DESIGN OF UNLOADING AND STORAGE AREA FOR LIQUIFIED PETROLEUM GAS

A thesis submitted in partial fulfillment of the requirements for the Degree of

Master of Technology

(Pipeline Engineering)

By

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May, 2010

CERTIFICATE

This is to certify that the work contained in this thesis titled "DESIGN OF UNLOADING AND STORAGE AREA FOR LIQUIFIED PETROLEUM GAS" has been carried out by Yogendra Yadav under my supervision and has not been submitted elsewhere for a degree.

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(Yogendra Yadav)

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ABSTRACT

This project report gives a design for unloading and storage area for Liquefied Petroleum Gas for industrial installation. Detailed design of two cylindrical horizontal bullets of 44 MTons capacity each has been proposed. This report also included design of gasket, bolt size flange thickness and manhole thickness. And compressor selection for filling the LPG in the storage tank from the unloading of tanker is discussed.

Also included the calculations necessary to access the consequences of major accidents for LPG like fireball radius, duration of fire ball and burn effects. Recommendations have been made as per OISD 144 "Code for bulk Liquefied Petroleum Gas storage for Industrial, Domestic, and Bulk Storage".

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NOMENCLATURE

Cylindrical shell

f_p	-	Circumferential stress (N/mm^2)
f_p	-	Longitudinal or axial stress (N/mm^2)
Di	-	Internal diameter (mm)
Do	-	Outside diameter (mm)
t	-	Thickness (mm)
p	-	Design pressure (N/mm^2)
J	–	Weld joint efficiency (0.85)
F	-	Design or permissible stress at design temperature (N/mm^2)
f_t	-	Tangential stress (N/mm^2)
f_a	-	Total longitudinal stress (N/mm^2)
T	–	Torque about vertical axis (for cylindrical vessel 500 Nm)

Gasket, bolt flange thickness

G	-	Gasket mean diameter (mm)
W_{m1}	-	Bolt load at normal condition (N/mm^2)
W_{m2}	-	Bolt load at operating conditions (N/mm^2)
Y	–	Gasket seating stress (N/mm^2)
m	-	Gasket factor (value = 2)
b	–	Effective gasket seating (mm)
A_{m1} and A_{m2}	-	Cross section of bolts
f_a	–	Permissible tensile stress in bolt at atmospheric condition. (N/mm^2)
f_b	–	Permissible stress in bolt under operating condition. (N/mm^2)
t_f	-	Flange thickness (mm)
B	–	Bolt circle diameter (mm)
C	–	Corrosion allowance (mm)
T	–	Thickness of cover excluding corrosion allowance (mm)

Risk calculations

R	–	Radius of fire ball in meters
M	–	Mass of fuel in Metric tons
t*	–	Duration of fire ball in seconds
qt	–	Radiative flux incident on target (kw/m2)
E	–	Surface emissive power (KW/m2)
F	–	View factor
T*	-	atmospheric transmissivity

Compressor and pump

x	-	no. of cylinders
I	-	1 for single acting
A	-	Area of piston in cylinder, the influence of piston rod is neglected because its cross-section area is 2 to 3 % of piston area.
N	-	Speed (rpm)
L	-	Stroke (m)
n_{ov}	-	overall efficiency (0.85%)
Cm	$\leq$	3 m/s for medium compressors
$\mu \equiv$		0.8 for fluorocarbon compressors
n	-	index of compression (1.13)
P1	-	inlet pressure (pa)
P2	-	outlet pressure (pa)
V1	-	volumetric flow rate (m^3/min)
$\eta mech$	-	Mechanical efficiency (0.85)
Q	-	Flow rate in m^3/ min
P_d	-	differential pressure in bar

1.0 INTRODUCTION

Liquefied Petroleum Gas, otherwise known as LP Gas or simply LPG, is obtained from refining crude oil in petroleum refineries and fractionating natural gas available from oil and gas fields.

There has been a tremendous growth in the use of LPG as domestic fuel as well as in industries. This rapid growth in demand of LPG has led to a substantial increase in the requirement of bulk storage and handling facilities. Because of its flammability and explosive nature, LPG is a hazardous substance (Refer Table-2 for safety related properties of LPG). The purpose of this report is to recognize the potential hazards of LPG and recommend guidelines on safety procedures and practices to be followed in its storage and handling.

SCOPE

This document covers operation of equipment and facilities connected with storage and handling of LPG at Gas Processing Plants, Refineries and other Bulk Handling installations. It also includes some basic concepts for design and construction of such facilities. It does not include the requirements associated with bottling and other marketing functions or transportation of LPG by trunk pipelines. Also, unless otherwise indicated, it does not apply to refrigerated, underground and mounded storage of LPG.

Liquefied petroleum gas

The term applies to a mixture of certain light hydrocarbons derived from petroleum which are gaseous at normal ambient temperature and atmospheric pressure but may be condensed to the liquid state at normal ambient temperature by the application of moderate pressure.

LP gases mainly consist of one or more of the following hydrocarbons:

a) Propane (C_3H_8)
b) n-butane (C_4H_{10})
c) Butylene (C_4H_8)
d) Propylene (C_3H_6)
e) Iso-butane (C_4H_{10})

Types

There are three types of LP gases, based on their principal constituents:

a) **Commercial Butane** – A hydrocarbon product composed predominantly of butanes, butylenes or their mixtures.

b) **Commercial Butane-Propane mixture** - A hydrocarbon product composed predominantly of butanes and/or butylenes with propane and/or propylene.

c) **Commercial Propane** - A hydrocarbon product composed predominantly of propane , propylene or their mixtures.

Marking – The cylinders/containers shall be marked as prescribed by statutory authorities in this regard. They shall bear the labels marked with the following information:

a) Name and type of the materials.

b) Mass n kg of the material in the container

c) Maximum vapor pressure in case f commercial butane –propane mixture only; and

d) Manufacturer's name and trade-mark, if any.

Each cylinder/container shall also be marked with the caution label **"FLAMMABLE"** together with the corresponding symbol for labeling dangerous goods

