Planning for Safety Control on Hazardous Material Distribution Depot.

S.K.Roh,
Prof. Architectural Engineering, KwangWoon University, Korea

S.W.Jun, T.H.Kang, Y.M.Seo
Graduate student, Architectural Engineering, KwangWoon University, Korea

ABSTRACT

The safety of LPG vessel storage has been simply designed and controled with blast wave barrier structure concept regardless of its quantity or hazardous situation. The limit of regal controls on LPG vessel storage need to be identified in terms of safety buffer distance from LPG explosion. The level of overpressure effect and heat radiation to the safety structure and neighbouring human activity required to be estimated to find the gap between existing controls on such storage. To this content the paper discuss the issues on the approach to the blast wave barrier and safety separation distances.

1. Recent trends of Major Gas Accident.

- The gas related accidents have been growing recently, with their frequent occurrence and catastrophic damage resulted in Korea.

- The characteristics of LPG distribution accidents generally known as rare event with high consequence when it developed to the condition of vapour cloud explosion.

Incident frequency < Damage effect(consequence)

2. Recent trends of LPG accidents in Korea.

- The comparison between gas related accident and general fire accident has shown almost 12 times of higher fatality than gas accidents, while the number of gas accidents occurrence has shown 100 times less than fire accidents.

· Damage Consequence of Accident by Gas & Fire.

Year	Human Damage(Death)		Human Damage(injury)	
	Gas	Fire	Gas	Fire
1991	0.148	0.032	2.287	0.100
1992	0.459	0.029	1.641	0.076
1993	0.320	0.031	2.454	0.064
1994	0.375	0.025	2.331	0.056
1995	0.250	0.022	0.981	0.048
Aver	**0.314**	**0.027**	**1.492**	**0.066**

[Source] Korea Gas Safety Company A01.2 KM005139

- Increase of LPG explosion threat for criminal purpose including intentional behavior.
- Mismanagement of safety or control mishaps by the consumers and distributors are linearly increase with LPG consumption .

3. Study Scope

- Understanding the background of safety buffer distance within related regulations such as Building Structure Code, or Regulatory Provisions to High Pressure Gas Safety Control Law.
- The role of blast wave barrier to reduce the safety distance from the explosion overpressure effect.
- The level of Individual Risks at surrounding area from LPG retail storage.

4. Problems of Local LPG retail storage safety.

(1) The government strengthened the safety management to the license holders including delivery of LPG vessel, however, the educated safety personnel

frequently leave the position (Job) because of low income and safety reason.

(2) Long term plan for installation remoted refill LPG system by using sensing gauge which called volume base scale has been successfully reduce the LPG incident in Japan for the last ten years.

- Volume base scale supply system can cover the problems of weight base supply system such as precise quantity measurement, uncertain volume of left over in cylinder, inconvenience of sudden recharge or delivery during the gas use.
The most significant of volume base supply system is remote sensing control meter (mycom meter) enables directing any gas leakages on the supply line .

- It is the most effective and best approach, however, even though the system installed, it is still insufficient to keep safety at the distribution depot for it needs to relocate to suburban area because it still needs certain amount of safety separation distance.

- To set up this system in Korea it requires enormous financial investment at earlier stage and eventhough the system were installed the safety of consumers can be insured, but it can not be say that the distribution or retail storage are safe for they need to be relocate to a remoted area from the congested urban land uses.

(3) No adequate regulation or code for safety separation distance from LPG vessel distribution depot at the densely populated area.

5. Code or Regulations for Retail LPG vessel storage.

- The safety of LPG manufacturing and storing are not dealt by fire prevention act but by high pressure gas safety and management act. It is also designated the safety separation distance of bulk LPG handling or sales services in the building code. However, it has been substituted by LPG safety

or management act.

- The Seoul metropolitan ordinance for building control requires minimum 4 meters of safety separation distance from neighboring landuse where the $200m^2$ of total floor space and LPG refill facilities or dangerous goods installation area.

- High pressure gas safety and management act requires less than 10 tons of the LPG storage or refill facilities need to be kept in distance of 17m for the 1st class protection facilities and 12m for the 2nd class such as residential houses. (Safety and Business Control Law of Liquefied Petroleum Gas Enforcement Regulations)

- From local rule (ku municipality) for LPG sales or distribution depot control the size of storage should be less than 2.9tons within $18m^2$ with concrete or concrete block, metal plated structure blast wave barrier. However, such cases do not requires any further safety separations from neighboring facilities or landuses even the residental houses.

6. Blast wave barrier concept

- Local regulation for safety separation of LPG facilities based on LFL(Lower Flammable Limit) concept which has been applied to protect between process facilities when a mishap occurred within the plant area.
This kind of concept can not appreciable to LPG retail depot because LPG leakage formulate sudden rise of dispersed gas particle density to a flammable level within the blocked storage condition.

