7th CPSS

Chemical Process Safety Sharing

BLEVE Prevention on Liquefied Petroleum Gas Storage.

Webinar (Zoom)
May 07, 2021

Anupol Paiboonruamsilp (SCG)

Presenter Biography

Company : SCG Chemicals

Current Position : Lead Process Safety Engineer

Working Experience : 15 years

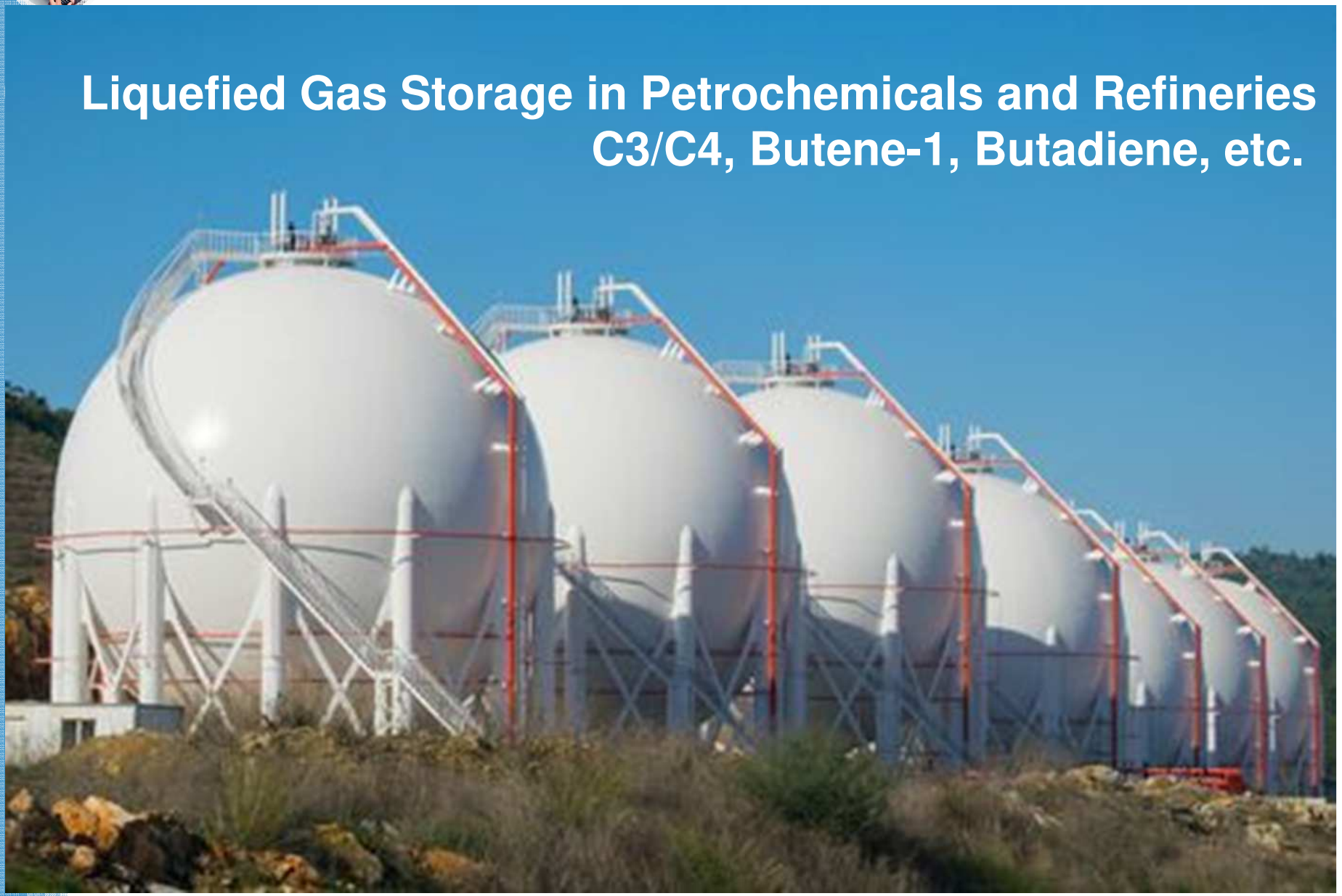
Anupol Paiboonruamsilp

Presentation Abstract:

Liquefied Petroleum Gas or LPG is commonly stored in the Petrochemical Industries and Refineries. A large inventory of the liquefied gas can cause catastrophe with the worst case consequence of a Boiling Liquid Expanding Vapor Explosion or BLEVE. There are many disasters in the past associated with a leakage from liquefied gas, and those lesson learnt have been taken as the design code and standard nowadays.

This presentation summarizes the essentials of Process Safety in Design taken from the listed International Code and Standards as well as Engineering Best Practice for the liquefied gas storage and handling. This is to prevent not just only a BLEVE but also other high hazards such as jet fire, flash fire or vapor cloud explosion etc. Since prevention of high hazards from liquefied gas storage must be integrated between prevention measures and mitigation measures. Moreover, the cycle of Process Safety Management or PSM will be taken into account to ensure safe operation of the liquefied gas handling including mechanical integrity of storage tank, safety protection system, and related equipment for mitigation.

Liquefied Gas Storage in Petrochemicals and Refineries
C3/C4, Butene-1, Butadiene, etc.



Major Hazards of Liquefied Gas Storage

Gas Dispersion

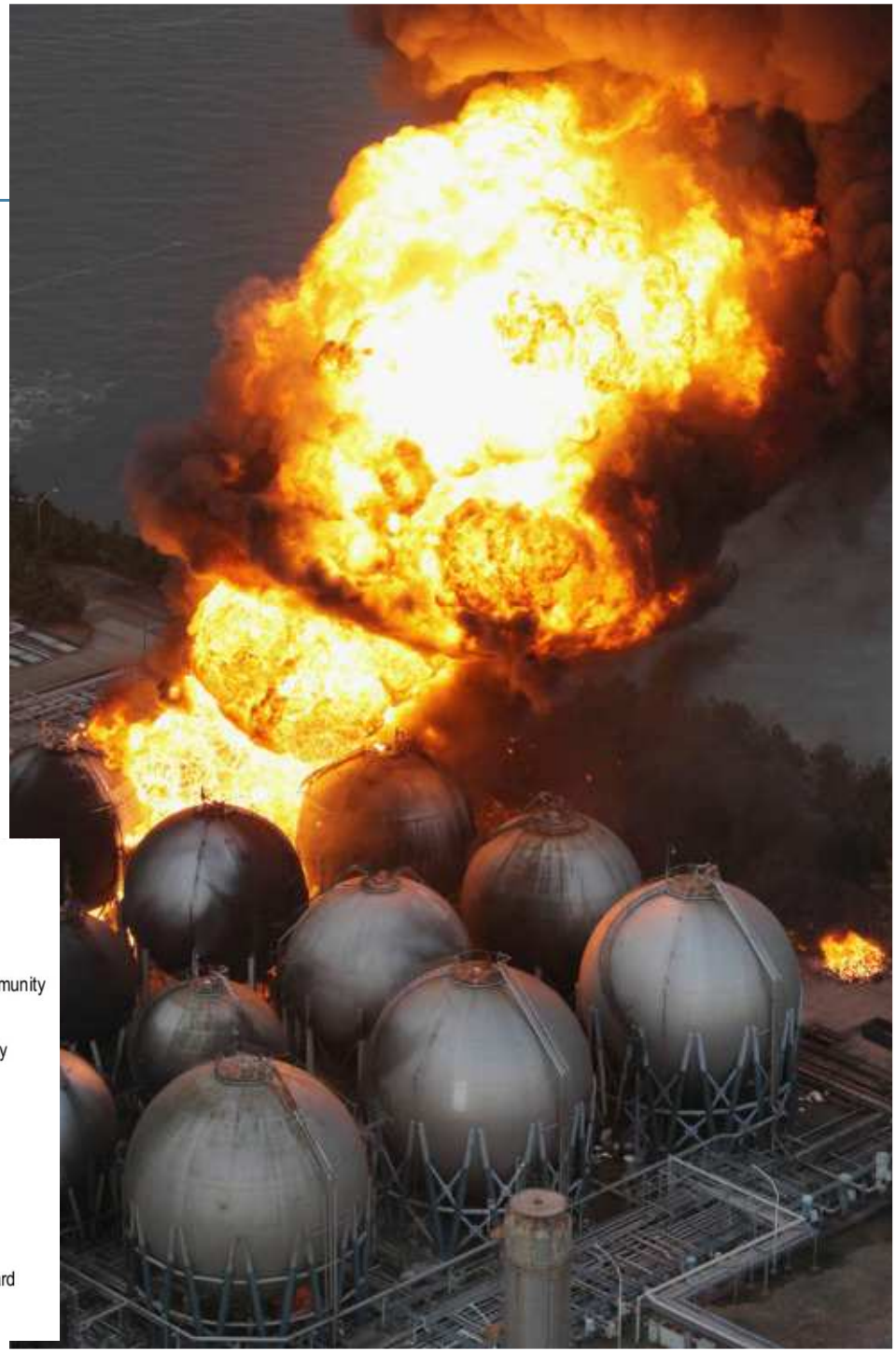
Jet Fire

Flash Fire

Vapor Cloud Explosion

BLEVE / Fire Ball

WHEN	WHERE	WHAT	FATALITIES	REGULATIONS
1966	Feyzin, France	LPG Bleve	18	First LPG prescriptive regulations
1984	Mexico	LPG Bleve	600+	US Emergency Planning and Community Right-to-Know Act 1986
1988	Norco, USA	Propane FCCU		US OSHA 1910-119 Process Safety Management 1992
1989	Pasadena TX, USA	Ethylene/ isobutane	23	
1992	La Mède, France	Gasoline/LPG FCCU	6	EU Seveso II Directive 1996
1998	Longford, Australia	LPG, brittle fracture	2	UK Control of Major Accident Hazard Regulations 1999



