



Safety Considerations in the Design of LPG Storage Vessels

Bejoy Bharatiya

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 m³ 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.

Safety Design Features

- ☞ Concept of a single nozzle in the liquid zone.
- ☞ Remote operated fire-safe emergency shut off valves
- ☞ Sloping and elongating the liquid nozzle.
- ☞ Redundancy of level instruments.
- ☞ Manhole at top of sphere.
- ☞ Insulation/fireproofing of sphere & supports.
- ☞ Paving and sloping of diking/impounding/ground underneath
- ☞ Gas/Fire detection, deluge and sprinkler system.

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.

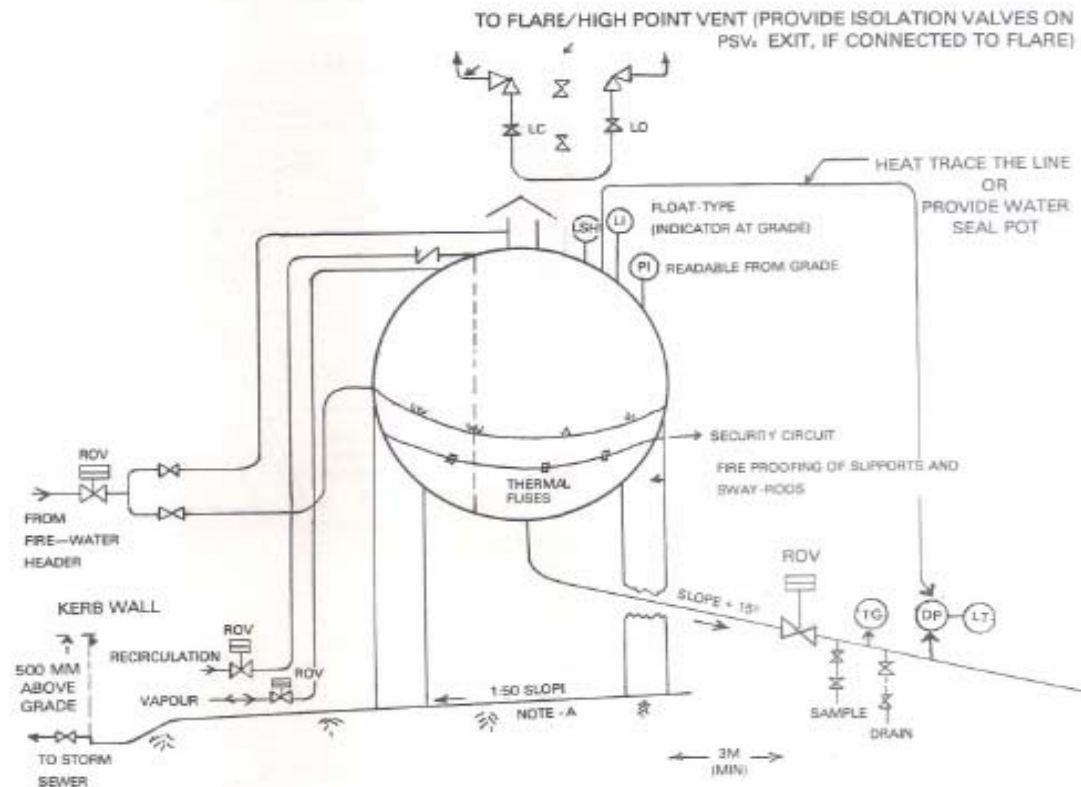
Typical Leakage Rates (kg/s) from failure of nozzles in liquid or vapor phase

Leak Rate	Liquid Phase	Vapor Phase	Two Phase
kg/s/m ²	26000	2200	6500

Typical values of risks (figures denote risk/million /yr at a distance of 100m from sphere)

	Single Nozzle at bottom	Multiple nozzles at bottom
Risk due to flash fire	8.5	21
Risk due to 5psi overpressure	39	72
Risk due to 2 psi overpressure	39	72
Risk for fatality	32	64

