Sphere Storage Risk Evaluation xxxxxx Refinery Co.

Prepared and

Presented by HSB PLC

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Executive Summary

- The focus of the risk evaluation was to provide QRA of potential LPG accidental releases which could lead to intolerable fire or explosion events and consequential exposure to plant operations, personnel, and the public.

- Consequence and event tree probability models were applied to evaluate the LPG spare storage fire and explosion risk.

Executive Summary

- Result
  - BLEVE(Boiling Liquid Expanding Vapor Explosion)
    - approximately **4×10^{-4}** incidents per sphere tank farm year
    - approximately **3000ft** exposure personnel and community
  - UVCE(Unconfined Vapor Cloud Explosion)
    - approximately **6×10^{-6}** incidents per sphere tank farm year
    - approximately within **500 ft** radius blast damage to tanks, processing unit and equipment

Executive Summary

- Risk Reduction Recommendations
  - Short-term
    - include a fire protection strategy ***fireproofing or improved water spray*** coverage - flanges, valves, fittings and liquid LPG piping connected to the bottom of the sphere tanks
    - include a strategy to optimize the use of the existing water spray systems in terms of response time by considering the installation of remotely actuated control valves
  - Long-term
    - consider include risk reduction for ***sampling and water draw-off operations*** which involve human error factors
    - provision of a tank water flooding connection would provide the benefit of displacing LPG with water if an accidental release occurs at the bottom of the tank and can not be readily isolated

Risk Evaluation Approach

The risk evaluation process performed by HSB PLC integrates the judgment of experienced engineers, techniques of deterministic and probabilistic modeling, and historical fire and explosion loss incident data.

- ***Identification and selection of LPG system failure modes***
- ***Fire and explosion consequence modeling***
- ***Risk analysis using event tree models***
- ***Risk reduction measures***

Risk Evaluation Approach

- Failure Mode Assessment
  - Leakage from valve stem seals and flange gaskets
  - Leakage when taking a sample or drawing water
  - Leakage from transfer piping because of corrosion, mechanical damage, or from screwed piping connection
  - Failure of a transfer pipe flexible joint or cargo hose at the interface between a fixed facility and a truck, railroad tank car, or tank ship
  - Leakage from a storage vessel because of corrosion
  - Tank overfilling, which forces liquid out the pressure relief safety valves

Risk Evaluation Approach

- Consequence Modeling
  - LPG release mode(instantaneous or continuous)
  - Rate and duration of LPG discharge
  - Time to ignition
  - Initial mixing with air and cloud dispersion characteristic
  - Performance of risk reduction measures to reduces….
    - Touch fire
    - Flash fire due to delayed ignition of a vapor cloud
    - BLEVE(Boiling Liquid Expanding Vapor Explosion)
    - UVCE(Unconfined Vapor Cloud Explosion)

Risk Evaluation Approach

- Risk Analysis Using Event Tree Models
  - Design Effectiveness
  - Availability
  - Reliability

$$P_S = P_{DAB} \times P_{OLA} \times P_{OR}$$

DAB : Effectiveness Design Application Basis

OLA : Online Availability

OR : Operational Reliability on Demand

Risk Evaluation Approach

- Proposed Risk Reduction Measure

Risk Tolerance Incidents/Year	Risk Reduction Actions
>1.0 x 10-3	Further risk evaluation and risk reduction need
1.0 x 10-3 to 1.0 x 10-5	Further risk evaluation and risk reduction warranted, should be considered
<1.0 x 10-5	Further risk evaluation and risk need not be considered

LPG Fire and Explosion Incident Data

- A relative breakdown of consequential effects in terms of type of fire or explosion and/or in terms of resulting damage
- Identification of representative or dominant failure mode which have led to accidental release LPG
- Identification of ignition sources and, in some cases, the size of the release prior to ignition
- Information concerning the general effect of loss mitigation factors
- Information for the generation of credible loss scenarios and the structuring or event tree analysis