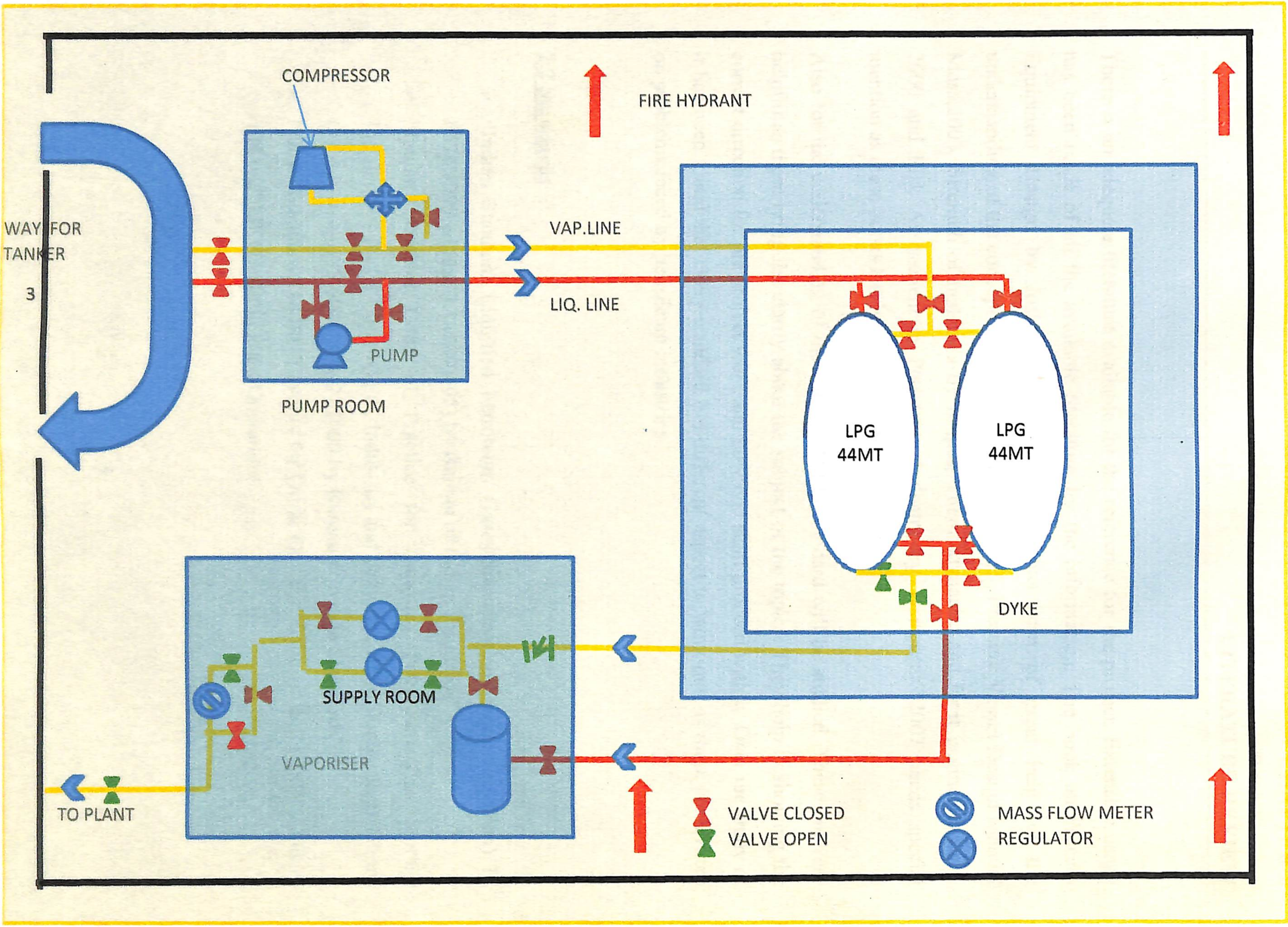


fig 1.layout for LPG storage area

CHAPTER 2

LITERATURE REVIEW

There is an adequate literature available for the reference for the project. Extensive usage has been made of all the available literature for the information. The book on Process Equipment Design by Joshi and Mahajani 2005 has been of great help for the understanding of the concept of design of cylindrical shell, Pressure Vessel Design Manual Moss,2003, Strength of materials by Rajput, Thermodynamic and Heat engines .Yadav, 2000 and Risk Assessment in Petroleum Industry by. Hamsagar, 2007 needs special mention as these books has been extensively used.

Also for the understanding of the concept OISD standard will be studied. These are very helpful as these bring the clarity about the subject of the topics. They help in showing the correct direction for the project work and how one shall proceed with it. Over the study of it has been found that every standard has different aspect to work out, as these are written on problems faced by petroleum industries.

2.2 Standards

- "Indian Standard Liquified Petroleum Gases-Specification (second revision) IS 4576:1999 edition 3.1 (2003-05) by Bureau of Indian Standards"
- "Indian Standard Code of Practice for Liquified Petroleum Gas Storage Installations Part-2 Commercial, Industrial and Domestic Bulk Storage Installations (First revision) IS 6044(part-2):2000 by Bureau of Indian Standards"
- "OISD Standard 118 on "Layouts for Oil & Gas Installations" and OISD Standard 144 on " LPG Bottling Plant Operations".

2.3 Scope of Study

This study will include the design of LPG storage, cylindrical shell and the effective consequences of risk. The Project will also incorporate equipment required for safe and efficient operation of plant.

2.4 Limitations of the Study

1. Data is collected from secondary sources so there are chances of error.
2. Availability of time and budget constraints.
3. Technical analysis will be used to design for a particular values and assumptions but sometimes it may not yield effective results.

FORMULATION

3.1 Design for Cylindrical shells (Joshi and Mahajani, 1996)

The following design procedure is applicable for shells having the ratio of outside diameter to inside diameter not exceeding 1.5.

3.1.1 Cylindrical shell: The internal pressure in the shell gives rise to stresses in the shell thickness, one in the circumferential and other in the longitudinal direction.

Circumferential stress, $f_p = \frac{pD}{2t}$ (3.1)

Longitudinal or axial stress, $f_a = \frac{pD}{4t}$ (3.2)

Where, p – internal pressure in (N/mm^2)

D – mean diameter of shell (mm)

Both of the above stresses are tensile. Since the circumferential stress is greater, this is taken as the design stress. The shell is generally formed by a joint in longitudinal direction, which is considered in terms of joint efficiency. The thickness of the shell is, therefore, given by

$$t = \frac{pD}{2fj} = \frac{pDi}{2fj-p} = \frac{pDo}{2fj+p} \quad (3.3)$$

Where, p- design pressure

D-mean diameter

J – joint efficiency

f- design or permissible stress at design temperature

Di- internal diameter

Do – outside diameter

In addition to the internal pressure, the other loadings are the weight of the vessel with its contents and the wind. The effect of offset piping can also be taken into account. The stresses created due to each of the above loadings can be stated as:

a) Stress in the circumferential direction due to internal pressure as per eq. (3.1). This is also known as tangential or hoop stress.

$$f_t = \frac{p(Di + t)}{2t} \quad \text{(tensile)} \qquad (3.4)$$

Where, t- thickness of shell calculated from eq. (3.3).

b) Stresses in the longitudinal or axial direction

i. Due to internal pressure as per eq.(3.2)

$$f_t = \frac{pD}{4t} \text{ (tensile)} \qquad (3.5)$$

ii. Due to weight of vessel and contents

$$f_2 = \frac{W}{\pi t(D+t)} \text{ (compressive)} \qquad (3.6)$$

Where, W is weight of vessel and contents

The weight W, includes weight of vessel shell, vessel fittings, internal fittings, external fittings (ladders, platform etc.) and weight of liquid fill in the vessel. The vessel will be filled with water for hydraulic pressure test and may fill with process liquid due to miss operation.

The weight of vessel therefore, increase by 10 to 15 percent on account for the above fittings and to obtain the weight W.

iii. Due to wind or piping in the case of vertical vessel or due to weight of vessel in the case of horizontal vessels.

$$f_3 = \pm\frac{M}{Z} = \frac{W}{\pi Di^2 t} \text{ (tensile or compressive)} \qquad (3.7)$$

Where, M –bending moment, due to loads normal to the vessel axis

Z – modulus of section of the cylindrical vessel

Now,

$P_{lw} = k\ P_l\ h_l Do$ up to 20 m height

Where, k- coefficient depending on the shape factor (0.7 for cylindrical surface)

P_l- wind pressure for lower part of vessel (400 to 1000 N/mm^2

h_l- height in meters

Do- outside diameter of the vessel

The bending moment due to wind at the base of the vessel is determined by

$M = P_{lw}H / 2$ (up to $H \leq 20$ m)

$$f_3 = \pm \frac{M}{Z} = \frac{W}{\pi Di^2 t} \quad \text{(tensile or compressive)} \qquad (3.7)$$

Total stress in the longitudinal or axial direction

$$f_a = f_t + f_2 + f_3 \quad \text{(tensile or compressive)} \qquad (3.8)$$

Stress due to offset piping

$$f_s = \frac{2T}{\pi t Di (Di+t)} \qquad (3.9)$$

where, T – torque about vertical axis (for cylindrical vessel 500 Nm)

Now, combining the above stresses on the basis of shear strain energy theory criterions, the equivalent stress is

The equivalent stress is

$$f_R = \{f_t^2 - f_t^2 f_a + f_a^2 + 3f_s^2\}^{1/2} \quad (3.10)$$

For satisfactory design, the following conditions must be satisfied

f_R (tensile) <= f_t (permissible)

f_a (tensile) <= f_t (permissible)

f_a (compressive) <= f_t (permissible)

if these conditions are not satisfied, the thickness t will have to be increased by employing the trial and error method. The final thickness should be determined by addition of corrosion allowance.

3.2. Design calculations for flange thickness, bolt selection and gasket. (Joshi and Mahajani, 1996)

3.2.1. Basic gasket load (b_o) = N/2

$$N = (D - E)/2 \quad (3.21)$$

If $b_o > 6.3$

Then, effective gasket seating

$$b = 2.5\sqrt{bo}$$

(3.21a)

G, gasket mean diameter = D – 2 b (3.21b)

3.2.2. Bolt loads

Atmospheric condition W_{m1}

$$W_{m1} = \pi bGy \quad (3.22a)$$

Where, b – effective gasket seating

G – gasket mean diameter (mm)

y – gasket seating stress (N/mm^2)

$$W_{m2} = \pi 2bGmp + \frac{\pi}{4}G^2 p \quad (3.22b)$$

Where, G-gasket mean diameter (mm)

m- gasket factor (2)

b – effective gasket seating (mm)

p- design pressure (N/mm^2)

The bolt load either W_{m1} or W_{m2} will create a tensile stress in cross-section of bolt.

Now,

$$A_{m1} = \frac{Wm1}{fa} \quad , \quad A_{m2} = \frac{Wm2}{fb} \qquad (3.22c)$$

A_{m1} and A_{m2} are cross section of bolts

f_a – permissible tensile stress in bolt at atmospheric condition. (N/mm^2)

f_b – permissible stress in bolt under operating condition. (N/mm^2)

Actual area of bolts (A_b) should be greater than A_{m1} and A_{m2}.