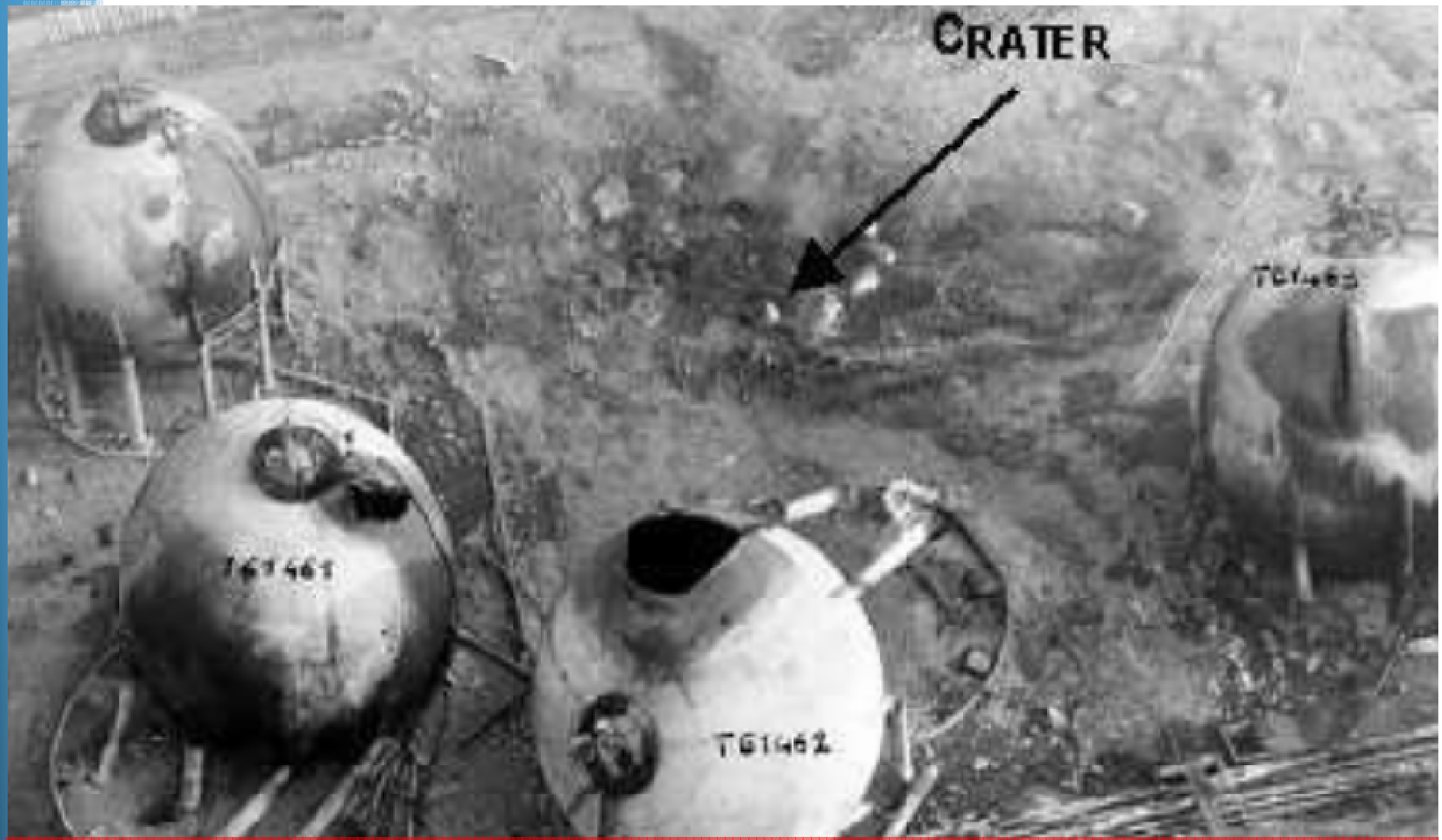
Catastrophes in the Past from BLEVE

Feyzin Refinery in France

- 4 Propane spheres of 1,200 m3
- 4 Butane spheres of 2,000 m3
- 2 horizontal tanks C3/C4 of 150 m3.

Major accident happened when an operator was sampling in the propane storage with ignorance of strict operating procedure!

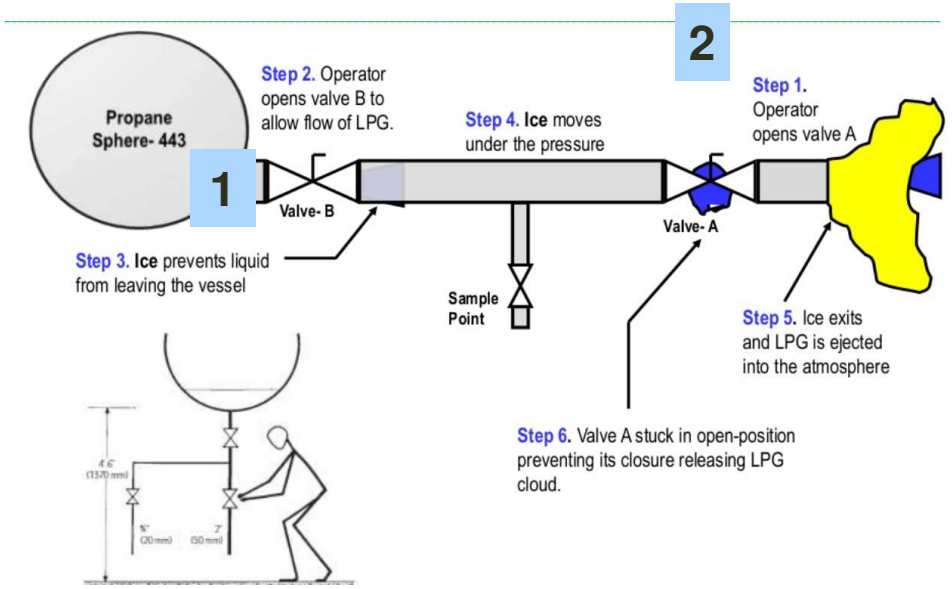
Gas spread out to the roads alongside the plant , and ignited.



LPG BLEVE in 1966,
18 people killed,
81 injured.
The asset damage to be about 18 MUSD .

Incident Investigation, II

- The SOP during sampling was not followed.



- Inadequate firewater spray and poor drainage system.

- Ignition source control, vehicles movement restriction in the storage area on gas detector alarm.

- Inadequate overpressure protection system.

What is BLEVE?

- A BLEVE is a Boiling Liquid Expanding Vapor Explosion, which occurs when the pressurized liquid inside a pressure vessel, reaches temperatures higher than that liquid's boiling point.

- If the vessel can no longer contain the pressure inside of the sealed tank due to the high temperatures, it will mechanically fail, causing the explosion.

Three (3) Factors to cause BLEVE

- Overpressure due to boiling liquid above atm.
- Vaporization rate is more than venting rate.
- Material loose it's integrity due to prolong heating.

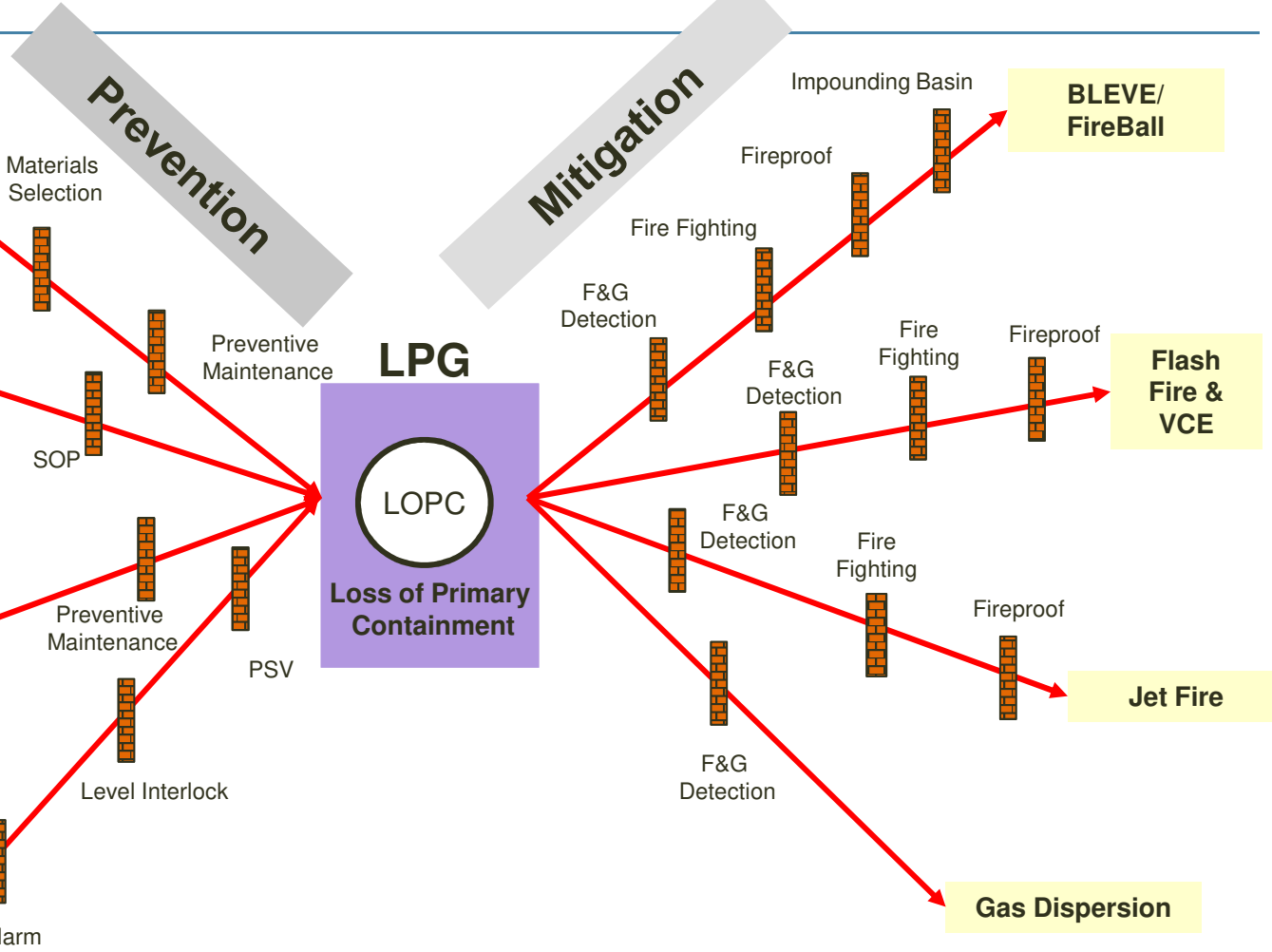
Other Major Hazards on Liquefied Gas

Leakage
from Valve Stem , flanges

Operator Error
Sampling, dewatering

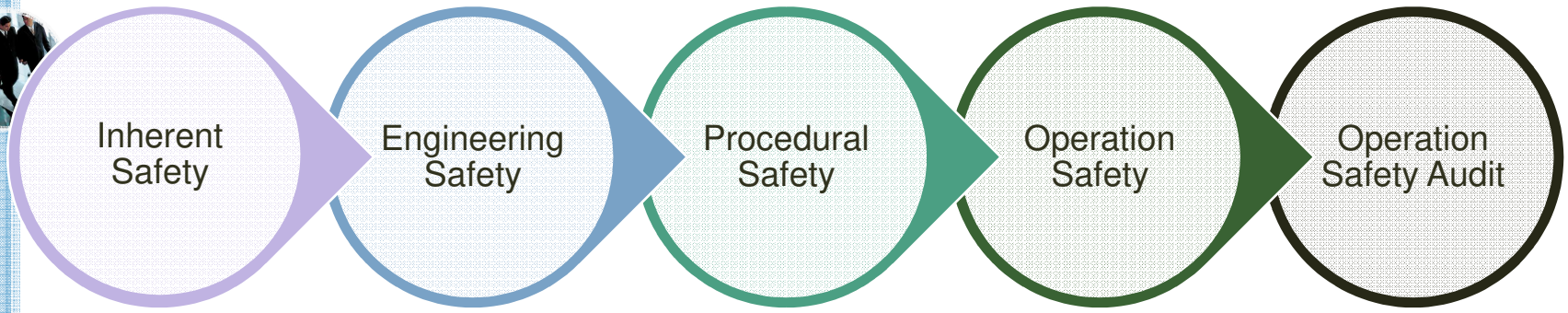
Failure of transfer piping/vessels, corrosion

Overfilling
By BPCS failure etc.