LPG Fire and Explosion Incident Data

In this study of LPG releases over a 30-year period, API lists the following major release causes:

- Leakage from valve stem seals and flange gaskets
- Leakage when taking a sample or drawing water
- Leakage from transfer piping - corrosion, mechanical damage, screwed piping connections
- Failure of transfer pipe flexible joint or cargo hose
- Leakage from a storage vessels - corrosion
- Tank overfilling, which forces liquid out the pressure relief safety valves

LPG Fire and Explosion Incident Data

Relative percentage of accidents from 80 LPG fire and explosion loss incidents:

Type of incidents	Percentage
Flash Fire	41%
BLEVE	21%
UVCE	19%
CVE	19%

LPG Fire and Explosion Incident Data

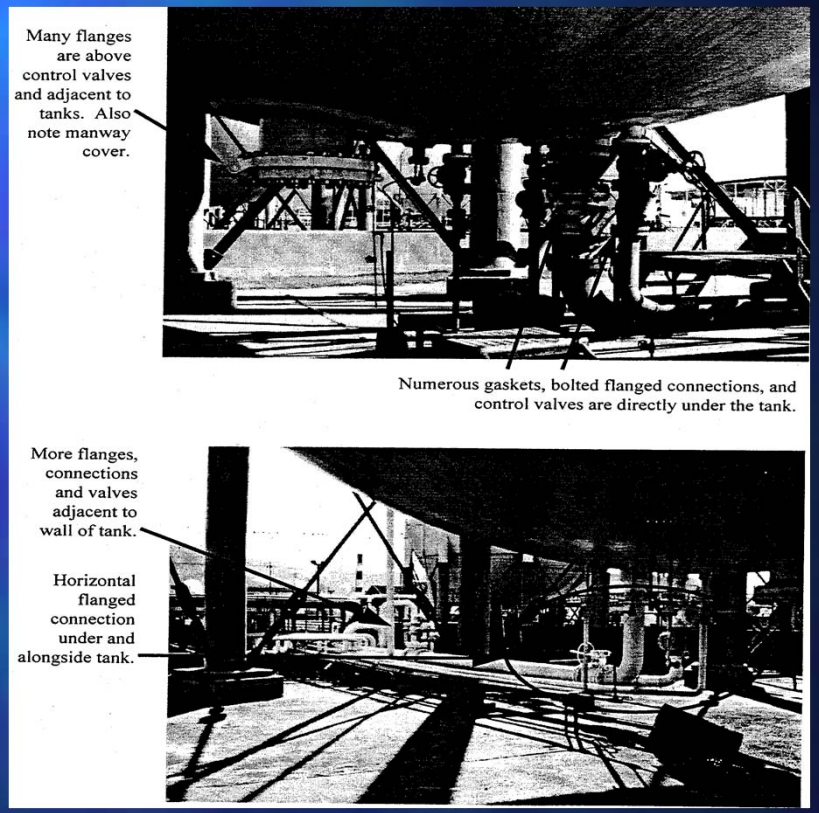
- Immediate Causes
  - Hose Rupture
  - Overfilling
  - Freezing of pressure release valve in the open position
  - Rupture/leakage of tank connections
  - Collision of motorized vehicles during operation
  - Maintenance error
  - Natural causes
- Ignition Causes
  - Motorized vehicles
  - Electric motors and switch gear
  - Electrical lights and switches
  - Atmospheric discharges (lightning)
- Ignition distance ***15-180m***
- Ignition delay of up to ***35 minutes***

Failure Mode Assessment

- Leakage from flanges, valves and fittings located at the bottom of tanks
- Failure to isolate following sampling or water draw-off operations
- Failure of LPG liquid transfer lines connected to bottom of tanks
- Failure of LPG vapor lines and connected to top of tank
- Liquid overflow from relief vent due to overfilling
- Major tank failure