- The Safety devices for such LPG cylinder storage generally controled by their own Local government's(ku) ordinance. The size of storage and fire proof walls, roof and doors with its consisting materials controled by Local code for blast wave barrier. (High Pressure Gas Safety Control Law. C : 2-1-22, 1996. 6. 7)

- The materials of storage roof requires light fireproof or fire resistance

structure, however, many of them located within multi-use slab buildings or some coner of shops or houses, and for the convenience of short distance delivery most of the storage are located in the middle of high density residential area. Often those storage door frequently opened, unlocked in day time and charged vessels loaded at out-door which could be a highly hazardous activity.

· The metal plate structure uses T-6mm plate with higher than 2m of T shape poll welded at each 1.8m distance, are widely equipped as a LPG storage recently.

· Japanese control for safety buffer distance is based on the protection to human body from an explosion of LPG sales on storage facilities. In case of manufacturing facilities requires more than 50m of safety buffer distance or follow the separation distance estimating equation, such as $D=0.480\sqrt[3]{K\cdot W}$ (in case of no blast wave barrier) However, if the barrier installed the safety buffer distance can be reduced by 60% ($D=0.29\sqrt[3]{K\cdot W}$).

T.1 Safety Distance of Flammable Gas Manufacture Facility.

Safety Distance	
blast wave barrier Non-exist	**blast wave barrier exist**
$D = 0.48\sqrt[3]{K\cdot W}$	$D = 0.29\sqrt[3]{K\cdot W}$
· D : Safety Distance(m) · K : Explosion calculation · W : Capacity of the Explosive(ton)	

[Source] Code for LPG safety, Industrial Complex Safety regulation.1977

7. Comparisons of various estimation for safety buffer distance.

To understand LPG retail storage's safety level the overpressure effect to a neighbouring facilities need to be estimated.

Assuming the LPG in storage at each 20kg or 50kg vessel were released and ignited, the overpressure effect to the concrete or metal barrier to a distance of 3meters can be estimated up to 100psi and 150psi, which indicate the total destruction of concrete wall. (annotation*1)

However, from the computer model(PHAST) the 20kg LPG vessel explosion overpressure effect could reach 10.16psi(=0.7bar) at 14 meters. If there were no barrier the overpressure level also indicate building almost completely destructed.

T.2 Effect of Explosions Overpressure on People and Buildings

(A) Effects on Buildings	
Building almost completely destroyed	0.7 bar
Heavy building damage	0.35 bar
Repairable building damage	0.10 bar
Widespread glass damage	0.05 bar
10% broken glass	0.02 bar
(B) Effect on People	
100 % lethality	5 - 8 bars
50 % lethality	3.5 - 5 bars
Threshold lethality	2 - 3 bars
Severe lung damage	1.33 - 2 bars
50 % eardrum rupture	2 - 2.33 bars(over 20 years of age)
50 % eardrum rupture	1 - 1.33 bars(under 20 years of age)

[Source] Methods and procedures for Health and Environmental Risk Assessment. UNEP. 1991

T.3 Consequence Effect of Heat Radiation on People and Equipment.

Incident Flux (kW/m2)	Damage to equipment	Damage to people
37.50	·Damage to process equipment. ·Cellulosed equipment will pilot ignite within one minute exposure.	· 100% lethality in 1 min. · 1% lethality in 10 s.
25.0	·Spontaneous ignition of wood after long exposure. ·Unprotected steel will reach thermal stress temp. ·Pressure vessels needs to be relieved or failure will occur.	· 100% lethality in 1min. · Signigicant injury in 10 s.
12.5	·Minimum energy to ignite wood with a flame. ·Melts plastic tubing. ·Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure.	· 1% lethality in 1min. · 1st degree burns in 10 s.
4.7		· Causes pain if duration is longer than 20 s but blistering is unlikely. · Possible injury after 30 s of exposure.
2.1		· Minimum to cause pain after 1 min.
1.6		· Causes no discomfort for long exposure.

[Source] Methods and procedures for Health and Environmental Risk Assessment. UNEP. 1991

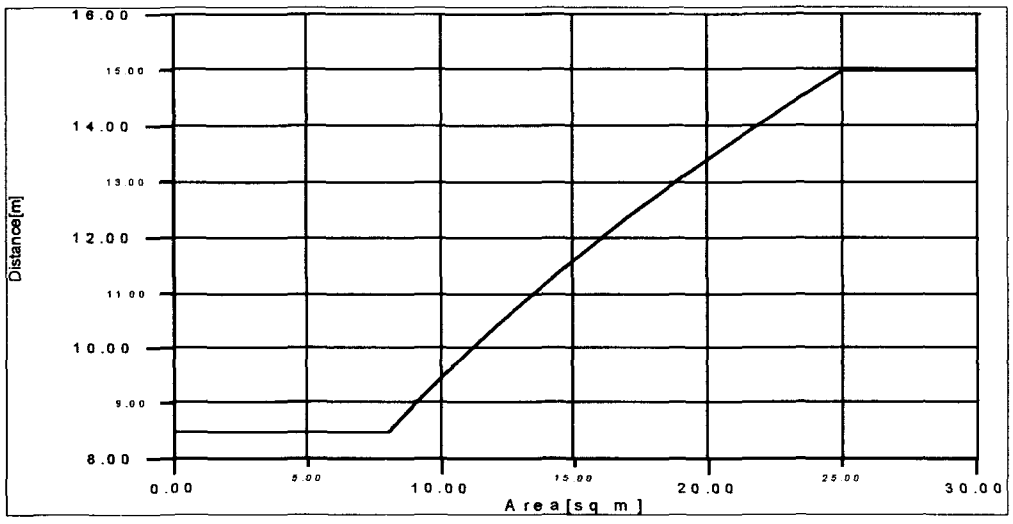
If the result were plugged to the Japanese application of mitigating distance where the blast barrier installed between LPG storage facilities and public use or other facilities nearby, the distance can be reduces by 8.4 meters.