3.2.3. To determine number and size of bolt, the larger of above two area A_{m1} and A_{m2} should be considered.

A large number of small sized bolt or a small number of large size bolt.

$$\text{Total number of bolts} = \frac{\text{mean daimeter of gasket(cm)}}{2.5} \qquad (3.23a)$$

For Diameter of bolt

$$A_{m2} = A_m \text{ x no. of bolts} \qquad (3.23b)$$

$$\text{Actual bolt area} = \frac{2\pi yGb}{fa}$$

$$\text{Bolt spacing} = \pi . \frac{\text{pitch circle diameter}}{\text{number of bolts}} \qquad (3.23c)$$

3.2.4. Flange thickness (t_f)

$$t_f = G^2\sqrt{\frac{p}{KFa}} + c \qquad (3.24)$$

where, $k = \frac{1}{0.3 + 1.5\, Wm \frac{hg}{HG}}$

G – Diameter of gasket load reaction to bolt area (mm)
P – design pressure (N/mm^2)

Fa – permissible stress 130 N/mm^2
B – bolt circle diameter (mm)
c – corrosion allowance (mm)
Wm –total bolt load
hg – radial distance from gasket load reaction to bolt circle
hg = (B-G) / 2 (mm)

H = total hydrostatic end force

$$H = \frac{\pi p G^2}{4}$$

3.2.5. Bolt pitch connection factor (C_f)

Flange thickness of = 30 mm

$$C_f = \sqrt{\frac{bolt\ spacing}{2(bolt\ diameter) + flange\ thickness}} \qquad (3.25)$$

Bolt pitch connection factor (C_f) should be always greater than 1.0

3.2.5.1. Thickness calculation for manhole cover

$$T = C \times d \sqrt{\frac{p}{f}} \qquad (3.25a)$$

Where, T – thickness of cover excluding corrosion allowance (mm)
p – design pressure N/mm^2
f – allowable stress in N/mm^2 for material of construction
C – a factor depending upon method of attachment

$$C = \sqrt{0.31 + 190 \left(\frac{fb \times hg}{p \times d^3}\right)}$$

f_b –bolting load

$$f_b = \frac{Am + Ab}{2} \times fa$$

3.3. Design calculation to access the consequences of major accidents for LPG. (Hamsagar, 2007))

3.3.1. Fire ball Radius

$$R = 29\, M^{\frac{1}{3}} \quad (3.31)$$

Where, R – radius of fire ball in meters
M – mass of fuel in M .Tons

3.3.2. Fire ball duration

$$t^* = 4.5\, M^{\frac{1}{3}} \quad (3.32)$$

where, t* – duration in seconds
M – mass of fuel in M . Tons

3.3.3. The radiative flux incident on a target some distance away from LPG tank is given by

$$q_t = E.F.T \quad (3.33)$$

where, qt – radiative flux incident on target (kw/m2)
E – Surface emissive power (kw/m2)
E = 270 (kw/m2) for cylinders ,horizontal ,vertical tanks and 200 (kw/m2) for spheres
F – view factor, $F = \frac{R^2 r}{(R^2 + r^2)^{\frac{3}{2}}}$
Where ,R – is the fireball radius
r – is ground level distance between target and LPG tank
And ground level distance between target and LPG tank should be greater than 2R
T* – Atmospheric transmissivity, T* = 1- 0.058 ln r

3.3.4. Thermal dose or pulse can be calculated

$$\text{Thermal dose /pulse} = q_t \times t^* \quad (3.34)$$

Where , qt – radiative flux
t*- Duration of fireball.

3.4. Design calculation for selection of Compressor (reciprocating single stage)

(Yadav, 2000)

If free air (or gas) delivered with v (m^3/min) is to be compressed from pressure p_1 and Pressure p_2 in a single stage compressor.

$$V = x.i.A.L.N.\ n_{ov} \quad (m^3/min) \tag{3.41}$$

Where, x- no. of cylinders

i=1 for single acting

A-area of piston in cylinder, the influence of piston rod is neglected because its cross-section area is 2 to 3 % of piston area.

N-speed (rpm)

L- stroke (m)

n_{ov} - overall efficiency (0.85%)

To find main dimension, we select either mean piston speed Cm or $\mu = \frac{L}{D}$

$$Cm = \text{mean piston speed} = 2\frac{LN}{60}$$

$Cm \leq 2$ m/s for small compressors

$Cm \leq 3$ m/s for medium compressors

$Cm \leq 5$ m/s for large compressors

The ratio μ depends not only on the delivery pressure of the compressor but also on the speed of the machine.

The ranges of μ are:

$\mu \geq 0.5$ for vacuum pump and high speed compressors

$\mu \equiv 0.8$ for fluorocarbon compressors

$\mu \equiv 1$ for ammonia compressors

$\mu = 4$ to 6 for high pressure compressors

Thus, the equation (3.41) becomes

$$= \frac{\pi.x.i.30\ Cm\ \eta ovD^2}{4}$$

Hence, for a single stage compressor, we can calculate the cylinder diameter D. The ratio μ will give the value of stroke L.

Work done on gas during compression or Power required

$$\text{W.D} = \frac{n.P1.V1}{(n-1).\eta mech.60}[\left(\frac{p2}{p1}\right)^{\frac{n-1}{n}} - 1] \qquad (3.42)$$

Where, n- index of compression (1.13)

P1- inlet pressure (pa)

P2- outlet pressure (pa)

V1- volumetric flow rate (m^3/min)

$\eta mech$- mechanical efficiency (0.85)

1. Design of Cylindrical shell

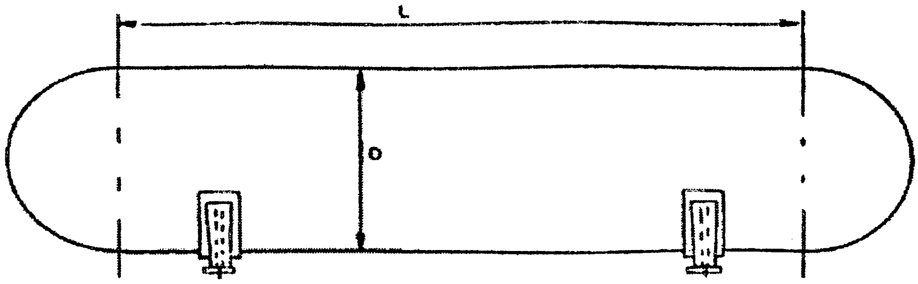


Figure. 2.0

Water holding capacity = 1, 05,000 ltr

Volume of cylindrical tank = $\pi D^2 L/4$

$105\ m^3 = \pi D^2\ 12.5\ m /4$ (Assume L=12.5 m)

$D^2 = (105x4)/(3.142x1250)$

$D = 3.25\ m$

Data for Shell:

1. Internal Diameter = 3250 mm
2. Material Stainless Steel = 0.5 Cr 18 Ni Mo 3
   Permissible stress = 130 N/mm^2
3. Internal Pressure = 1.033 $N/\ mm^2$ (150 psi)

Calculations

a) For thickness calculation as per eq. 3.3

$$t = \frac{pD}{2fj} = \frac{pDi}{2fj-p}$$

p – design pressure(1.1p =1.1363)

Di – internal diameter ,mm

J – Joint efficiency (0.85)

f – design /permissible stress of material (130 N/ mm^2)

t = (1.1363x3250) / (2x0.85x130-1.1363)

t = 16.7 mm

Thickness t= 16 mm will be satisfactory, but for factor of safety

we will assume t = 16+2 mm

t = 18 mm (say)

Hence, Outer diameter = 3250 + 2(18)

= 3286 mm

Internal diameter = 3250 mm

i. Now stress in circumferential direction due to internal pressure

Stress in the circumferential direction due to internal pressure is also known as tangential or hoop stress as per eq. 3.4

$F_t = p(Di + t) / 2\,t$ (tensile)

$= 1.1363(3250+18) / 2x18$

$\mathbf{f_t = 103.15\ N/\ mm^2}$ **(tensile)**

ii. Stress in longitudinal direction or axial direction as per eq. 3.5

1. Due to internal pressure

$f_l = p\ Di / 4\,t$ (tensile)

$= 1.1363x3250 / 4x18$

$\mathbf{f_l = 51.29\ N/\ mm^2}$ **(tensile)**

2. Due to weight of vessel and contents as per eq. 3.6

$f_2 = W/(\pi t(Di + t)$

where, W – The weight W includes weight of vessel shell, vessel fittings, internal fittings, external fittings (ladders, platforms) and weight of liquid to be filled in vessel.