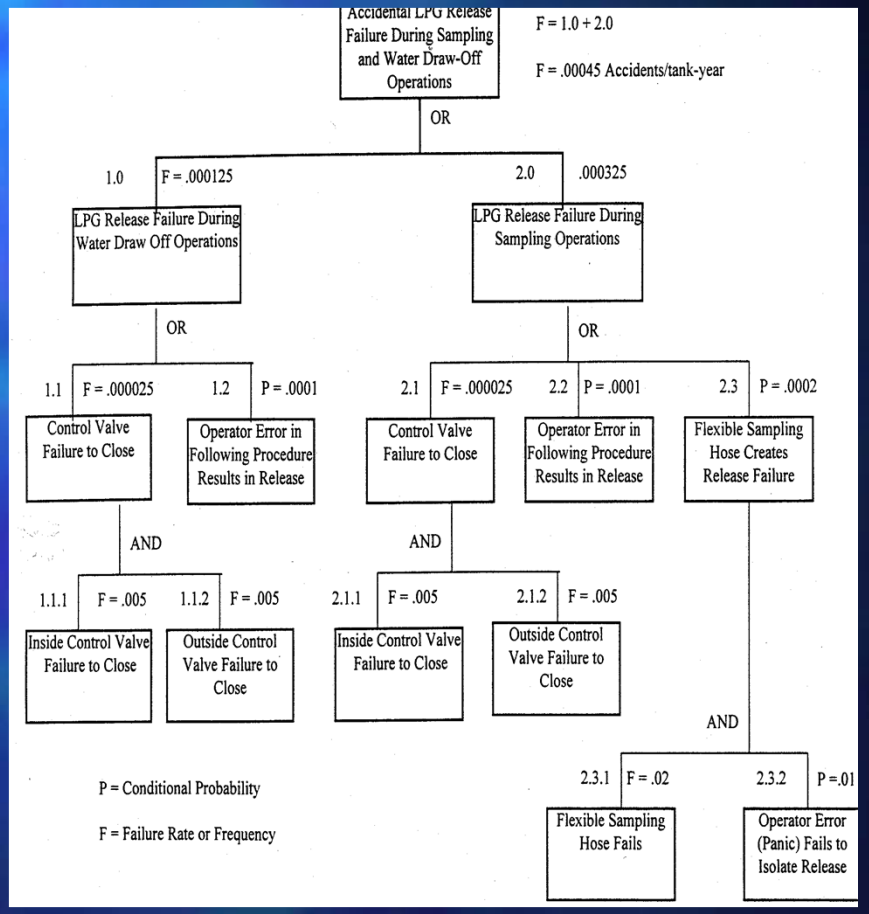
Failure Mode Assessment

- Leakage gaskets, valves…
  - 6-inch fill line
  - 10-inch discharge line
  - 4-inch recirculation
  - 2-inch water draw-off
  - 1-inch sampling line
  - Instrumentation connection
- Failure rate $0.0099/10^6$ Hr (CCPS RT Data)
- Potential failure rate 0.022/tank farm year



Failure Mode Assessment

- Failure to isolate sampling or water draw-off
  - Estimated failure rate 0.00045/tank year
  - Estimated failure potential 0.009/tank farm year