HOW TO PREVENT AND MITIGATE ?



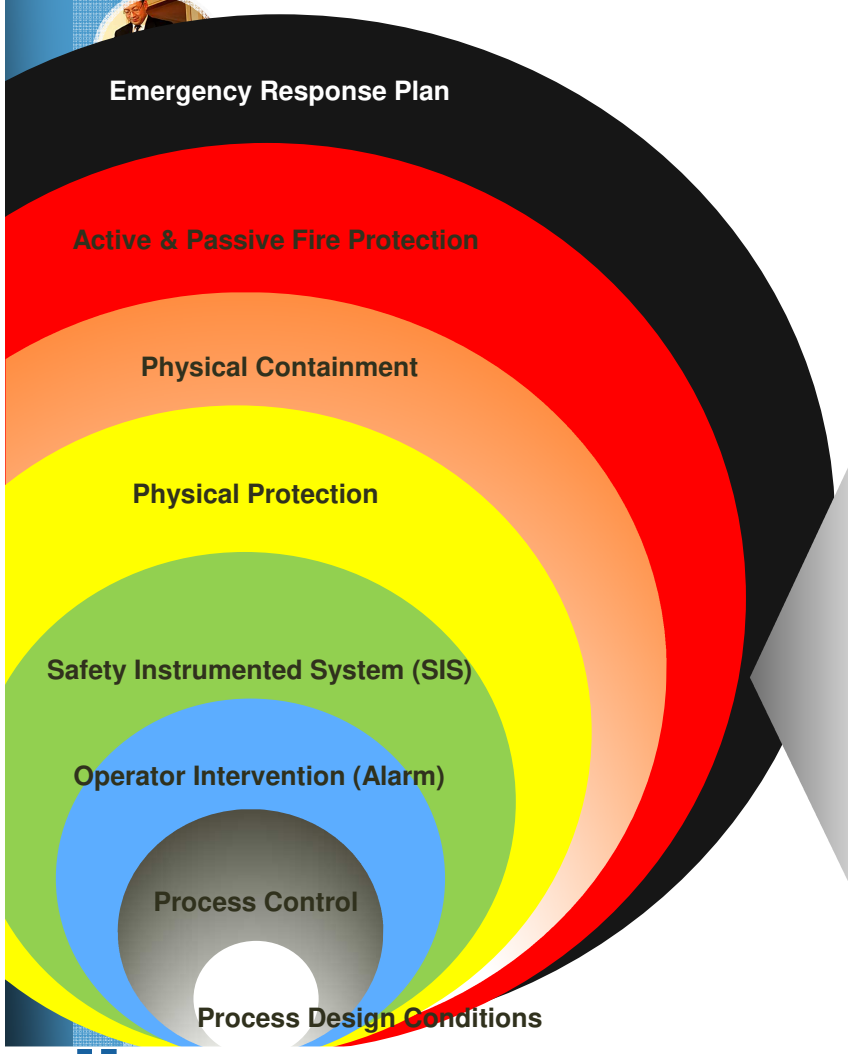


RISK REDUCTION

Process Safety in Design

Process Safety Management

Process Safety in Design to Prevent LPG Hazards



Layer of Protection Concept

- Facility Siting
- Process Design Conditions
- Process Safety Design

- Maximum Allowable Working Pressure
- Minimum Metal Temperature
- Storage parameters indications
- Control System – pressure & level alarms & switches
- Maximum flow check valve
- Pressure Safety Valve
- Blowdown System
- Safety Studies such HAZOP & SIL
- Fire & Gas Detection System
- Emergency Shutdown System
- Storage Vessel Shapes
- Vessels Spacing
- Containment
- Catchment & Slope
- Area Classified Electrical Devices
- Fire Proofing of Vessels
- Flame Proof Instrument Devices
- Flame Proof Conduits & Cables
- Fire Water System
- LPG Transfer Pump & Tanker Loading system



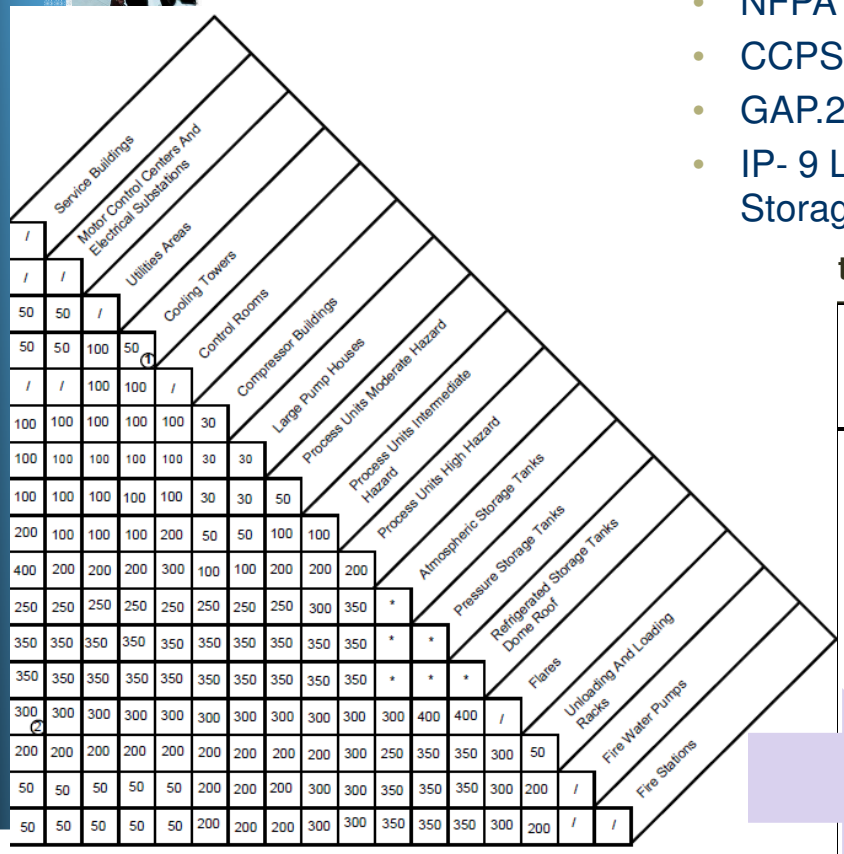
Process Safety in Design to Prevent LPG Hazards

- **Facility Siting**
  - Code-based Approach.
  - Consequence-based Approach.
  - Risk-based Approach.

Process Safety in Design to Prevent LPG Hazards

Facility Siting

- Code-based Approach
  - API 2510 Design and Construction of LPG Installations
  - NFPA 59 Utility LP-Gas Plant Code
  - CCPS, Guidelines for Facility Siting and Layout
  - GAP.2.5.2 - Oil & Chemical Plant Layout Spacing
  - IP- 9 Liquefied Petroleum Gas, Volume 1 Large Bulk Pressure Storage & Refrigerated LPG



tables are typically flammable-hazard-exclusive (no explosive/toxic)

Initail	Destination	Distance (m)				
		Thai Law	GAP.2.5.2	API 2510	NFPA 59	CCPS Guideline
Sphere	CCR	30.0	106.7	30.5	122.0	107.0
	UT Area	N/A	106.7	15.2	122.0	76.0
	ATM Tank	N/A	39.0	26.0	11.8	52.0
	Other spheres	10.5	21.0	10.5	10.5	21.0
	Fence - Public Way	60.0	N/A	61.0	N/A	76.0
	Fence - Adjacent Industry	60.0	N/A	61.0	N/A	61.0
	Impounding Basin	N/A	N/A	15.2	N/A	N/A
	Flare	N/A	122.0	30.0	N/A	N/A
	Truck Loading/Unloading	N/A	106.7	15.0	7.6	N/A
	Fire water pump	N/A	106.7	15.3	N/A	N/A

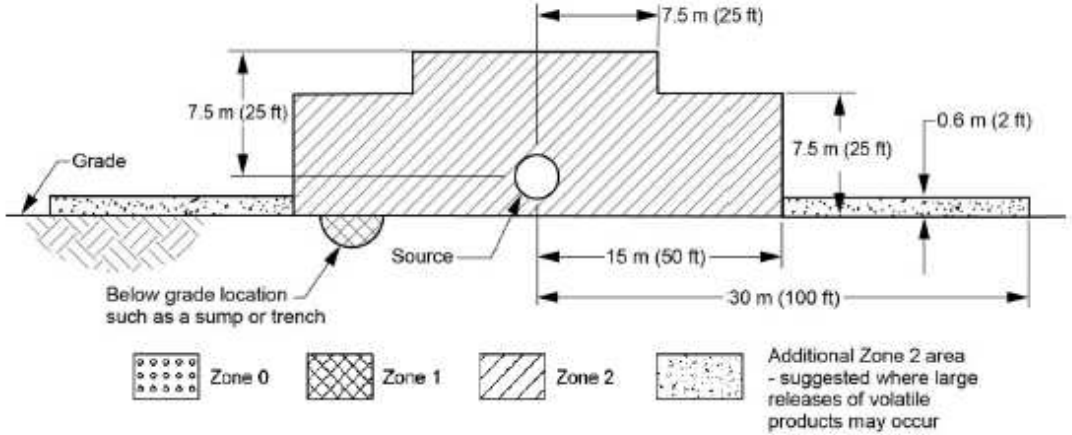


CAUSTION ! Safety Distance Vs HAC

Attention !

Initail	Destination	Distance (m)					
		Thai Law	GAP.2.5.2	API 2510	NFPA 59	CCPS Guideline	NFPA 30
Sphere	CCR	30.0	106.7	30.5	122.0	107.0	N/A
	UT Area	N/A	106.7	15.2	122.0	76.0	N/A
	ATM Tank	N/A	39.0	26.0	11.8	52.0	6.0
	Other spheres	10.5	21.0	10.5	10.5	21.0	N/A
	Fence - Public Way	60.0	N/A	61.0	N/A	76.0	N/A
	Fence - Adjacent Industry	60.0	N/A	61.0	N/A	61.0	N/A
	Impounding Basin	N/A	N/A	15.2	N/A	N/A	N/A

Safety Distance from a sphere to a public way requires up to 76 m.
HAC radius of Liquefied gas requires up to 30 m.