The LPG explosion for pressurized vessel accompany with heat radiation. The explosion of 20kg vessel case can be reach 25kw/m^2 at 17.5 meters, and 50kg indicate to 22.5 meters with the same level of heat radiation. If 25kw/m^2 of heat radiation was exposed to human body by one minute, the fatality level can reach to 100%.

Such explosion at the LPG vessel, the Japanese safety control case is based on 0.125kgf/cm^2(=1.78psi) for explosion overpressure. If this level applied to 20kg, 50kg and 2.9 tons of LPG vessel storage with no blast wave barrier the distance will be 0.9, 1.22 and 4.72m, and the barrier installed it will be reduced by 0.54, 0.74 and 2.58 meters.

The LPG vessels in above cases reviewed by quantity based estimation, however, in Japan small scale LPG retail storages safety distances controled by the storage floor space. The Korea LPG safety act the vessel storage floor space should be over 19m^2. If such case applied into the graph (Fig.1), the required safety distances will be 7.85m to the neighbouring landuses.

[Fig.1]Isolation Safety buffer distance by size of LPG vessel storage floor space (2nd class)



[Source] Code for LPG safety, Industrial Complex Safety regulation. 1977

Finally, refer from the risk assessment manual for International Atomic Energy Association.(IAEA), if the neighbouring population density were assumed 160persons at one hector and 2.9tons of LPG vessel were exploded the maximum damage(100% fatality) area will be 0.2ha and the maximum distance will be 25m. The probability of assumed accident occurrence at such LPG vessel storage could be 1×10^{-4}per year. However, it is also neglected the conditions of blast wave barrier. The IAEA manual is based on 1bar of overpressure or 7kw of heat radiation with 30seconds, are applied to protect human damage to such area.

Conclusion.

From the various approaches, the explosion overpressure of even such a small quantity LPG vessels can reach to human body as well as neighbouring properties.

The existing safety control to LPG vessel retail storage could be valid to protect neighbouring landuse or human activity. Therefore blast wave barrier should be accompanied with safety buffer distant concept.

Although the required safety distance were varied each other, the applied acceptable overpressure or heat radiation levels are generally concentrated to protect human fatality rather than to protect domino effect to a neighbouring LPG facilities.

It is also required that the stringent control of out door stock loading, because the ignition or release of gas could happened most probably in such occasion as primary mishap.

Annotation (*)

* 1

· $W = \frac{\eta M E_c}{E_{CTNT}}$

· $R_G = Z_G W^{1/3}$

- W = equivalent mass of TNT(kg or lb)
- M = mass of flammable material released
- η = empirical explosion yield (or efficiency) (ranges from 0.01 to 0.10)
- E_c = lower heat of combustion of flammable gas (kJ/kg or Btu/lb)
- E_{cTNT} = heat of combustion of TNT (4437~4765kJ/kg or 1943~2049Btu/lb)
- R_G = radial distance from charge (ft)
- Z_G = scaled ground distance ($ft/lb^{1/3}$)

Acknowledge

- This work supported by KOSEF(96-0602-01-01-3)

Reference

1. High Pressure Gas Handling Act, Rapid finding Table Japan E Petroleum Industry. News.
2. High pressure Gas Vol 20. 1983.
3. LPG Safety Act for Optimum Control -17th Edition Japan.
4. LPG facility Inspection system Japan. 1990. 6.
5. LPG Safety Act for Optimum Control - New Edition. 1996. 4.
6. High Pressure Gas Handling Act. 6th Edition-2. Japan.
7. LPG Safety Act, Industrial Complex Safety regulation - Safety Inspector manual-Japan.1989. 11 .
8. PROCEDURAL GUIDE FOR ITERATED HEALTH AND ENVIRONMENTAL RISK ASSESSMENT AND SAFETY MANAGEMENT IN LARGE INDUSTRIAL AREAS. UNEP. Vienna. Austria. 1991.
9. Manual for the classification and privatization of risks due to major accidents in process and related industries. - IAEA. Vienna. Austria.1991.
10. Chemical Process Quantitative Risk Analysis.
11. Chemical Process Safety: Fundamentals with Applications. [Daniel A. Crowl /Prentice Hall. 1990.]
12. Gas accident Annual [K.G.S.O 1995]
13. High Pressure Gas Safety Management Act [Kumim sa / Kim. S. H, Bee. S.H 1997]