Failure Mode Assessment

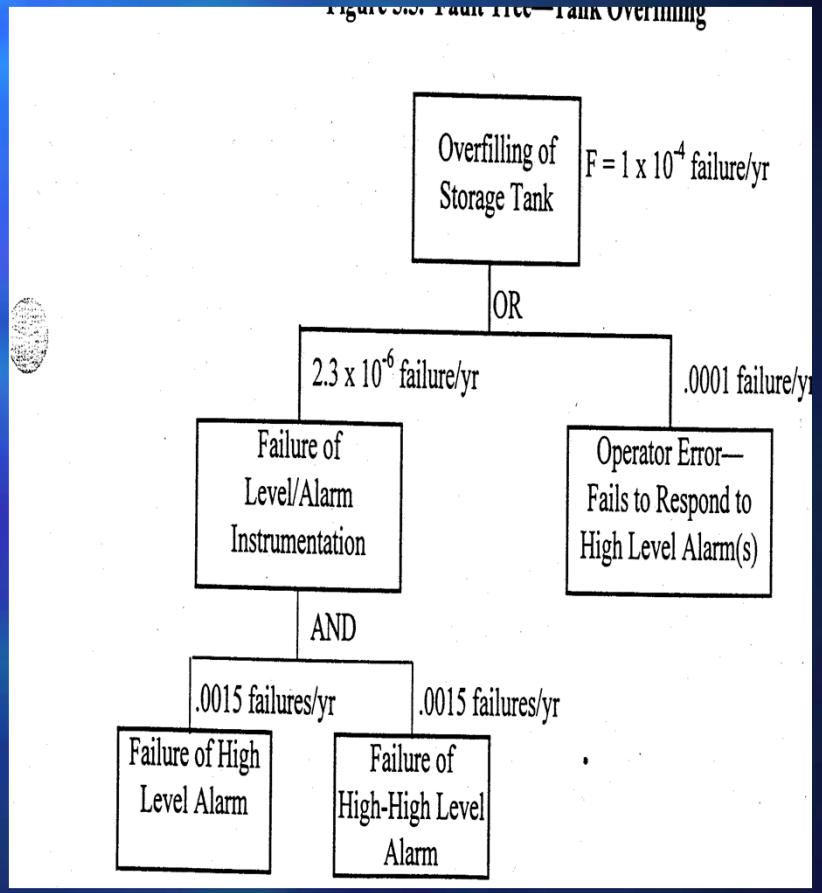
- On the majority of spherical tanks there are five liquid line piping connections to the bottom of the tank which are 1-inch or greater
  - 6-inch fill line
  - 10-inch discharge
  - 4-inch recirculation
  - 2-inch water draw-off
  - I-inch sampling line
- Estimated failure rate $0.000335(3.35 \times 10^{-4})$
- Estimated failure potential $0.0007(7.0 \times 10^{-4})$

Failure Mode Assessment

Item	Size of Failure	Failure Rate
Small≤50 mm diameter (<2 inch piping)	Full bore rupture	8.8×10^{-7}(m yr-1)
	20% of pipe diameter	8.8×10^{-6}(m yr-1)
Medium>50mm diameter ≤150mm diameter (2-10 inch piping)	Full bore rupture	2.6×10^{-7}(m yr-1)
	20% of pipe diameter	5.3×10^{-6}(m yr-1)

Failure Mode Assessment

- Overfilling prevention
  - High level/alarm
  - High-high level/alarm
  - High pressure Tr/alarm
  - Manual shutdown
- Failure rate $0.17/10^6$
- Estimated failure rate 1.0×10^{-4}
- Estimated failure potential 2.0×10^{-3}