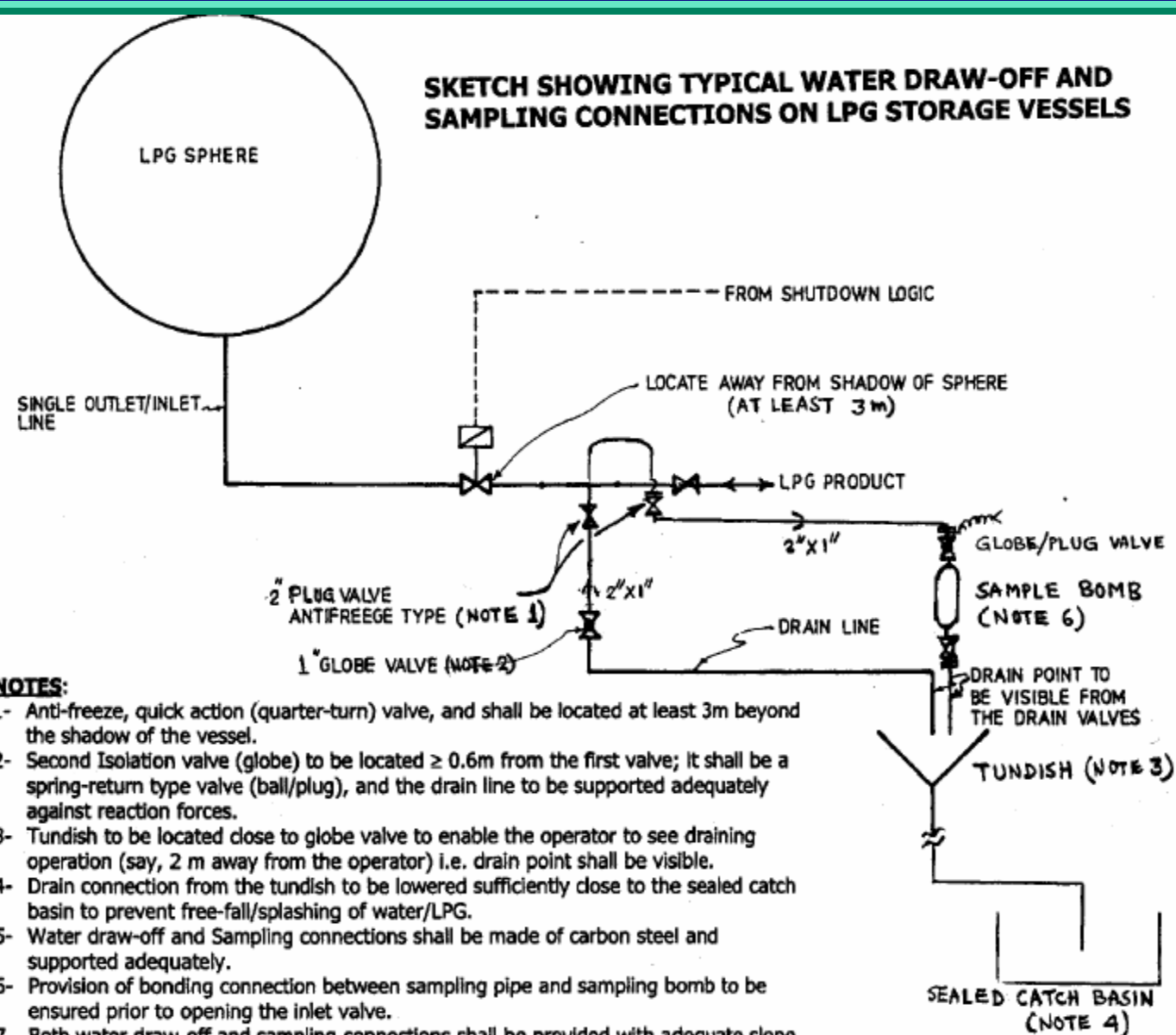
Typical LPG Sphere with Single Inlet/Outlet Nozzle



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

SAFETY FEATURES OF LPG SPHERE (TYPICAL)

Typical LPG Sampling Connections



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.