[1] Distances given are for typical refinery installations: they shall be used with judgment, with consideration given to all factors discussed in the text. In some instances, greater or lesser distances may be justified.

Figure 20—Adequately Ventilated Process Location with Heavier-than-air Gas or Vapor Source Located Near Grade (See 9.2.1.1)

Process Safety in Design to Prevent LPG Hazards



Facility Siting

- Consequence-based Approach
- Risk-based Approach
  - Blast Loading
  - Thermal Radiation
  - Flammable gas concentration
  - Toxic concentration and exposure duration
- All consequences are evaluated against building design criteria, and equipment.

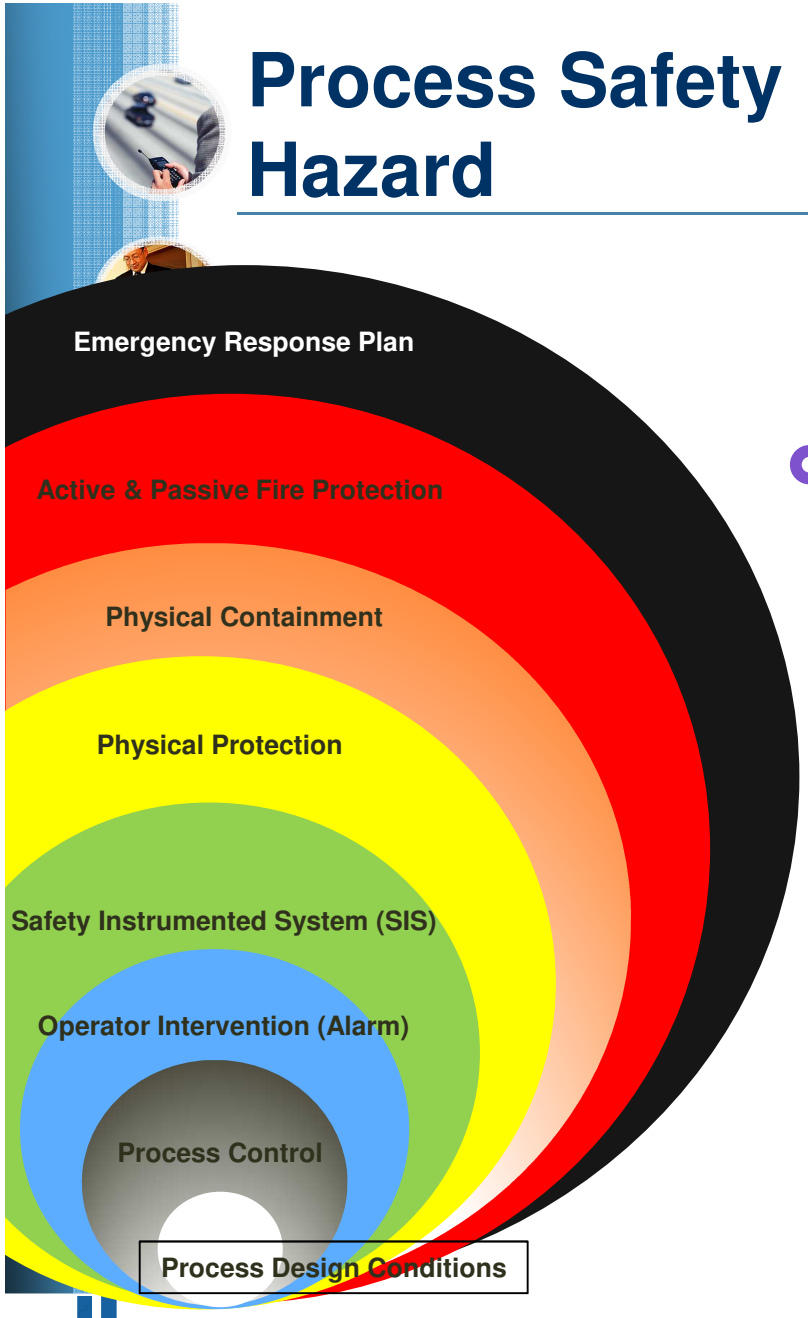
Table 2.8 Damage Estimates for Common Structures Based on Overpressure [6]

Pressure		Damage
Psig	kPa	
0.02	0.14	Annoying noise (137 dB if of low frequency 10-15 Hz)
0.03	0.21	Occasional breaking of large glass windows already under strain
0.04	0.28	Loud noise (143 dB), sonic boom, glass failure
0.1	0.69	Breakage of small windows under strain
0.15	1.03	Typical pressure for glass breakage
0.3	2.07	"Safe distance" (probability 0.95 of no serious damage[1] below this value); projectile limit; some damage to house ceilings; 10% window glass broken
0.4	2.76	Limited minor structural damage
0.5-1.0	3.4-6.9	Large and small windows usually shattered; occasional damage to window frames.
0.7	4.8	Minor damage to house structures
1.0	6.9	Partial demolition of houses, made uninhabitable
1.0-2.0	6.9-13.8	Corrugated asbestos shattered; corrugated steel or aluminium panels, fastenings fail, followed by buckling; wood panels (standard housing) fastenings fail, panels blown in
1.3	9.0	Steel frame of clad building slightly distorted
2	13.8	Partial collapse of walls and roofs of houses
2.0-3.0	13.8-20.7	Concrete or cinder block walls, not reinforced, shattered
2.3	15.8	Lower limit of serious structural damage
2.5	17.2	50% destruction of brickwork of houses
3	20.7	Heavy machines (3000 lb) in industrial building suffered little damage; steel frame building distorted and pulled away from foundations
3.0-4.0	20.7-27.6	Frameless, self-framing steel panel building demolished; rupture of oil storage tanks
4	27.6	Cladding of light industrial buildings ruptured
5	34.5	Wooden utility poles snapped; tall hydraulic press (40,000 lb) in building, slightly damaged
5.0-7.0	34.5-48.2	Nearly complete destruction of houses
7	48.2	Loaded, lighter weight (British) train wagons overturned
7.0-8.0	48.2-55.1	Brick panels, 8-12 inch thick, not reinforced, fail by shearing or flexure
9	62	Loaded train boxcars completely demolished
10	68.9	Probable total destruction of buildings; heavy machine tools (7,000 lb) moved and badly damaged, very heavy machine tools (12,000 lb) survive
300	2068	Limit of crater lip

Reference : OGP Risk Assessment Data Directory, Vulnerability of Plant/Structure

Process Safety in Design to Prevent LPG Hazard

Prevention Safeguards



Failure of transfer piping/vessels, corrosion

Leakage from Valve Stem , flanges

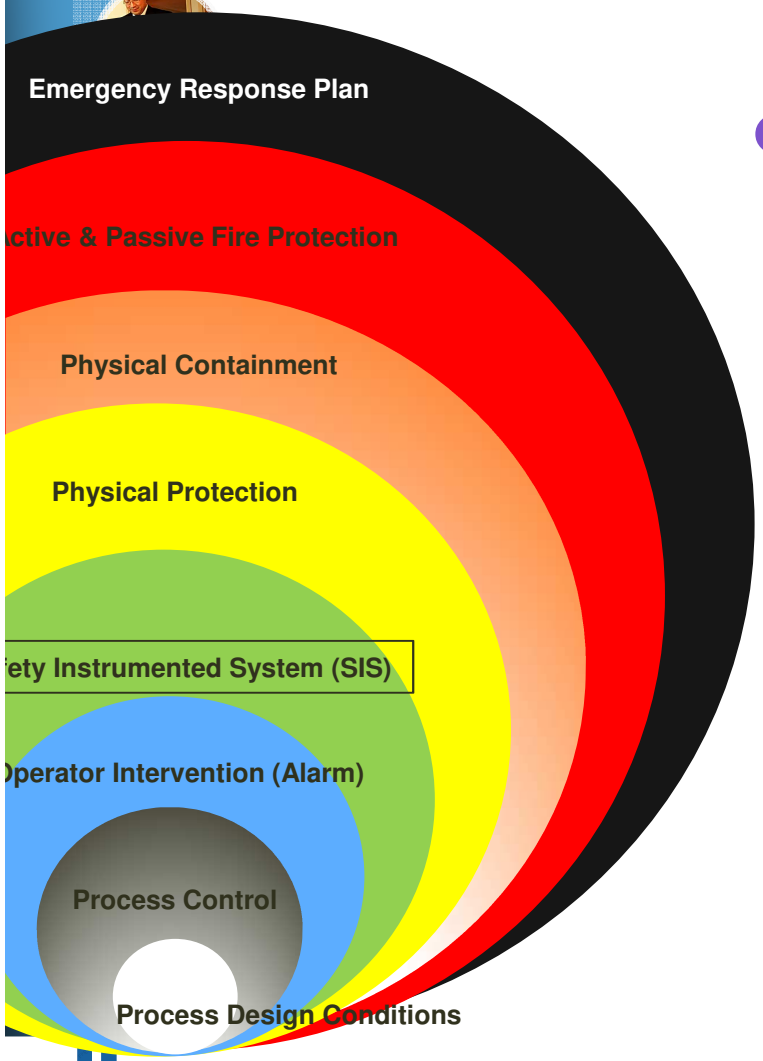
Process Design Condition

- Design Pressure :
  - Max Design Pressure : The vapor pressure at the design temperature.
  - Vacuum Design : Full Vacuum or Partial Vacuum with other safeguards.
- Design Temperature :
  - Max design temperature : Mechanical design temperature or Max ambient temp + margin (25 Deg C).
  - Min design temperature : Considering during emergency DE pressuring due to adiabatic flashing temp of LPG.

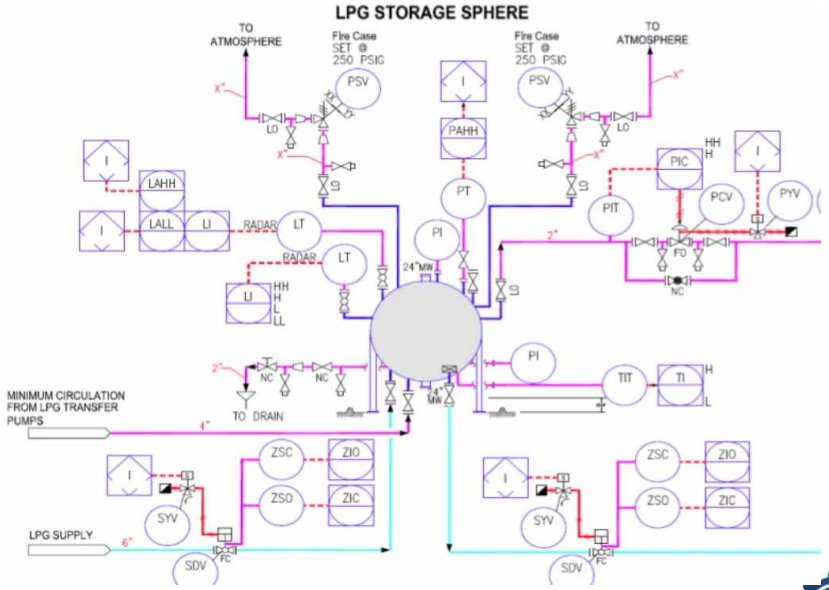
Process Safety in Design to Prevent LPG Hazard

Prevention Safeguards

Overfilling
By BPCS failure etc.