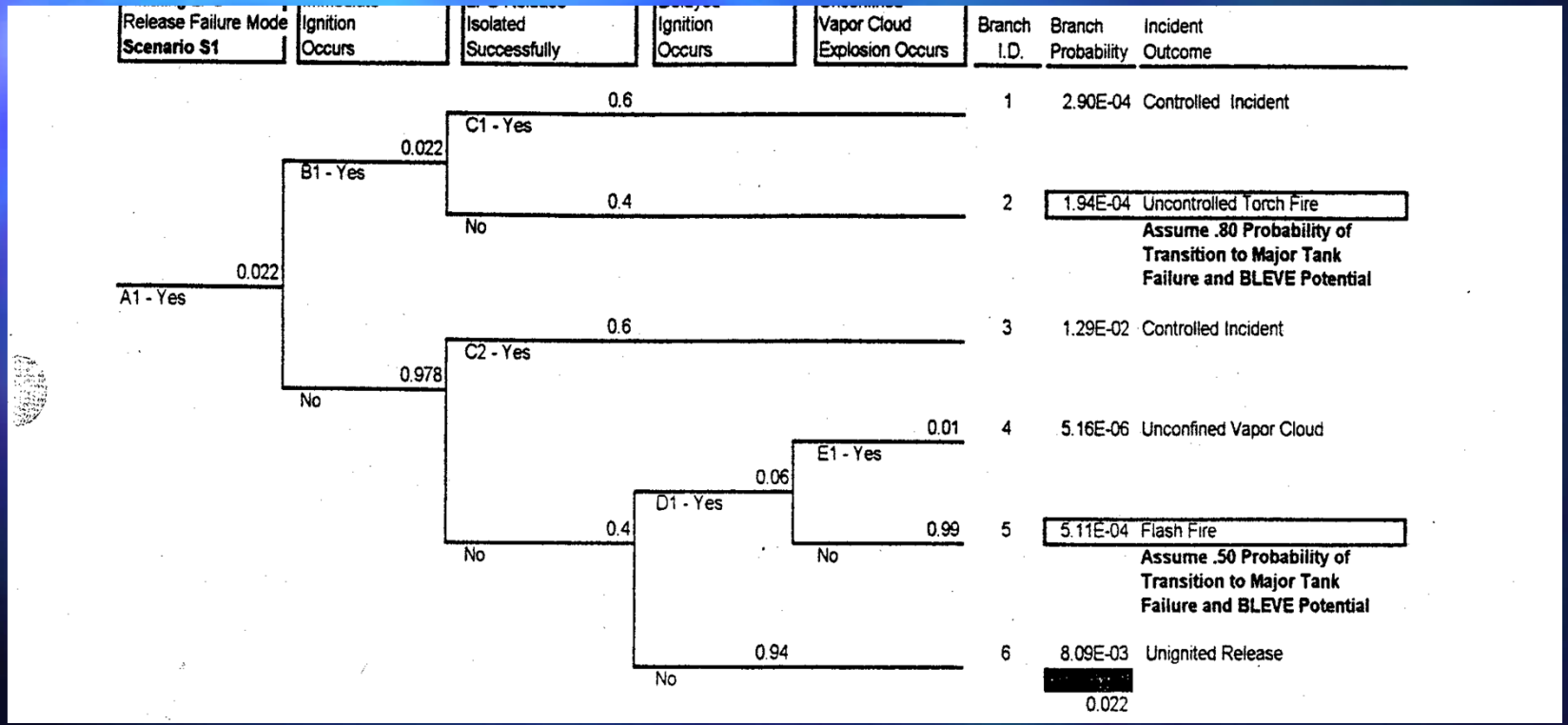


Failure Mode Assessment

- Major Tank Failure : Primary factors which contribute to failure rate potential include the following
  - Design philosophy and quality
  - Inspection philosophy and quality
  - Maintenance philosophy and quality
  - Operational philosophy and quality
  - Safety standards
- Estimated failure frequency 8.3×10^{-6}/year
- Estimated failure potential frequency 1.7×10^{-4}/year

Risk Analysis

- S1 Event tree analysis(Leakage flange, valve….)



UVCE and BLEVE Likelihood

Scenario	UVCE Likelihood	BLEVE Likelihood
S1 Leakage from Flanges,Valves, Fittings at BTM of Tank	5.16 x E-06	1.70 x E-04
S2 Failure to Isolate Following Sampling or Water Draw-Off	5.75 x E-06	1.04 x E-04
S3Fracture of LPG Liquid Transfer Line Connected to BTM of Tank	5.89 x E-05	1.32 x E-04

