active (water spray) and passive (insulation) fire protection, 5) inadequate overpressure protection (no remote depressuring valve) and 6) failure to brief the local fire brigade on how to deal with this type of incident.

Lessons

Storage sphere support legs should be reinforced (for shrapnel impact protection). The sphere and its support legs should be insulated (for fire protection). The ground below the sphere should be sloped towards a collection pit located remotely (to avoid pooling below). A deluge system capable of flooding the outer (insulated) surface of the sphere should be provided (and regularly tested). The sphere drain nozzle should be DN 50 (2" NS). The drain line should include a remote-operated, accessible, fire-safe, quick shut-off valve (at min distance from the drain nozzle) and a throttling valve at least 1 m (3 ft) further downstream. It should reduce to DN 19 (¾" NS) downstream of the throttling valve (to restrict flow). It should be self-draining with no pockets and well-braced to minimise vibration while in operation. The number of flanges in the line should be minimised and screwed fittings should be prohibited (except for instruments). A flammable gas detection system alarming to DCS should be provided (for early leak detection).

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