Surface area of cylindrical vessel = Surface area of (hollow cylinder + Sphere)

$= 2\pi rl + 4\,\pi\,r^2$

$= 127643750 + 33187375\ mm^2$

Volume = Surface Area x Thickness

$=127643750 \times 18 + 33187375 \times 36\ mm^3$

$= 3492333000\ mm^3$

Volume $= 3.49\ m^3$

Mass = volume x density

$= 3.49\ m^3 \times 7200\ kg/\ m^3$

Mass of shell = 25,128 kg

Weight of liquid filled = 44,000 kg

Total weight = 25,128 + 44000

= 69,128 kg

With safe = 69128 x 1.1

= 70,000 kg (say)

Net total W = 686,000 N

$f_2 = W / (\pi\ t\ (Di + t)$

$= 686{,}000 / (3.142 \times 18(3250+18))$

f_2 = 3.72 N/ mm^2 **(Compressive)**

3. Due to wind load or due to weights of vessel in the case of horizontal vessel. as per eq. 3.7

$$f_3 = M / Z$$

Where, M - bending moment, due to loads normal to the vessel axis

$Z = \pi D^2_i t$ modulus of section of cylinder

$$\mathbf{P_{wl} = k\, p_l h_l D_o}$$

Where, p_l - wind pressure for 400 to 1000 N / m^2

h_l - height of vessel 8 m

D_o- outer diameter of vessel 3.286 m

K – co-eff of depending on shape factor 0.7 for cylinder surface

$$P_{wl} = 9100 \text{ N}$$

Bending moment due to wind

$$Mw = P_{wl} \times H/2$$

$$= 36400 \text{ Nm}$$

$$f_3 = M / Z$$

$$= 364000000 / (3.142 \times 3250 \times 3250 \times 18)$$

$$\mathbf{f_3 = 0.0609\ N / m^2} \qquad \textbf{(Compressive)}$$

Total stress in the longitudinal direction or axial direction as per eq. 3.8

$f_a = f_t + f_2 + f_3$ (tensile or compressive)

$= 51.29 - 3.72 - 0.0606$

$f_a = 47.5094$

$\mathbf{f_a = 47.50\ N/mm^2}$

iii. Stress due to offset piping or wind as per eq. 3.9

$f_s = 2T / \pi\, t\, Di\, (Di + t)$

Where, T – torque about the vessel axis = 500 Nm

$f_s = 2 \times 500 \times 1000 / (3.142 \times 18 \times 3250 \times 3268)$

$\mathbf{f_s = 1.66\ N/mm^2}$

Combining the above stresses on the basis of shear strain energy theory criterions as per eq. 3.10

The equivalent stress is $\mathbf{f_R = \{f_t^2 - f_t^2 f_a + f_a^2 + 3f_s^2\}^{1/2}}$

For satisfactory design, the following conditions must be satisfied

f_R (tensile) <= f_t (permissible)
f_a (tensile) <= f_t (permissible)
f_a (compressive) <= f_t (permissible)

$f_R = \{103.15^2 - (103.15 \times 51.29) + 51.29^2 + 3(1.66^2)\}^{1/2}$

$\mathbf{f_R = 89.37\ N/mm^2}$

Both f_R and f_a are less than permissible tensile stress (**130 N / mm^2**)

Hence, the design is safe and within permissible limits.

4. Calculation for gasket ,bolt size, flange thickness and blind thickness

Assumptions

1.	Design pressure		1.1363 N/mm^2
2.	Design temperature		-42°C to 55 °C
3.	Outer flange diameter	A	620 mm
4.	Pitch circle diameter	B	560 mm
5.	Gasket type CAF		3.2 mm thickness
6.	Gasket OD	D	520 mm
7.	Gasket ID	E	456 mm
8.	Gasket factor	m	2

(Material for gasket is asbestos)

9.	Minimum design seating stress	y	11.2 N/mm^2
10.	Bolt stress at ambient temperature	f_a	152.864 N/mm^2
11.	Bolt stress at design temperature	f_b	152.08 N/mm^2

(Material for bolts is hot rolled carbon steel)

A. Gasket load (3.21)

Basic gasket load (b_o) = N/2

$N = (D - E)/2$

$N = (520 - 456)/2$

$N = 32$

$\therefore b_o = 16$

If $b_o > 6.3$

Then, effective gasket seating as per eq. 3.21a and 3.21b

$b = 2.5\sqrt{bo}$

$b = 2.5\sqrt{16}$

$b = 10$ mm

G, gasket mean diameter = $D - 2b$

$G = 520 - 2 \times 10$

$G = 500$ mm

B. Bolt loads as per eq. 3.22

I. Atmospheric condition W_{m1}

$W_{m1} = \pi b G y$

Where, b – effective gasket seating

G – gasket mean diameter

y – gasket seating stress

$= 3.142 \times 10 \times 500 \times 11.2$

$W_{m1} = 175952$ N

II. $W_{m2} = \pi 2bGmp + \frac{\pi}{4} pG^2$

$= 3.142 \times 2 \times 10 \times 500 \times 2 \times 1.1363 + (3.142 \times 1.1363 \times 500^2)$

$W_{m2} = 294141.1976$ N

The bolt load either W_{m1} or W_{m2} will create a tensile stress in cross-section of bolt.

as per eq. 3.22c

$A_{m1} = \frac{Wm1}{fa}$, $A_{m2} = \frac{Wm2}{fb}$

A_{m1} and A_{m2} are cross section of bolts

f_a – permissible tensile stress in bolt at atmospheric condition.

f_b – permissible stress in bolt under operating condition.

i. $A_{m1} = \frac{175952}{152.864}$

$A_{m1} = 1151.03\ mm^2$

ii. $A_{m2} = \frac{294141.1976}{152.08}$

$A_{m2} = 1934.12\ mm^2$

Actual area of bolts (A_b) should be greater than A_{m1} and A_{m2}.

To determine number and size of bolt, the larger of above two area A_{m1} and A_{m2} should be considered. as per eq. 3.23a

A large number of small sized bolt or a small number of large size bolt.

Total number of bolts $= \frac{mean\ daimeter\ of\ gasket(cm)}{2.5}$

$= \frac{50}{2.5}$

Number of bolts = 20

Number of bolts should be multiple of 4.

Now,

Diameter of bolt as per eq. 3.23c

A_{m2} = A_m x no. of bolts

1934.12 = $\frac{\pi}{4} d^2 \times 20$

d^2 = $\frac{1934.12 \times 4}{3.142 \times 20}$

d = $\sqrt[2]{123.11.39}$

d = 11.09 mm

d $\cong$ 12 mm

Table 1.0- for bolt specifications

S.No.	Size	Major dia. Mm	Pitch mm/thread	Pitch dia. mm	Minor dia. Mm
1	M12	12	1.75	10.863	10.11
2	M14	14	2.0	12.701	11.84
3	M16	16	2.0	14.701	13.84
4	M18	18	2.0	16.376	14.48

$D_{min} = D_{maj} - 1.08 \times \text{Pitch}$

$D_{pitch} = D_{maj} - 0.649519 \times \text{Pitch}$

Bolt area = $\frac{\pi}{4}$ [Pitch diameter^2 + minor diameter^2] x No. of bolts/2

Bolt area for bolt

M12 = 1729.80 mm^2

M14 = 2368.29 mm^2

M16 = 3202.20 mm^2

M18 = 3753.46 mm^2

Now, Actual area $= \frac{2\pi y G b}{f a}$

$= \frac{2 \times 3.142 \times 11.2 \times 500 \times 16}{152.864}$

$A_b = 3683.31$ mm^2

Now, comparing individually with selected bolt area.

$A_b >$ M12

$A_b >$ M14

$A_b >$ M16

$A_b <$ M18

Hence, area for M18 is more than the actual area calculated.

Therefore, we did not selected the M18 and choose M16 size of the bolt.