Risk Analysis

- BLEVE Fireball Hazard Results

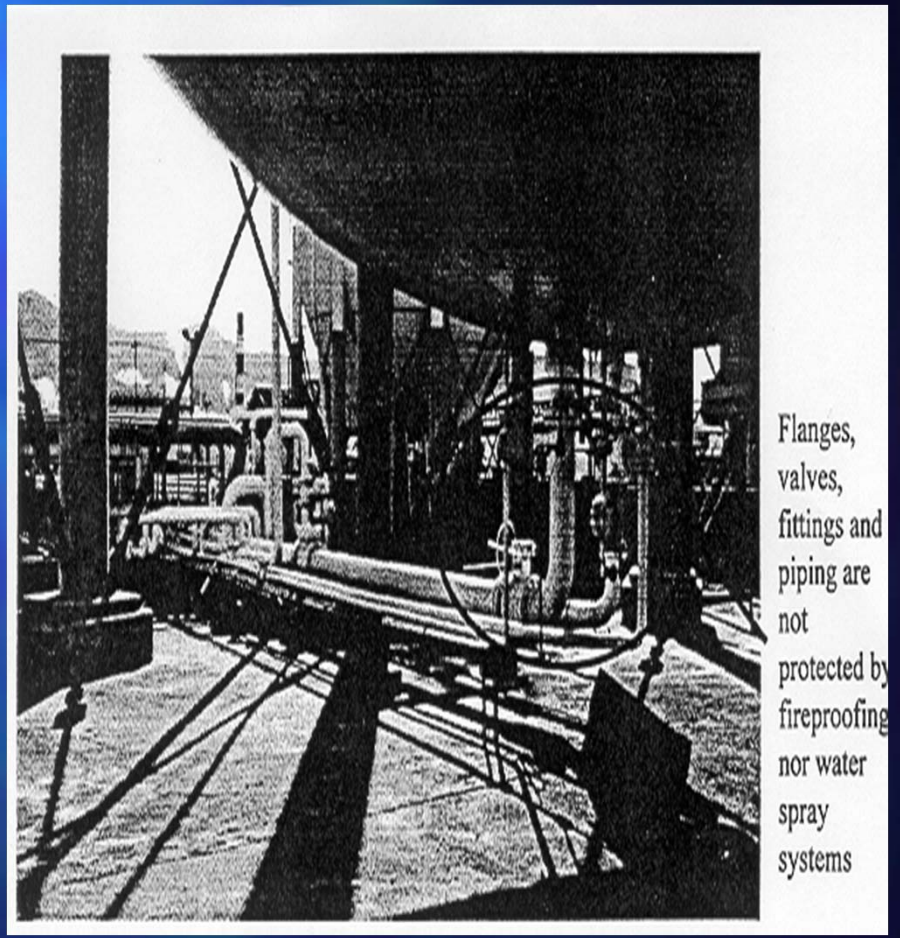
  - Maximum Fireball Diameter : ***455m***
  - Maximum Fireball Height : ***748m***
  - Fireball Duration : ***21.7sec***
  - Individual Risk Zone Radius : ***927m***
  - BLEVE Combined Likelihood : ***4.24×10^{-4}***

Risk Analysis

- Unconfined Vapor Cloud Explosion(UVCE)
  - 56m(15-29psi) : 90-100% PD, Major injury or fatality
  - 106m(5-7psi) : 70-90% PD, Moderate exposure to individuals
  - 146m(3-5psi) : 50-70% PD, Minor exposure to individuals
  - 218m(1-3psi) : 25-50% PD, Minor or negligible exposure to individuals

Proposed Risk Reduction Measures

- Protection of valves, flanges, and fittings at the bottom of tanks
  - Fireproofing
  - Water spray system improvements