- **Safety Instrumented System**
  - Overpressure protection scenarios
    - Liquid overfilling case.
  - Emergency Isolation –
    - Remote Isolation Valve



7th Chemical Process Safety Sharing (CPSS)
May 07, 2021, Thailand

Chemical Process Safety Sharing

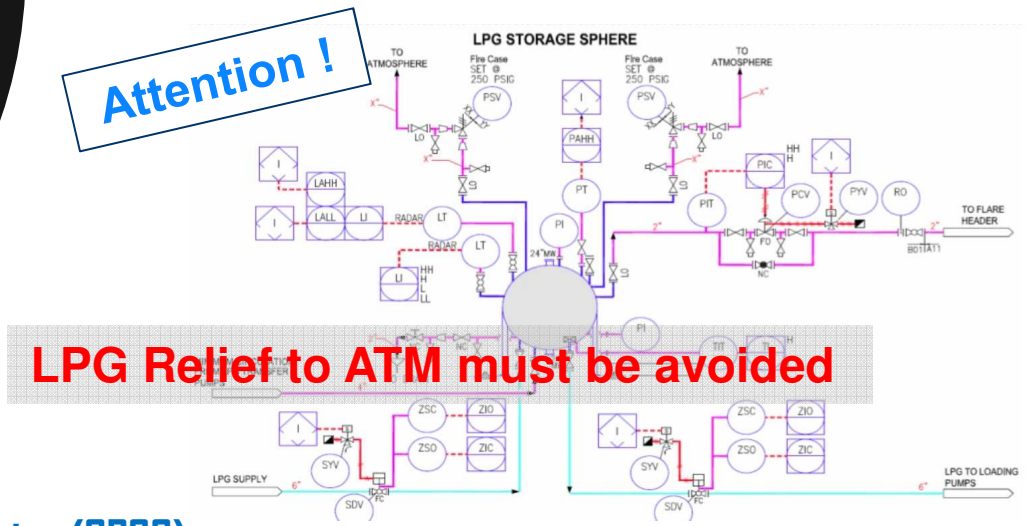
SCG GC IRPC Thaioil TIChE

Process Safety in Design to Prevent LPG Hazard

Prevention Safeguards

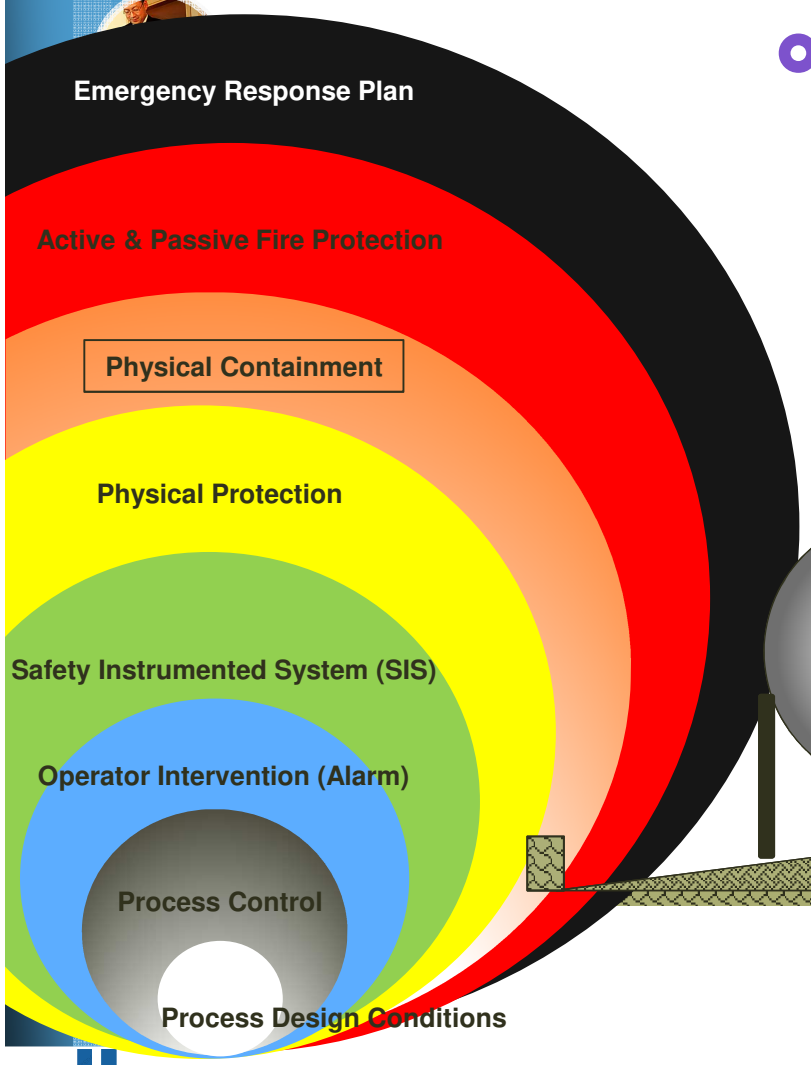
- **Physical Protection**
  - Safety Valves -
    - External Fire
    - Liquid Overfilling (if required)*
  - Depressurization system (if used)
    - Emergency Depressurization API 521

" Depressuring to a gauge pressure of 690 kPa (100 psi) in 15 min"

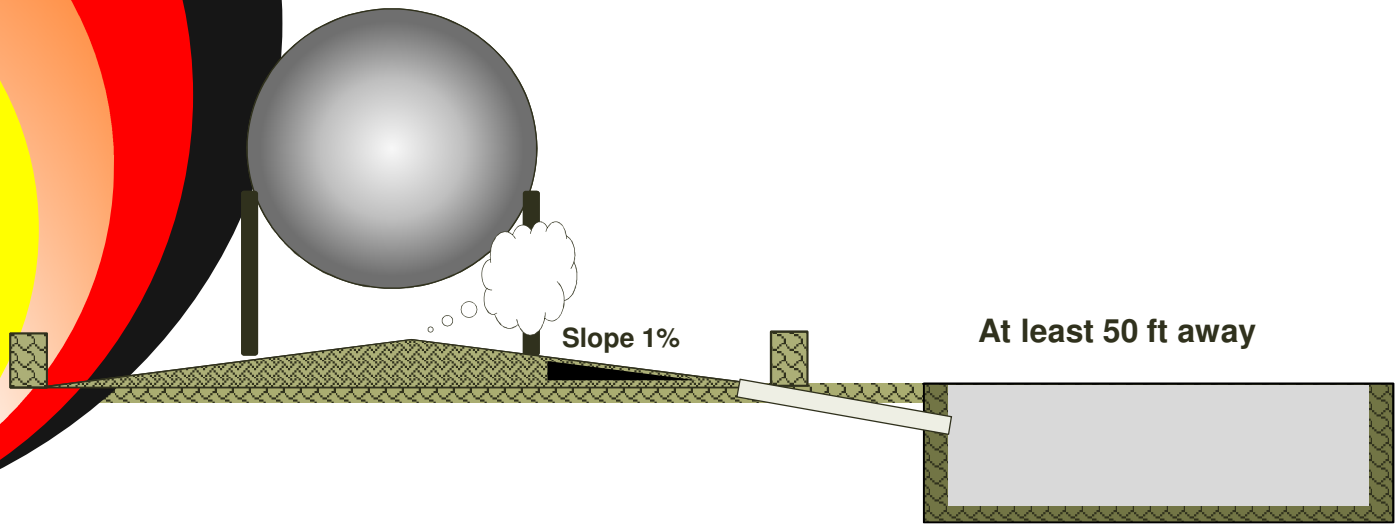


Process Safety in Design to Prevent LPG Hazard

Mitigation Safeguards

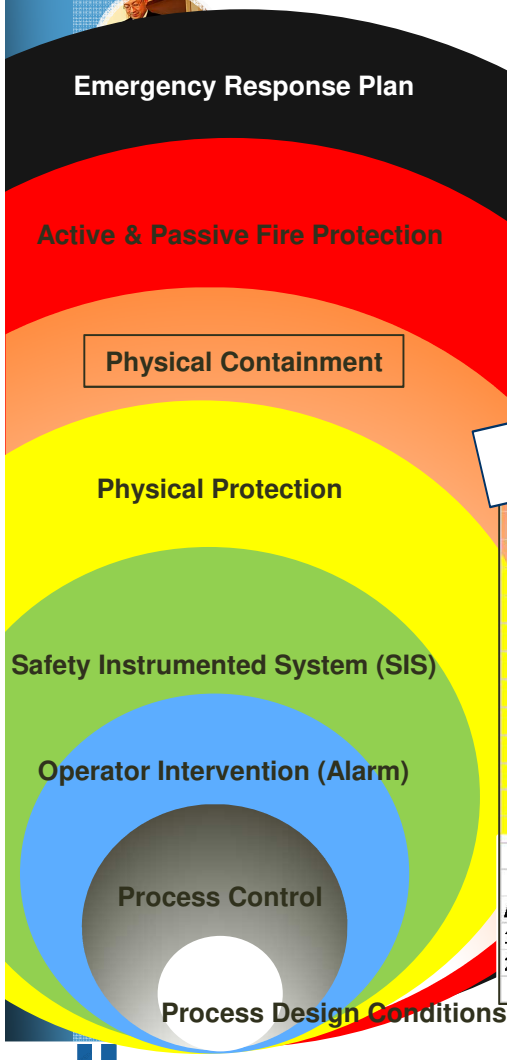


- **Physical Containment**
  - Dike
    - Grading shall be min of 1% slope.
    - Min height of 1ft (concrete), min 1,5ft (earth).
  - Remote Impounding Basin
    - Be able to contain at least 25-50% of volume depending on its vapor pressure [API 2510].