Now,

Pitch circle diameter = OD of gasket + 2 x diameter of bolt + 8

= 520 + 2 x 16 + 8

Pitch circle diameter = 560 mm

Assumed Pitch circle diameter is 560 mm

Outer diameter of flange = Pitch circle diameter + 2 x diameter of bolt

= 564 + 2 x 16

Outer diameter of flange = 596 mm

Assumed Outer diameter of flange is 620 mm

Therefore, the assumed data are satisfactory

Now,

1. Bolt spacing $= \pi \frac{pitch\ circle\ diameter}{number\ of\ bolts}$

$= \frac{3.142\ x\ 560}{20}$

Bolt spacing = 87.97 mm

(d) Flange thickness (t_f) as per eq. 3.24

$$t_f = G^2\sqrt{\frac{p}{KFa}} + c$$

where, $k = \frac{1}{0.3+1.5\, Wm \frac{hg}{HG}}$

G – Diameter of gasket lad reaction to bolt area
P – design pressure
Fa – permissible stress 130 N/mm^2
B – bolt circle diameter
c – corrosion allowance
Wm –total bolt load
hg – radial distance from gasket load reaction to bolt circle
hg = (B-G) / 2
H = total hydrostatic end force

$$H = \frac{\pi p G^2}{4}$$

$$\text{Now, } k = \frac{1}{0.3+1.5 \times 294141.1976 \times \frac{30}{\frac{\pi \times 1.1363 \times 500 \times 500^2}{4}}}$$

$$K = 2.388$$

$$t_f = 500\sqrt{\frac{1.1363}{2.388 \times 152.864}} + 1.5$$

$$t_f = 27.896 + 1.5$$

$$t_f = 29.396 \text{ mm}$$

$$t_f \cong 30 \text{ mm}$$

Bolt pitch connection factor (C_f) as per eq. 3.25

Flange thickness of = 30 mm

$$C_f = \sqrt{\frac{bolt\ spacing}{2(bolt\ diameter) + flange\ thickness}}$$

$$C_f = \sqrt{\frac{87.97}{2 \times 16 + 30}}$$

C_f = 1.19 > 1 for safe design it should be always greater than 1

(e) Thickness calculation for manhole cover as per eq. 3.25a

$$T = C \times d \sqrt{\frac{p}{f}}$$

Where, T – thickness of cover excluding corrosion allowance

p – design pressure N/mm^2

f – allowable stress in N/mm^2 for material of construction

C – a factor depending upon method of attachment

$$C = \sqrt{0.31 + 190\left(\frac{fb \times hg}{p \times d^3}\right)}$$

f_b –bolting load

$$f_b = \frac{Am + Ab}{2} \times fa$$

$$= \frac{1151.03 + 3683.31}{2} \times 152.864$$

f_b = 369498.27 N

$$C = \sqrt{0.31 + 190\left(\frac{369498.27}{1.1363 \times 500^3}\right)}$$

$$C = 0.89$$

Blind thickness

$$T = 0.89 \times 500 \sqrt{\frac{1.1363}{130}}$$

T = 41.6 mm ≅ 42 mm

Required thickness = t + corrosion allowance

= 42 + 1.5

= 43.5 mm

Hence, nominal thickness provided for manhole cover is 45 mm.

4.3 Calculation to access the consequences of major accidents for LPG.

Fire ball Radius as per eq. 3.31

$$R = 29\, M^{\frac{1}{3}}$$

$$= 29 \times 44^{\frac{1}{3}}$$

$$R = 102.38 \text{ m}$$

a) Fire ball duration as per eq. 3.32

$$t = 4.5\, M^{\frac{1}{3}}$$

$$t = 4.5 \times 44^{\frac{1}{3}}$$

$$t = 15.88 \text{ sec}$$

b) The radiative flux incident on a target some distance away from LPG tank is given by as per eq. 3.33

$$q_t = E.F.T$$

E = 270 (kw/m^2) for cylinders ,horizontal ,vertical tanks

And 200 (KW/m^2) for spheres

$$F = \frac{R^2 r}{(R^2 + r^2)^{\frac{3}{2}}}$$

Where, R – is the fireball radius

r – is ground level distance between target and LPG tank

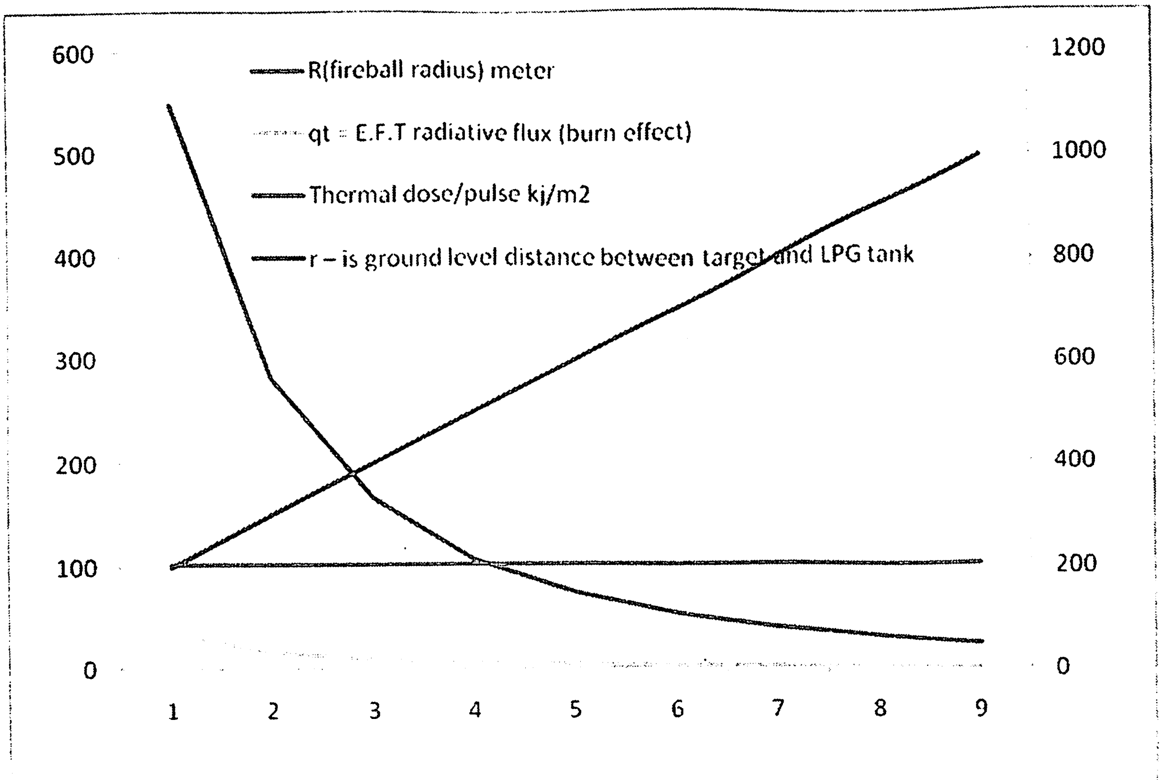
And ground level distance between target and LPG tank should be greater than 2R.

$T = 1 - 0.058 \ln r$

Table 2.0 for calculations for r, F, T, qt and thermal dose

S.No.	R(fireball radius) meter	r – is ground level distance between target and LPG tank	F – view factor	T–atmospheric transmissivity	q_t = E.F.T radiative flux (burn effect)	Thermal dose/pulse KJ/m^2
1	102.38	200	0.1848	0.6926	34.55	548.654
2	102.38	300	0.0987	0.6691	17.83	283.14
3	102.38	400	0.0595	0.6524	10.48	166.42
4	102.38	500	0.0394	0.6395	6.80	107.98
5	102.38	600	0.0278	0.6289	4.72	74.95
6	102.38	700	0.0207	0.6200	3.46	54.94
7	102.38	800	0.0159	0.6122	2.62	41.60
8	102.38	900	0.0126	0.6054	2.05	32.554
9	102.38	1000	0.0103	0.5993	1.66	26.36

Fig.3 Graph representing the relation between Distance vs. Radiative heat flux



The graph plot between Distance (m) and burn effect) we found that Burn effect decreases in cube root as distance from fire increases.

4. Calculation for compressor

Volumetric flow rate from annexure III at temperature 35 °C

Given v = 55.8 cfm @ 35 °C from Annexure 3

Converting from into m^3/min

1 cfm =1.7 m^3/min

$\therefore$ 55.8 cfm = 1.581 m^3/min

So, volumetric flow rate is 1.581 m^3/min

Now, from eq. 3.41

$$1.581 = \frac{\pi D^2 x Cm\, x 30 x 0.85}{4}$$

D^2 = 0.02631

D = 0.162 m

D = 162 mm

$$\mu = \frac{l}{d}$$

$$0.8 = \frac{l}{162}$$

l = 129.6 mm

l = 130 mm

Now, as from eq.3.42

$$W.D = \frac{1.13 \; x \; 482.419 \; x \; 1.581}{(1.13-1) \; x \; 0.85 \; x60} [\left(\frac{120}{70}\right)^{\frac{1.13-1}{1.13}} - 1]$$

$$= 8.27 \text{ KW}$$

Power consumption required for compressor is 1.1 times calculated power

Power = 9.0 KW

Selection of Pump (Corken data)

Principle of the vane stationary pump

The vane type pump is a special type of rotary positive displacement pump, known as a sliding Vane pump. The sliding Vane Pump has many of the positive displacement advantages of the gear pump, plus the ability to compensate for wear, and operate at a lower noise level.