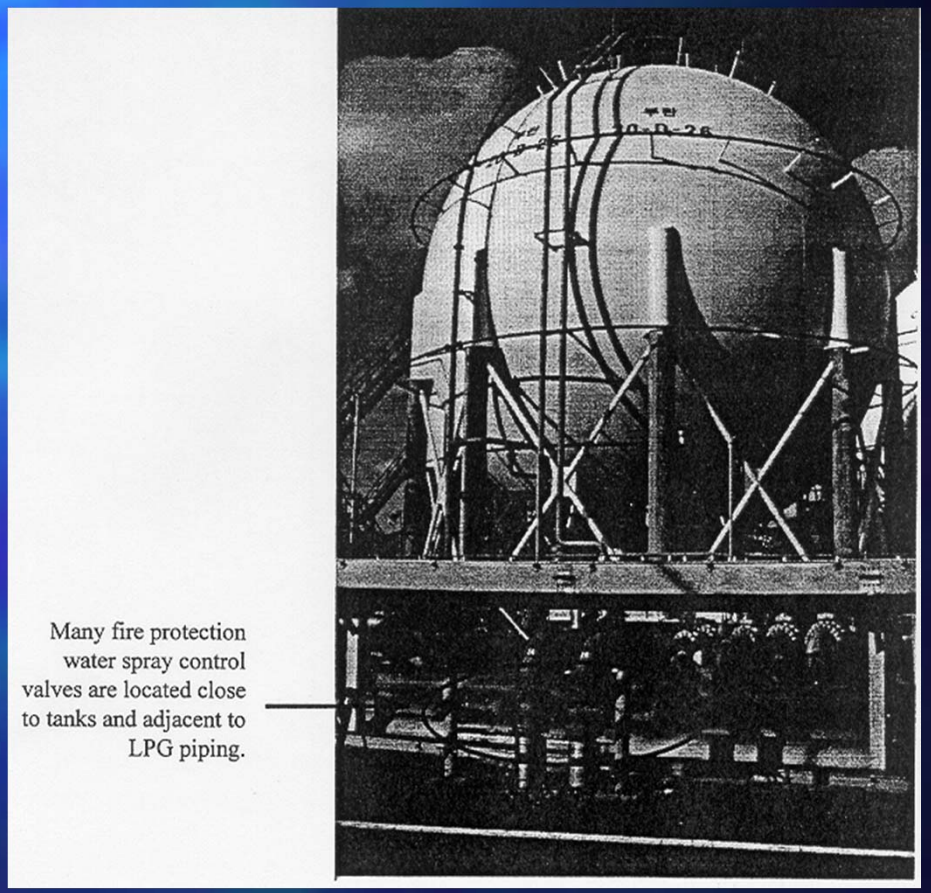


Flanges, valves, fittings and piping are not protected by fireproofing nor water spray systems

Proposed Risk Reduction Measures

- Remotely Actuated Water Spray System C/V

Control valves which can be remotely operated from a safe locations should be installed in place of the existing manual c/v valves to improve the performance success probability of the water spray system in providing quick, effective water spray cooling of the tanks for BLEVE prevention



Many fire protection water spray control valves are located close to tanks and adjacent to LPG piping.

Proposed Risk Reduction Measures

The control valves should be specifically designed for fire services use and fire rate. They should be fail safe and incorporate the following design feature

- Operation from safe, remote location, such as from the C/R which is constantly occupied
- Automatic operation at the valve via fusible element such as a section of plastic tubing in the air line to a pneumatic valve.
- Manual operation at the valve.

Proposed Risk Reduction Measures

- Reducing Risks During Sampling/Water Draw-off
  - Relocating sampling lines out from under the tanks

  * If this is not feasible, remotely actuated valves could be provided
  - A formal inspection,maintenance and testing program should be developed for the sampling and truck loading flexible hose
  - Water draw-off lines should terminate at least 10ft outside of the shadow of the tank
  - Clean drainage ditches

Proposed Risk Reduction Measures

- Water Flooding Connections
  - The provision of a water flood connection on the LPG product fill line connected to the bottom of the tank should be considered. This type of provision could be part of a contingency plan given a situation where release of LPG liquid occur from a tank bottom piping connection, flange, valve, or fitting which cannot be readily isolated.