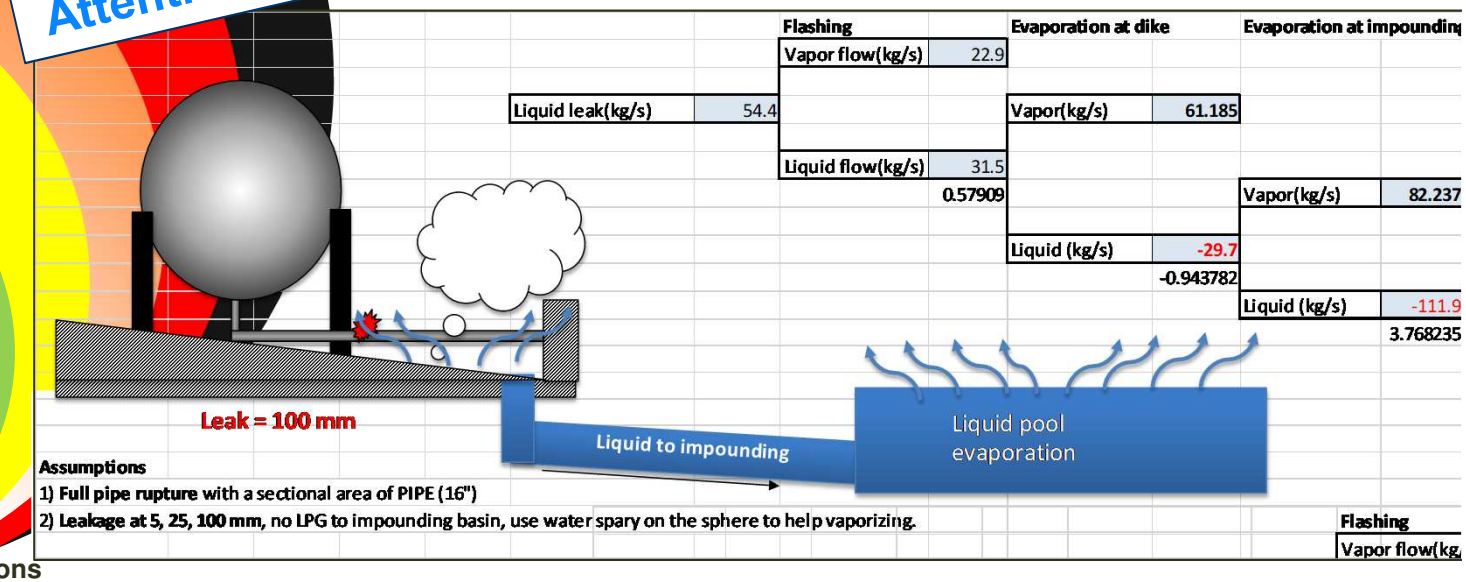


Process Safety in Design to Prevent LPG Hazard

Mitigation Safeguards



- **Physical Containment**
  - Remote Impounding Basin
    - This remote impounding basin is for pipe rupture
    - The study has shown that hole leaks at 5mm, 25 mm, 100 mm have no liquid to the basin.



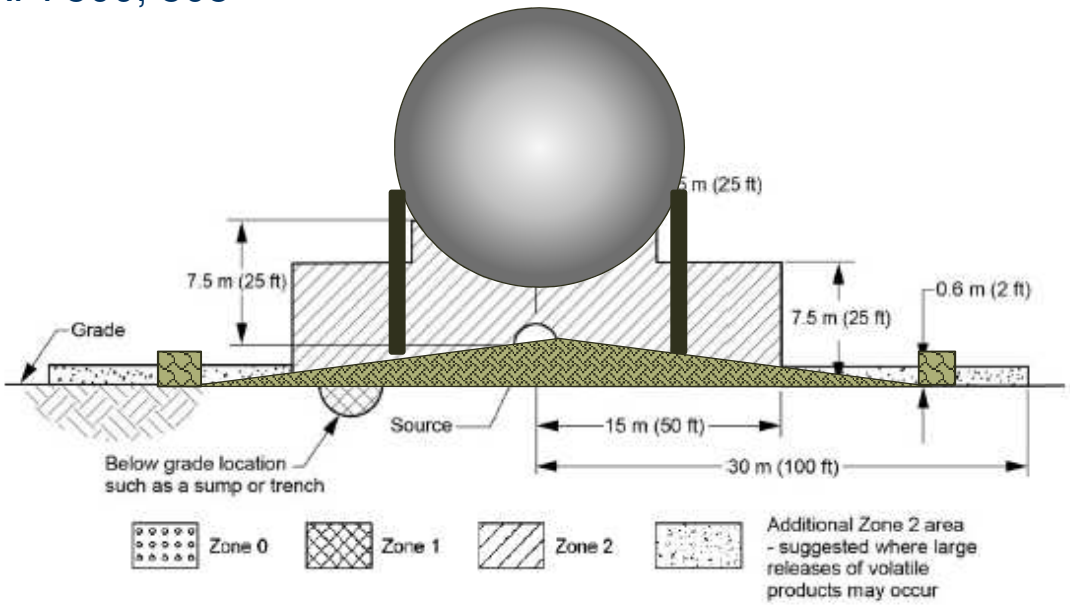
Process Safety in Design to Prevent LPG Hazards

Mitigation Safeguards

Nice to Know !

Hazardous Area Classification

- Code-based Approach
  - API 500, 505



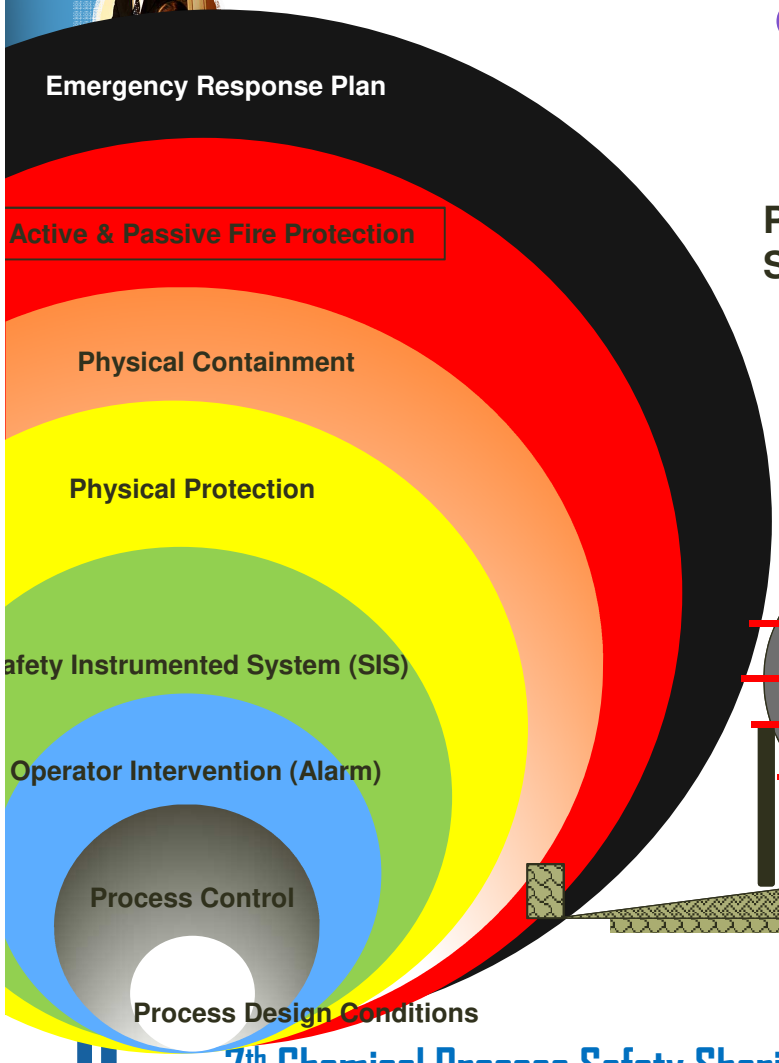
[1] Distances given are for typical refinery installations: they shall be used with judgment, with consideration given to all factors discussed in the text. In some instances, greater or lesser distances may be justified.

Figure 20—Adequately Ventilated Process Location with Heavier-than-air Gas or Vapor Source Located Near Grade (See 9.2.1.1)

Propane/Butane : IIA , Temp Class T3

Process Safety in Design to Prevent LPG Hazard

Mitigation Safeguards



Active Fire Protection

- API 2510A /API2030
- NFPA 15

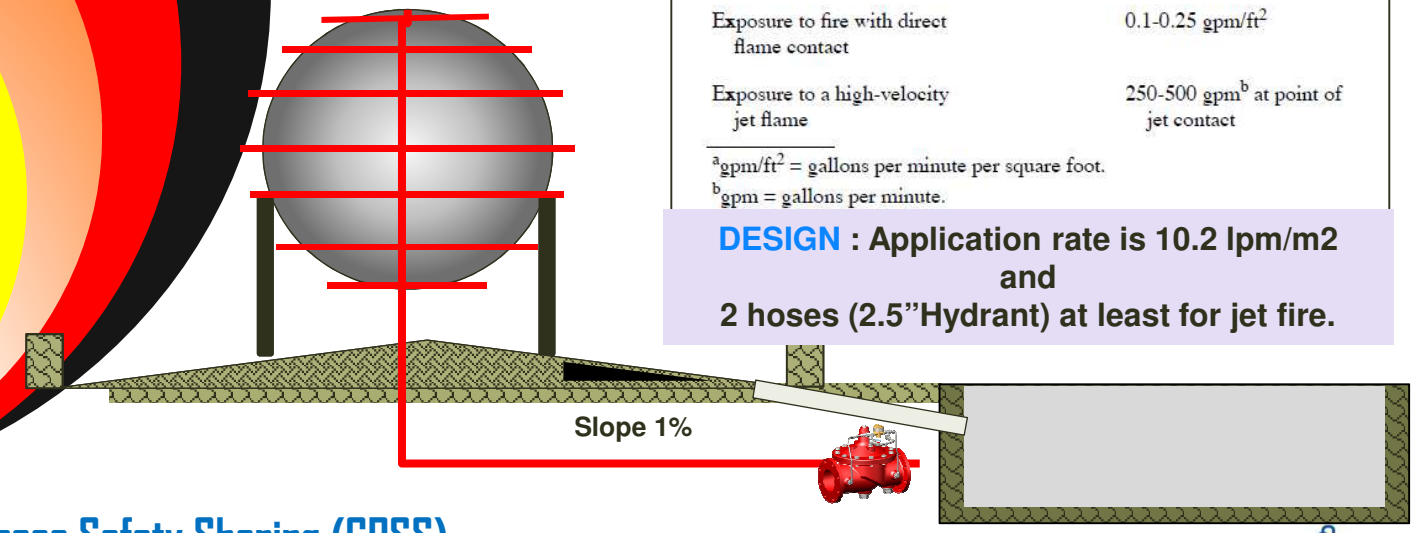
Primary methods : Water spray/Deluge valve, Fixed Monitor
Secondary methods : Hose Streams

Table 4—Fire Emergency Situations Requiring Special Consideration

Fire Exposure	Water Application Rate
Exposure to radiant heat and no flame contact	0-0.1 gpm/ft^{2a}
Exposure to fire with direct flame contact	0.1-0.25 gpm/ft^2
Exposure to a high-velocity jet flame	250-500 gpm^b at point of jet contact