The sliding vane consists of one rotor turning in a liner(called cam) machined eccentrically in a relation to the rotor, thereby displacing the liquid trapped between the rotor, cam and vanes. This pump is made with vanes produced from modern plastics which exhibit extremely low coefficients of friction. The vanes are self adjusting for wear, which gives the pump a very long life.

The case and Heads – are made of ductile iron (not cast iron) for extra strength.

The sliding vane – vane (blades) are manufactured of special plastic to provide excellent life and quiet operation

The Mechanical Seal – is designed for longer life under greater loads and may be inspected or replaced.

Bearings – are heavy duty roller type for long life

Pressure gauge – connections are ¼" pipe threads are provided in both inlet and outlet nozzles of case.

A relief valve – is built in as a part of the pump, this valve is adjustable under pressure. Even with this internal safety valve an external bypass valve must be installed.

Table 3.0 Pump specifications

S. No.	Specifications	Standard
1	Suction flange	2"
2	Discharge flange	2"
3	Maximum RPM	950
4	Minimum RPM	420
5	Minimum temperature	-25°F (-32°C)
6	Maximum temperature	225 °F (107°C)
7	Maximum working pressure	400 psig(27.6 bar)
8	Maximum differential pressure	125psig(8.5 bar)

Power required for pump in KW

$$P = \frac{Q \times Pd}{36}$$

Where, Q – flow rate in m^3/min

P_d – differential difference in bar

Total mass = 16000 kg

Density of LPG @15 °C 760 mm of Hg = 2.256 Kg / m^3

$$\text{So, Volume} = \frac{mass}{density}$$

$$= \frac{16000}{2.256}$$

$$= 7092.198 \ m^3$$

$$\text{Flow rate, } Q = \frac{volume}{time\ in\ hrs}$$

$$= \frac{7092.198}{4}$$

$$= 1773.049 \ m^3/\ hr$$

$$Q = 29.55 \ m^3/\ min$$

P_d – differential difference in bar is 8.5 bar

$$P = \frac{29.55 \times 8.5}{36}$$

$$P = 6.977 \text{ KW}$$

Power consumption required for power is 1.1 times calculated power

$$P = 7.67 \approx 8.0 \text{ KW}$$

CHAPTER 5

RESULTS AND DISCUSSION

The maximum capacity of an individual tank and group of tanks at industrial commercial and domestic premises shall be as follow.

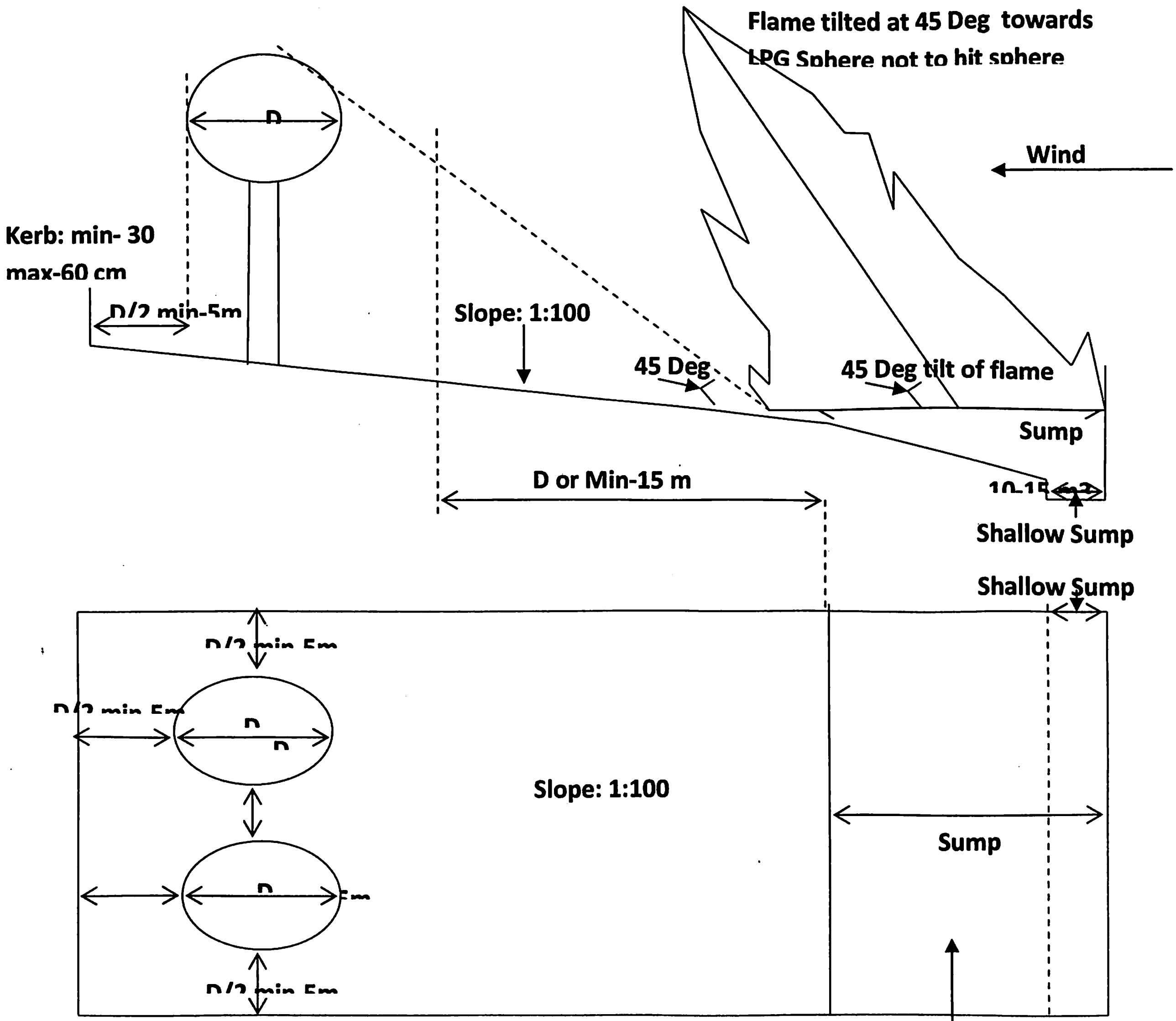
Table 4.0

S.No.	Premises	Maximum water capacity of an individual tank, liters.	Maximum water capacity of group of tanks liters.
1	Industrial	130000	260000
2	Commercial	40000	80000
3	Domestic	20000	80000

Shell flanges for vessels and equipment: General requirements limited to 5 cm nominal size. the shut-off valve should be provided with a length of piping terminating with a second shut-off valve limited to 2.5cm nominal size. The length of piping simultaneous obstruction of both valves is minimized. A sufficient length of piping should ensure that discharge will not take place beneath the tank. For smaller tanks, the shut-off valve should be limited to 2.5cm size and its outlet should be provided with a screwed plug or blank flange containing a drain hole of maximum 3mm size.

4.5. Design for liquefied petroleum gas storage installations

Fig. 4.0 LPG-Bulk Storage as per OISD-144:



LPG-Spill collection rate of approx. 5 kg/sec. Capacity to be considered as 10 cum. For 100mm outlet & 15cum. For 150 mm outlet.

GROUPING - Vessels shall be arranged into groups, each having a maximum of six vessels. Capacity of each group shall be limited to 15000 Cu.M. There shall be minimum spacing as

5.1. Location of storage tanks and regulating equipment

Location and spacing

1. Storage tanks and first stage regulating equipment if used, shall located outside of buildings
2. Each individual tank shall be located with all respect to the nearest important building or group of buildings or line of adjoining property which may be built on in accordance with table no 1.

The distance given refers to the horizontal distance in plan between the nearest point of storage tank and building/property line.

3. In heavily populated or congested areas the authority having jurisdiction may determine the need for other reasonable protective methods to be taken, such as, provision of fire walls etc.
4. If fire walls are to be provided, the authority having jurisdiction may determine the extent to which the safety distances for above ground tanks may be reduced.
5. Storage tanks shall not be installed one above the other.

6. No LPG tank(s) shall be located within the bunded enclosures of any other petroleum installation. The minimum distance of separation between LPG storage tanks and petroleum installation shall be as prescribed under the petroleum rules, 1976 or as prescribed under SMPV rules or as per distance specified above in table 1, whichever is more.
7. The number of storage tanks in one storage installation shall not exceed six. In case there are more than one storage installations, the safety distance between two installations, shall be the same as the distance between the tanks and the property line in accordance shall not be with table 1.