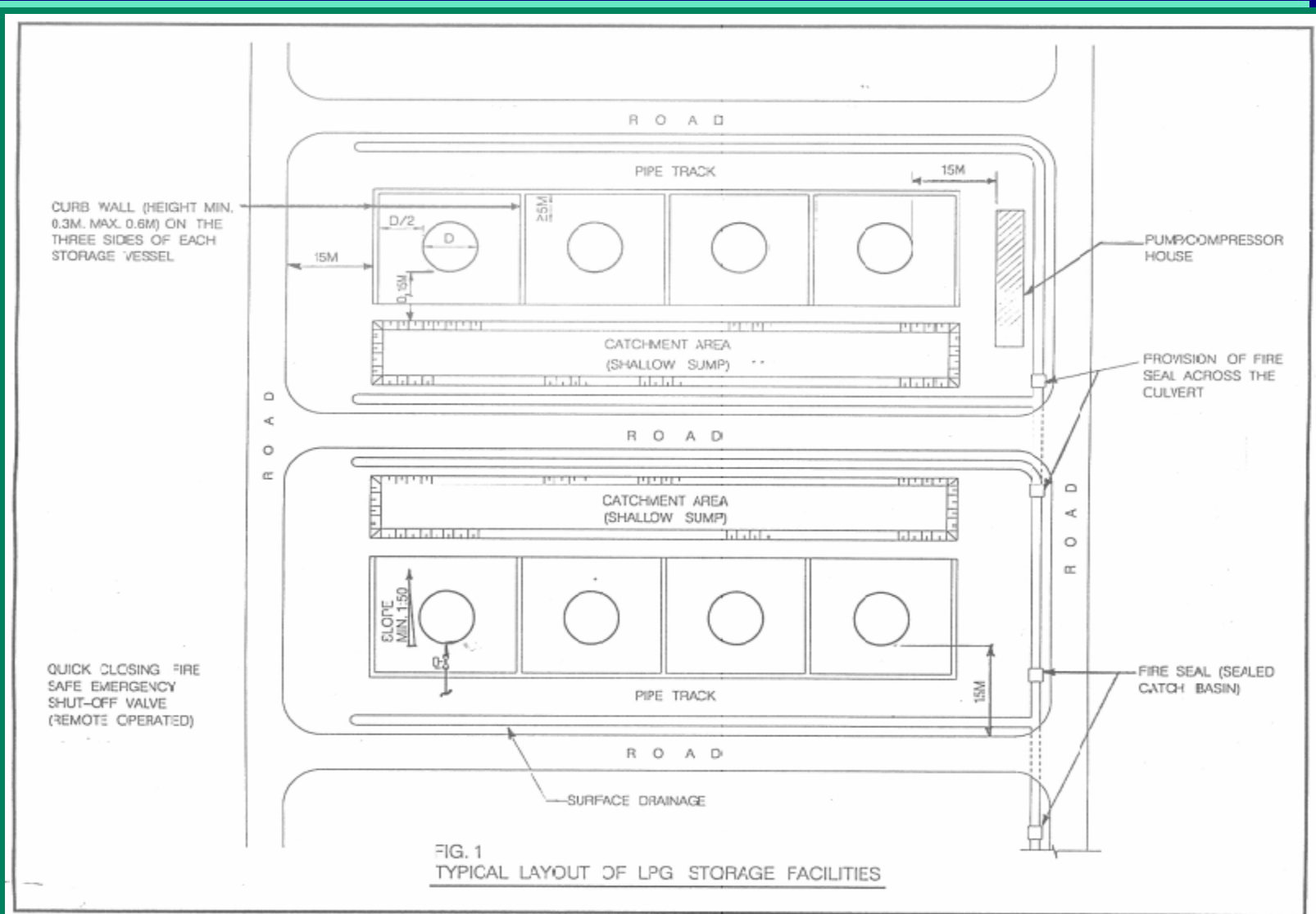


Location of catchment must be away to prevent fire exposure. There is need for a separation distance between sphere and impounding basin/catchment.



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.