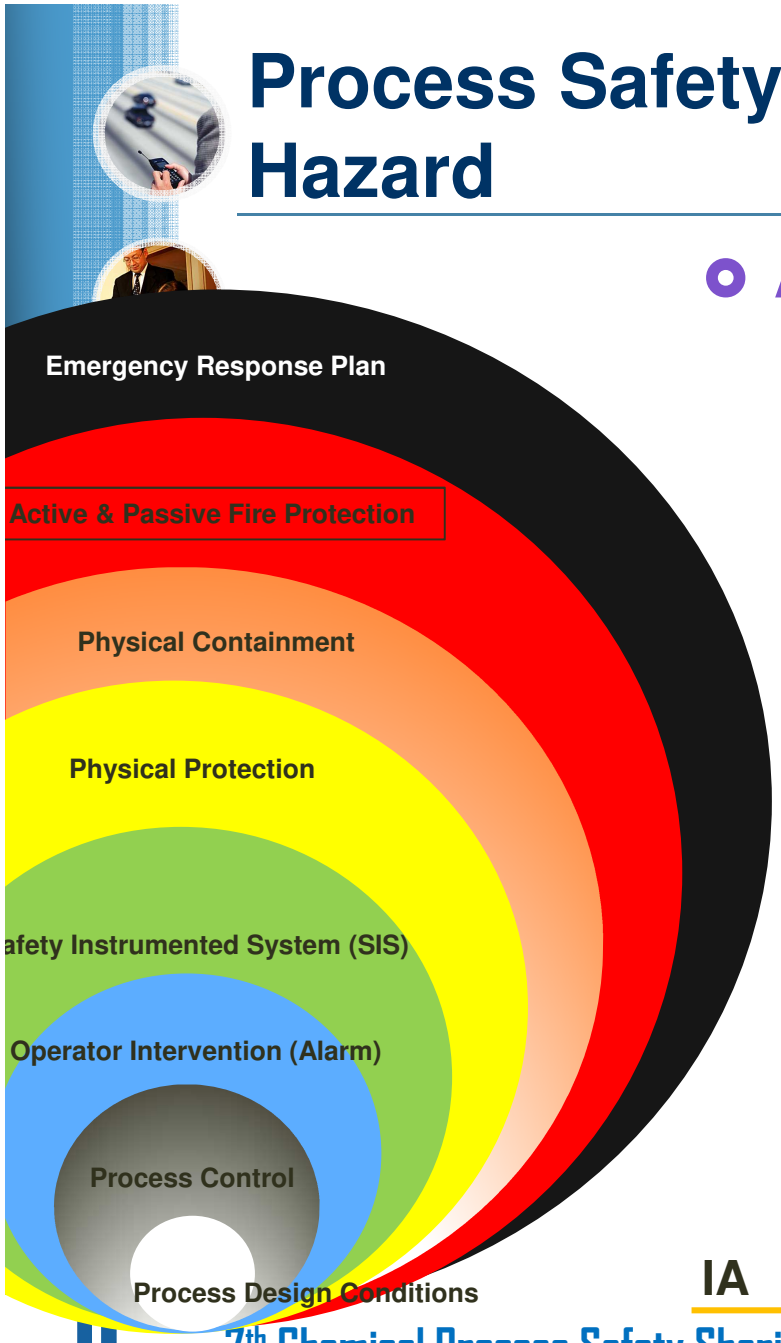
[a]gpm/ft^2 = gallons per minute per square foot.
[b]gpm = gallons per minute.

DESIGN : Application rate is 10.2 lpm/m2 and 2 hoses (2.5"Hydrant) at least for jet fire.



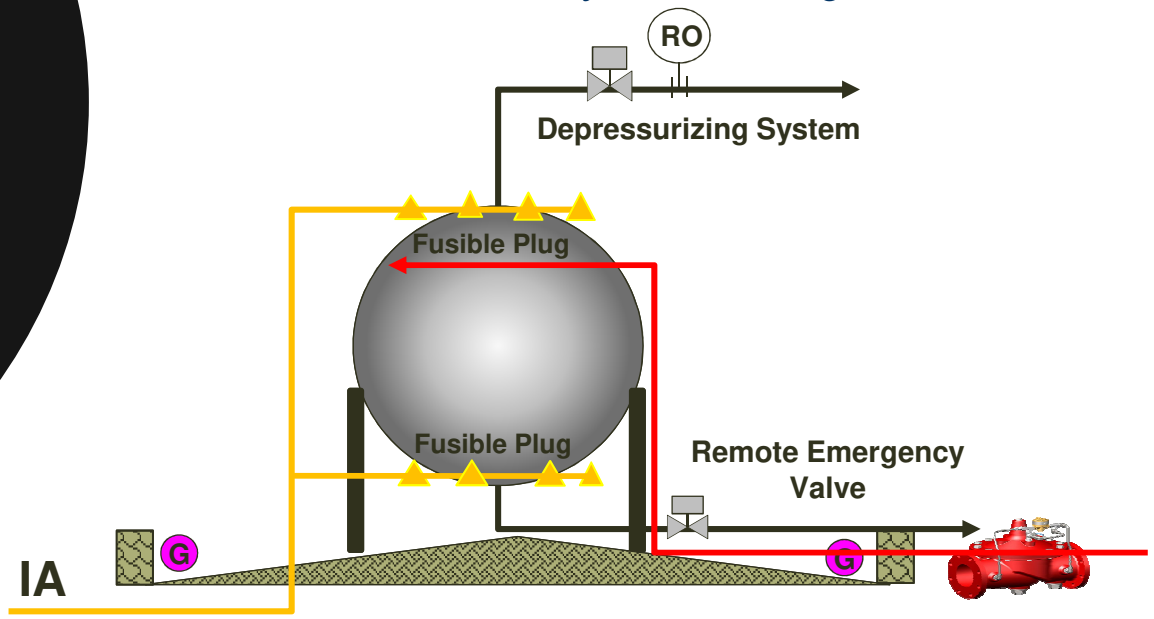
Process Safety in Design to Prevent LPG Hazard

Mitigation Safeguards



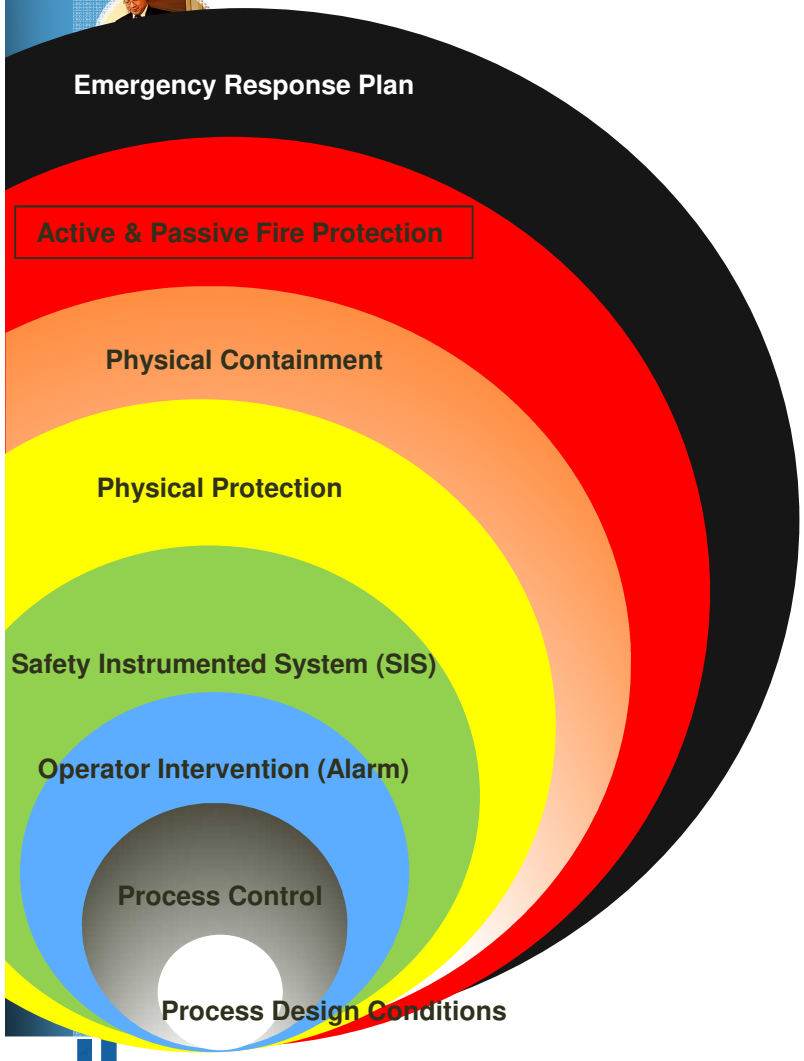
Active Fire Protection

- Fire Detection
  - Confirmed fire to activate fire fighting system (automatically/manually).
- Gas Detection
  - Single alarm.
  - Confirmed Gas by 2ooN voting.



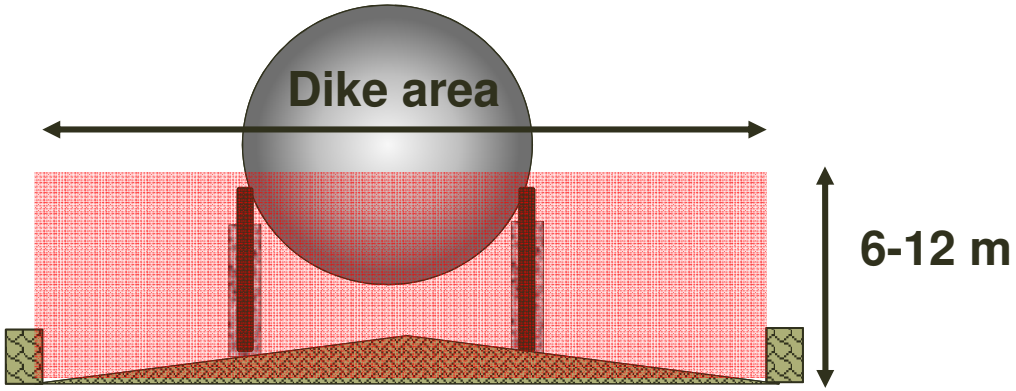
Process Safety in Design to Prevent LPG Hazard

Mitigation Safeguards



- **Passive Fire Protection**
  - API-2218 : Horizontal - The area shall extend to the dike wall, or 6 m from the storage whichever is greater
  - Vertical up to 6-12 m