5.2. Bunding

Since LPG is heavier than air, storage tank shall not be enclosed within bund walls. The accumulation of flammable liquid under LPG tanks shall be prevented by suitably slopping the ground.

5.3. Protection

1. To prevent trespassing or tampering, the area which includes tanks, direct fired vaporizers, pumping equipment and loading and unloading facilities shall be enclosed by an individual type fence at least 2 m high along the perimeter of the safety zone. Any fence shall have at least two means of exit Gates shall open outwards and shall not be self locking.
2. When damage to LPG system from the LPG tank Lorry is a possibility, precautions against such damage shall be taken.
3. Underground tanks shall be protected from above ground loading by providing a suitable curb to prevent a possible accidental damage to the tank and its fittings by LPG tank lorry.

5.4. Storage Tanks

1. Design code

Storage tanks shall be designed, fabricated and tested in accordance with IS 2825 or such standards as laid down or approved by the Chief Controller of Explosives, Government of India.

2. Design pressure

The design pressure of the tank shall be not less than at the vapor pressure of the particular LPG to be stored at the highest temperature that the contents of the tank may reach in service .The maximum temperature as prescribed by the Chief Controller of Explosives, Government of India, is 55°C for tank.

3. Fittings

3.1. General

A. Each tank shall be provided with the following fittings

I. Pressure relief valve connected to the vapour space – 02 No

II. Independent liquid vessel indicators/gauge-02 No.

III. Pressure gauge connected to the vapour space if the tank has over 2500 liters water capacity

B. Pipe joints over 50 mm nominal size shall be welded or flanged; joints of 50 mm nominal size or smaller shall be welded, flanged.

C. A manhole, if fitted on an underground tank shall not be less than 45 cm internal diameter and shall be in the form of an extended nozzle of sufficient length to bring the manhole cover above ground level.

D. All the tank fittings of underground tanks shall be on the manhole cover if the tank is equipped with manhole. If the tank is not so equipped, the fittings shall be on extended nozzles so as to be accessible at ground level subject to protection

3.2. Pressure Relief

A. Relief valves shall be spring loaded and set to discharge at 100 percent and reach full flow conditions within 110 percent of design pressure as required. The design of the valves shall be such that they cannot be inadvertently overloaded and that it is not possible to temper with their pressure setting. Relief valves shall be constructed so that the breakage of any part will not obstruct the free discharge of vapour under pressure.

B. The full flow capacity of pressure relief valves for above ground tanks shall be in accordance with Annex A. For underground tanks the full flow capacity of pressure relief valves may be reduced to not less than 30 percent of the prescribed value in Annex A.

C. Every relief valve shall incorporate the following permanent markings:

i. Manufacturer's name and valve type number.

ii. Nominal inlet and outlet sizes

iii. Start of discharge pressure and

iv. Certified discharge capacity of air at atmospheric pressure.

D. If provision is made to isolate any relief valve for testing/servicing ,then the remaining relief valves connected to the tank shall provide the full discharge capacity as per Annex .A.

E. For above ground tanks of over 4500 liters water capacity and for all underground tanks, relief valves shall be fitted with extended vent pipes adequately supported and having outlets at least 2 m above the top of the tank and at least 3.5 m above ground level .The vent pipes shall be fitted with loose fitting rain caps.

4. Shut-Off and Emergency Shut –Off Valves

a) All liquid and vapour connections on tanks, with the exception of those for relief valves, plugged openings and those where the connection is not greater than 1.4 mm diameter opening, shall have shut off valves located at minimum 3 m from the shadow of the vessel.

b) All liquid and vapour connections on the tanks with the exception of those for relief valves and drainage connections of small diameter, shall have an emergency shut-off valve, such as an excess flow valve, an automatically operated valve or remotely controlled valve. The emergency shut-off valve shall be in addition to the shut-off valve mentioned in (a) above, unless the valve is a remotely controlled valve which can be operated from a safe area and it is of a failsafe type. Emergency shut-off valves are not considered necessary where the connection to tank is restricted Where the connections to tank is restricted to not greater than 3 mm diameter for liquid and 8 mm diameter for vapour.

c) Where the emergency shut-off valve is of the excess flow type , it is closing rate o flow should be below that rate which is likely to result from a fracture of the line it is protecting .

d) Drain connections for larger tanks shall be provided with a shut-off valve which should be limited to 50mm nominal size. The shut –off valve should be provided with a length of piping terminating with a second shut-off valve limited to 25 mm nominal size. The length of piping between the valves should be such that the risk of simultaneous obstruction of both valves is minimized. A sufficient length of piping should be provided downstream of the second valve to ensure that discharge will not take place beneath the tank. For smaller tanks, the shut-off valve should be limited to 25 mm nominal size and its outlet should be provided with a screwed plug or blank flange containing a drain hole of maximum 3 mm size.

5.5.Painting of above –ground tanks

Tanks and their supports shall be adequately painted externally to prevent corrosion with a sun reflective paint such as white or as per colour approved by CCE. Aluminium paint shall not be used for this purpose.

a. **Installation of underground tanks**

Tanks shall be set on RCC concrete foundation, buried in a masonry pit and shall be surrounded with sweet sand. Where the water table may be high, tanks shall be securely anchored or weighted to prevent floating shall be securely anchored or weighted to prevent floating. The backfill material shall be free of rocks or other abrasive materials and shall be carefully consolidated. It is recommended that minimum 60 of cover should be provided on over the top of the tank, or any other recommendations as per CCE's approval condition.

It is recommended that specialist's advice should be obtained on corrosion protection of tanks, including coating materials and application, and whether cathodic protection is necessary or application of epoxy base paint as recommended in NFPA-58 or any other as per suggestion CCE's licensed condition.

b. **Marking of tanks**

Each tank shall be conspicuously and permanently marked to include the following :

a) The pressure vessel code to which it is made;
b) The manufacturer's name and serial number;
c) The water capacity in liters;
d) The maximum safe working pressure;
e) Test pressure; and
f) Test date

5.6. PIPING VALVES AND FITTINGS

i. Materials

All materials including non-metallic parts for valves, seals, gaskets and diaphragms shall be resistant to the action of LPG under the service conditions to which they are subjected.

Cast-iron piping materials shall not be used.

Seamless steel pipe is recommended. Electrical resistance welded steel pipe normalized throughout its length may be used.

Copper or brass pipe or tubing shall be seamless and shall be only used for sizes 12.5mm and under.

Steel pipe shall conform to one of the following Indian Standard specifications:

IS 1239(part 1), IS 1978 and IS 1979.

Copper pipe shall conform to IS 2501.

Brass pipe shall conform to IS 407.

Pipe thickness

To be decide as per design parameter of the system.

Pipe joints

pipe joints over 5 cm nominal size shall be welded or flanged. Joints of 5 cm nominal size or smaller may be welded, flanged, or screwed.

The fabrication of pipe work by fusion welding shall be carried out.

5.7 Valves

Valves shall be of cast steel. Only ball valves shall be used. Cast iron valves shall not be used.

5.8 Flanges and fittings

Steel flanges and flanged fittings shall conform either to section IV of IS 2825 or IS 4864.

Slip – on or welded neck flanges or screwed flanges may be used for sizes of 5 cm or smaller.

steel butt welded fittings shall be at least of the same schedule thickness as the pipe .

Steel socket couplings and fittings shall be in accordance with IS 4712 and may be either welded or screwed type.

Steel unions shall be in accordance with IS 1239(part 2). They should have ground metal-to-metal seats: gasket type unions shall not be used.

Plugs shall be solid steel plugs or steel ball plugs. Cast iron or brass plugs shall not be used.

5.9. Bolting

Bolting shall be supplied according to IS 1367(parts 1 to 3).

Installation and testing

Liquid and vapour pipelines shall be installed so as to have adequate 'flexibility' to accommodate any settlement of tanks or other equipment, thermal expansion, or contraction or any other stresses which may occur in the pipe work system.

Any equipment or section of pipeline in which liquid may be trapped, for example, between shut-off valves, shall be protected against excessive pressure caused by thermal expansion of the contents. The minimum setting of relief valves provided for this purpose shall be not less than the maximum pressure under normal operating conditions, of the section of pipeline which they are protecting. If pressure relieving devices discharge to atmosphere, the discharge should be arranged in a safe manner.

All pipeline system after installation shall be proved free from leaks at the following pressure or at the following pressure or at the maximum operating pressure whichever is higher

a) Vapour pipelines (up stream and downstream at 1.5 times working pressure)b) liquid pipelines (downstream) at 1.5 times working pressure.

Piping both underground and above-ground shall be protected against physical damage and corrosion.

