Safety Considerations in the Design of LPG Storage Vessels

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Discussion Outline

✓ Hazards of LPG Storage
  • Vapor Cloud Formation
  • BLEVE
  • Jet Flame Flash Fire

✓ Safety Design Features
  • Concept of Single Inlet/Outlet Nozzle in Liquid Zone
  • Impounding Basin/Diking/Catchment Area
  • Fire Protection System (incl. fireproofing)
Hazards of LPG Storage:

- **Major Incidents**: Incidents at Feyzin and Mexico have given impetus to study the hazards associated with LPG Storage.

- **Vapor Cloud Formation** – Large inventory, density of LPG higher than air, unconfined vapor cloud (drifting) and delayed ignition.

- **BLEVE** – When LPG sphere is subjected to external fire.

- **Jet Flame Flash Fire** – Joint Failure or small bore pipe failure
Effects of BLEVE:

- Duration of fireball is 20-40 secs depending upon the mass of liquid release.

- Diameter of typical fireball from release of 2400 m$^3$ LPG sphere is estimated as ~500m. Actual dia of fireball (Mexico) estimated from photograph to be ~200-300m.

- In case of delayed ignition, damage is due to blast wave generated by explosion.
Jet Flame Flash Fire

- Loss of containment (leak) results in continuous jet of hydrocarbons results in torch or jet flame.

- Impingement of jet flame on structure, pipeline or vessel is very damaging because of high intensity of heat release.

- Un-ignited hydrocarbons will form vapor cloud and may cause flash fire.

- Pressure Safety Valves may create similar scenarios.
<table>
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<th>Safety Design Features</th>
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<td>Concept of a single nozzle in the liquid zone.</td>
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<td>Remote operated fire-safe emergency shut off valves</td>
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<td>Sloping and elongating the liquid nozzle.</td>
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<td>Redundancy of level instruments.</td>
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<td>Manhole at top of sphere.</td>
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<td>Insulation/fireproofing of sphere &amp; supports.</td>
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<tr>
<td>Paving and sloping of diking/impounding/ground underneath</td>
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<td>Gas/Fire detection, deluge and sprinkler system.</td>
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Concept of Single Nozzle in Liquid Zone

Provision of a single inlet/outlet nozzle in the liquid zone (bottom) of sphere extending 3m (min.) beyond shadow of sphere/bullet.

This is based on the concept that potential of leak Rate (mass/time) is much more in case of leak occurring in liquid zone than in vapor zone (upper zone)

Leak rate (kg/s/m²): Liquid phase-26000; vapor phase-2200; Two-phase-6500 (typical values).

Increase in number of nozzles in liquid zone increases the risk by way of increasing the chance of failure.
Typical Leakage Rates (kg/s) from failure of nozzles in liquid or vapor phase

<table>
<thead>
<tr>
<th>Leak Rate</th>
<th>Liquid Phase</th>
<th>Vapor Phase</th>
<th>Two Phase</th>
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<tbody>
<tr>
<td>kg/s/m²</td>
<td>26000</td>
<td>2200</td>
<td>6500</td>
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Typical values of risks (figures denote risk/million yr at a distance of 100m from sphere)

<table>
<thead>
<tr>
<th>Risk scenario</th>
<th>Single Nozzle at bottom</th>
<th>Multiple nozzles at bottom</th>
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<tbody>
<tr>
<td>Risk due to flash fire</td>
<td>8.5</td>
<td>21</td>
</tr>
<tr>
<td>Risk due to 5psi overpressure</td>
<td>39</td>
<td>72</td>
</tr>
<tr>
<td>Risk due to 2 psi overpressure</td>
<td>39</td>
<td>72</td>
</tr>
<tr>
<td>Risk for fatality</td>
<td>32</td>
<td>64</td>
</tr>
</tbody>
</table>
Typical LPG Sphere with Single Inlet/Outlet Nozzle

SAFETY FEATURES OF LPG SPHERE (TYPICAL)

NOTE:
- MANHOLE AT TOP ONLY
- INLET/OUTLET NOZZLE STRESS-RELIEVING WITH SPHERE
- SLOPE IN SUCH A WAY THAT SPILLAGE FROM ROV (INLET/OUTLET) FLANGE DOES NOT PASS UNDER SPHERE
Typical LPG Sampling Connections

SKETCH SHOWING TYPICAL WATER DRAW-OFF AND SAMPLING CONNECTIONS ON LPG STORAGE VESSELS

NOTES:
1- Anti-freeze, quick action (quarter-turn) valve, and shall be located at least 3m beyond the shadow of the vessel.
2- Second Isolation valve (globe) to be located ≥ 0.6m from the first valve; it shall be a spring-return type valve (ball/plug), and the drain line to be supported adequately against reaction forces.
3- Tundish to be located close to globe valve to enable the operator to see draining operation (say, 2 m away from the operator) i.e. drain point shall be visible.
4- Drain connection from the tundish to be lowered sufficiently close to the sealed catch basin to prevent free-fall/splashing of water/LPG.
5- Water draw-off and Sampling connections shall be made of carbon steel and supported adequately.
6- Provision of bonding connection between sampling pipe and sampling bomb to be ensured prior to opening the inlet valve.
7- Both water draw-off and sampling connections shall be provided with adequate slope (say 1:50) to facilitate self-draining.
Impounding Basin/Diking/Catchment Requirements

- Design usually provides sloping of the ground underneath the vessel and an impounding basin or catchment to collect the leakage.

- Location of catchment must be away to prevent fire exposure. There is need for a separation distance between sphere and impounding basin/catchment.

- Height of flame may be approximated to twice the basin width. Article (Ref 6) recommends a min separation distance of flame height (thumb rule).
Typical LPG Storage Layout and Impounding Basin/Catchment Area
Fireproofing

It is important to ensure thermal protection during initiation of the event. However, there is evident of corrosion under insulation due to ingress of water.

Vessel legs are usually fireproofed with concrete.
Conclusions

Design parameters to minimize hazard potential or probability of occurrence can be analyzed by use of various risk analysis tools.

It is important that such design intentions are not violated during engineering and operational phase of the facilities.