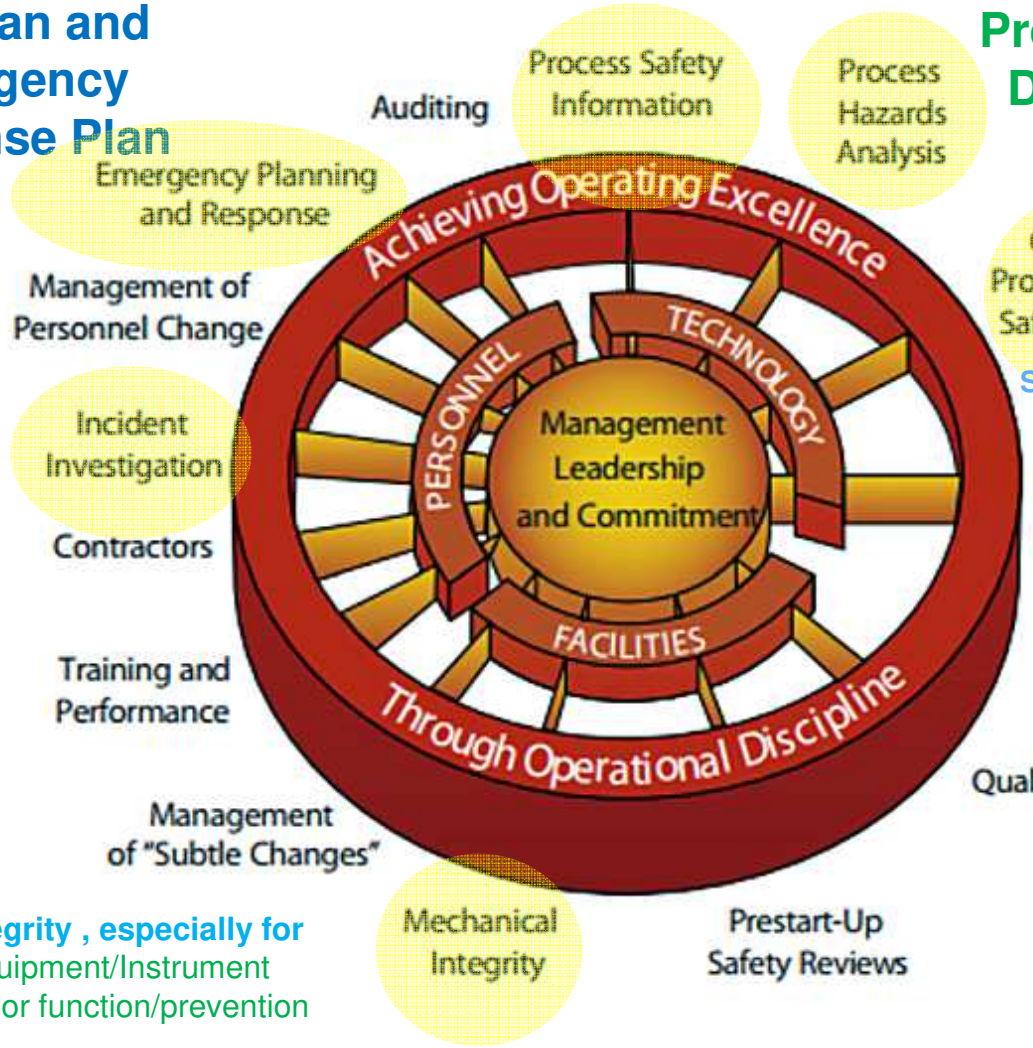
"Fireproofing shall be used to protect vessels if portable equipment is the only means of applying fire water."



PSM to Prevent LPG Hazards

Fire Plan and Emergency Response Plan

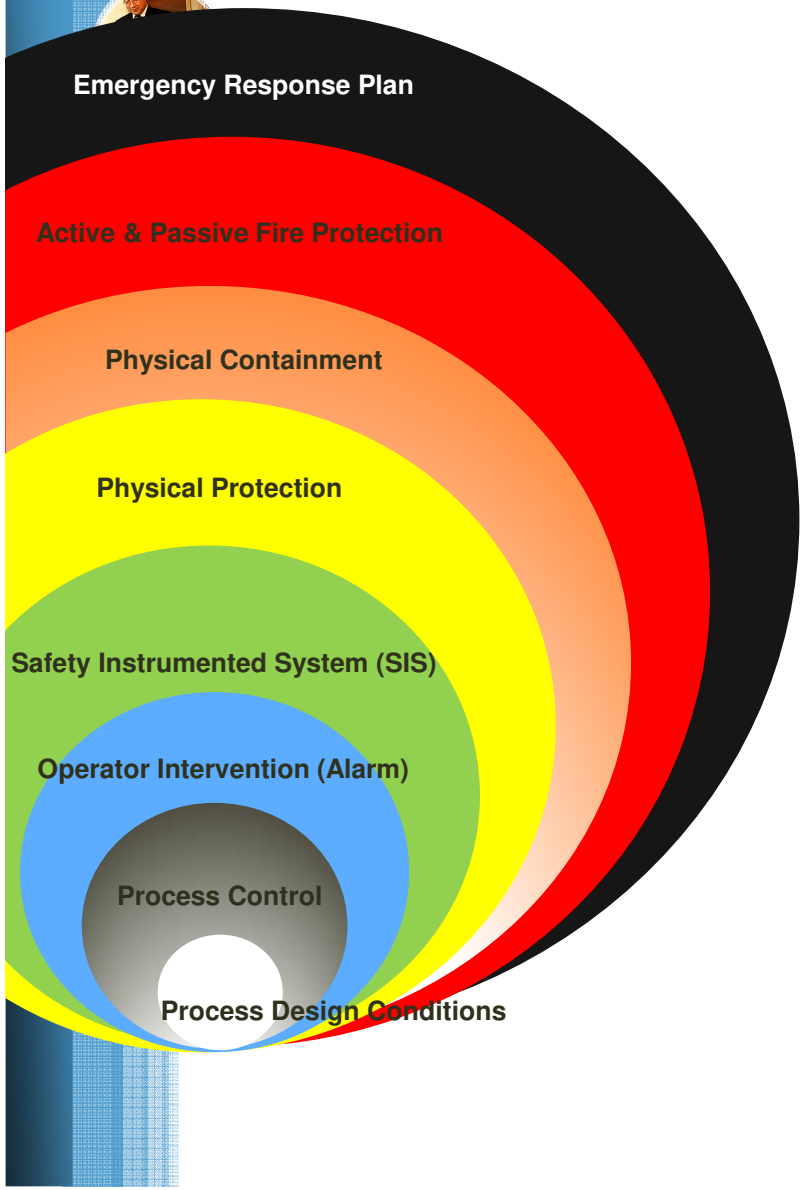
Process Safety in Design, FS etc.



Such as sampling, water drawing API2510

Material Integrity , especially for
Critical Equipment/Instrument
Containment or function/prevention

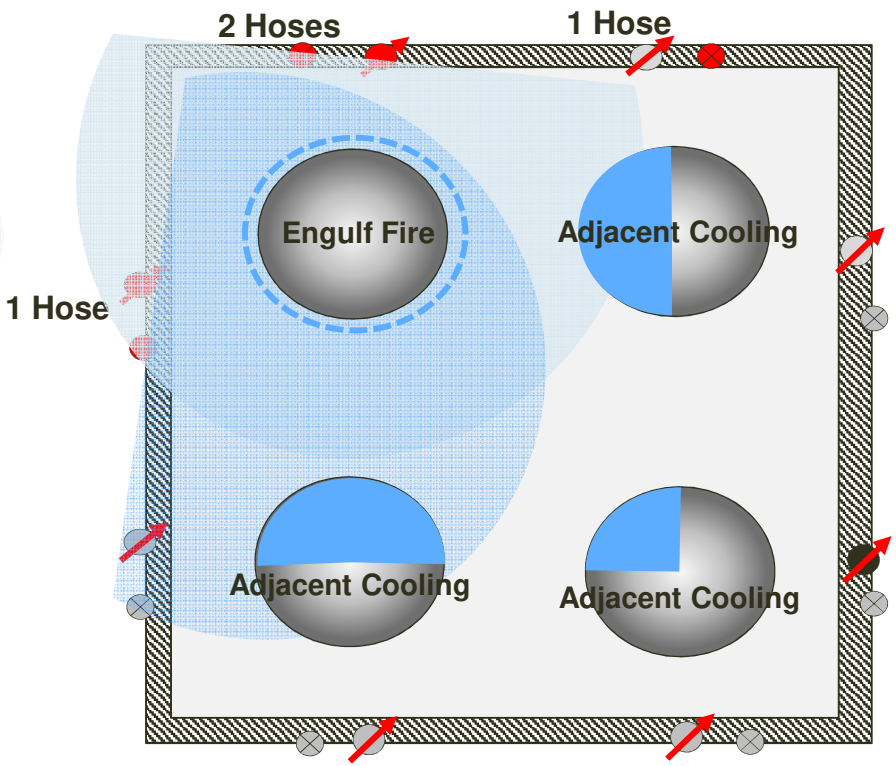
Pre-Fire Plan

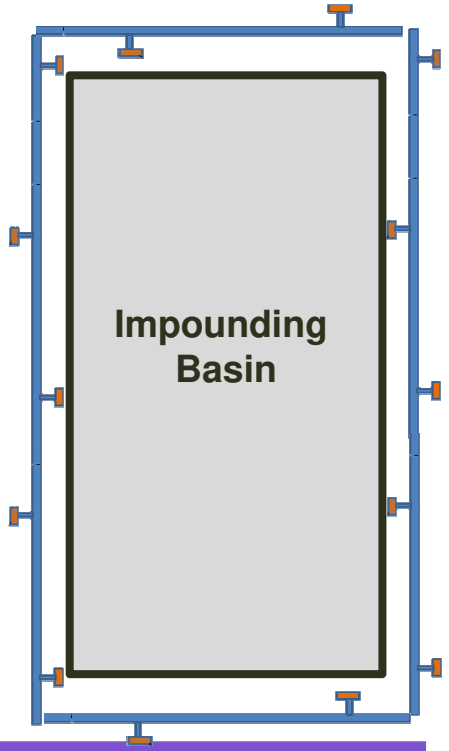


- **Typical scenarios**
  - Sample draw fire.
  - Relief valve vent fire
  - Ignite and unignited pressure leak
  - Ignited and unignited pool
  - Pump Fire
- **Small Fire or Large Fire**
  1) Isolation and depressurizing
  2) Fire water to cooling down

" Caution : Do not extinguish the flame with dry chemical fire extinguisher because the accumulated vapor may reignite, seriously injure fire fighters, and damage equipment."

Pre-Fire Plan





Fire fighting Equipment	Firewater Consumption
Spray water – Engulf	10.2 lpm/m2 + hydraulic margin with overdesign
Spray water – Adjacent	
Fixed Monitors + Hoses	Monitor : 750 gpm, Hose 2.5" : 250 gpm
Water Curtain	Water Curtain Vendor (K-factor)

Chemical Process Safety Sharing

Thank you for your attention