6. HOSES, PUMPS, COMPRESSORS, AND METERS USED FOR TRANSFER OF LPG

6.1 Hoses

6.1.1 The design ,materials, and construction of hoses shall be suitable for the grade of LPG which they are to handle. They shall be tested at 30kg/cm^2 during initial manufacturer and designed to withstand a minimum bursting pressure of four times the maximum pressure they will carry in service.

6.1.2 Hoses shall periodically be tested for electrical continuity, the frequency of the test depending on the amount of use.

6.1.3 Excess-flow valves, automatically operated valves, or remotely controlled valves or of quick shut-off couplings to be installed in pipelines to which hoses are connected to prevent discharge of LPG in the event of failure of the hose.

6.2 Pumps, compressors and Meters

6.2.1The design, materials, and construction of pumps. Compressors and meters shall be suitable for the type of LPG which is to be handled, and they shall be designed for the maximum outlet pressure to which they will be subjected in operation.

6.2.2 Seals used shall be of the mechanical type.

6.2.3 positive displacement pumps and compressors shall have by-pass or other suitable pressure relieving device against over pressure.

7. General safety requirements

7.1 Static electricity and lighting protection

Earthling and bonding , telecommunications and instrumentation shall be in accordance with IS 1913(part 1), IS 2309 and IS 3043.

7.2 hand torches if used shall be of approved flameproof type .

7.3 All electrical installations within the safety zone shall be of flame proof type conforming to IS 2148.

7.4 Grass and weed removal

Readily ignitable material, such as , weeds , long grass or any combustible material shall be removed from an area within 3m from the shell of any LPG tank of up to 2000 liters water capacity, and within 6m from the shell of larger tanks. If weed killers are used , chemicals which area potential source of fire hazard shall not be selected for this purpose.

7.5 Warning signs

No smoking or naked flames shall be permitted within the safety zone of the installation. Prominent notices to this effect shall be posted at access points.

8. Transfer of LPG

8.1 from road tank lorries

8.1.1 a minimum safety distance of 9m shall be maintained between :

a) Centre line of tank-lorry hard standing /discharge point and the adjoining property
b) Centre line of the tank- lorry hard standing and the storage tank shell.

8.1.2 The tank-lorry hard standing shall be within the fence area of the storage installation.

8.2 Instructions given in Annex C shall be strictly observed during the transfer of LPG from road tanker to the installed tanks.

9. FIRE protection

9.1 general

The possibility of a major fire outbreak, leading to direct flame impingement of the storage tank shall be minimized by sound engineering in plant design and layout, good operating practice and proper education and training of personnel on both routine operations and on action to be taken in an emergency.

9.2 water supply

Provision shall be made for an adequate supply of water and fire protection in the storage area according to the local fire services regulations, or minimum arrangements shall be made for spraying of water at the rate of 10 lpm on each vessel in the bund. Spraying of water to be arranged in the LPG pump/ compressor house also. The additional application of water may be by hydrants fixed monitors and through mobile equipment. Control of water flow should be possible from outside any danger area.

9.2.1 Hydrants, where provided, shall be readily accessible at all time so space as to provide for the protection of all tanks.

9.2.2 Sufficient lengths of fire hose shall be provided and be readily available. It is desirable to equip the outlet of each hose line with a combination jet and fog nozzle. These should be in good condition and periodically inspected.

9.2.3 Mobile equipment, field monitors, or fixed spray systems shall be designed to discharge water at a rate sufficient to maintain an adequate film of water over the surface of tank and support under fire conditions.

9.2.4 Consideration shall be given to the provision of mobile or fixed water-spray systems giving suitable and effective protection for road tanker and rail tank car loading and unloading areas.

9.3 Fire Extinguishers

At least two numbers of 10kg capacity dry chemical powder type and one number of 50kg capacity dry chemical powder type wheel mounted fire extinguishers shall be positioned near the storage area. In addition, minimum two numbers of 10kg DCP (dry chemical powder type) fire extinguishers shall be positioned at the product transfer area, that is, tank truck unloading area.

10. Instructions for transfer of LPG

1. Operations and training

The following recommendations apply to industrial and commercial installations

I. Those responsible for the operation of equipment and the handling of LPG should understand the physical characteristics of the product and be familiar with the relevant sections.

II. Responsible personnel should be trained in the fundamentals of fire fighting and fire control with particular reference to fires involving LPG. They should also be trained in the correct handling of any fire fighting and fire control equipment provided and should be exercised in this respect at frequent intervals. The locations of all gas and liquid piping and valves should be known and their use understood.

2. Product transfer

Before LPG is transferred from a container to any other container whether it is a storage tank, road tanker, rail tank car, or portable container, the following procedure should be followed.

a) The receiving container should be checked to ensure that it is in safe working condition and that it is not to be filled with a grade of LPG for which it is not designed.

b) The receiving container should be checked to ensure that it has sufficient ullage to receive the product being transferred to it.

c) The inter-connecting system, that is, pipe work, fittings, valves, hoses, etc. should be checked to ensure that it is in safe working condition.

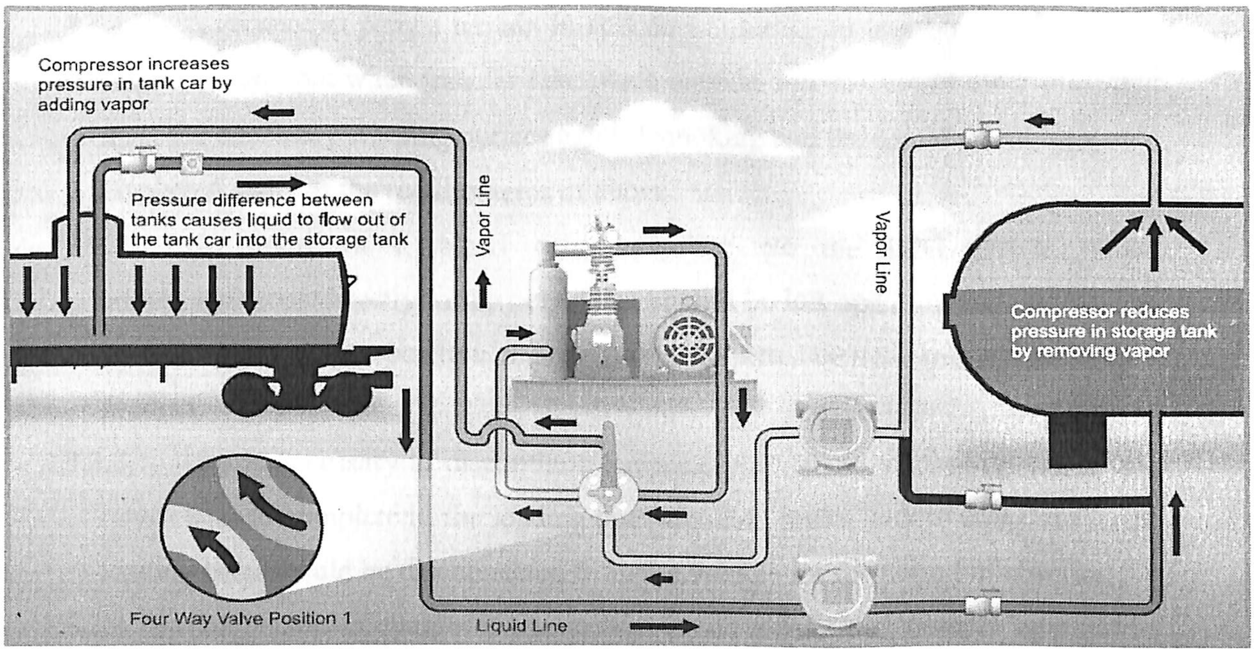
3. The inter-connecting system should be checked to ensure that product cannot be charged into lines, equipment or containers not designed to handle it and that unacceptable product contamination will not occur.

3.1. During LPG transfers from container to container and on completion of the operation, the receiving container should be checked to ensure that it is not being overfilled and on completion is not filled above its safe working level

3.2. In this case of road tankers and rail tank cars in addition to the requirements of above two procedure should as follows

a. The vehicle should be prevented from accidental movement during the transfer operation. The parking brake of a road tanker or hand brake of a rail tank car should be on and, where necessary, wheel chock blocks should be used.
b. Any driving units or electrical equipments not required and not specifically designed for the transfer operation should be stopped and/or isolated.
c. The tank of a road tanker should be electrically connected to the fixed installations before any product transfer operation is carried out.
d. Before the vehicle is moved, the electrical and the liquid and the vapour connections should be disconnected, care being exercised to avoid spillage. Where heel chock blocks have been used they should be removed. The vehicle should be checked to ensure that any LPG that has leaked or has been vented has safely dispersed.

Liquid Transfer



Vapor Recovery

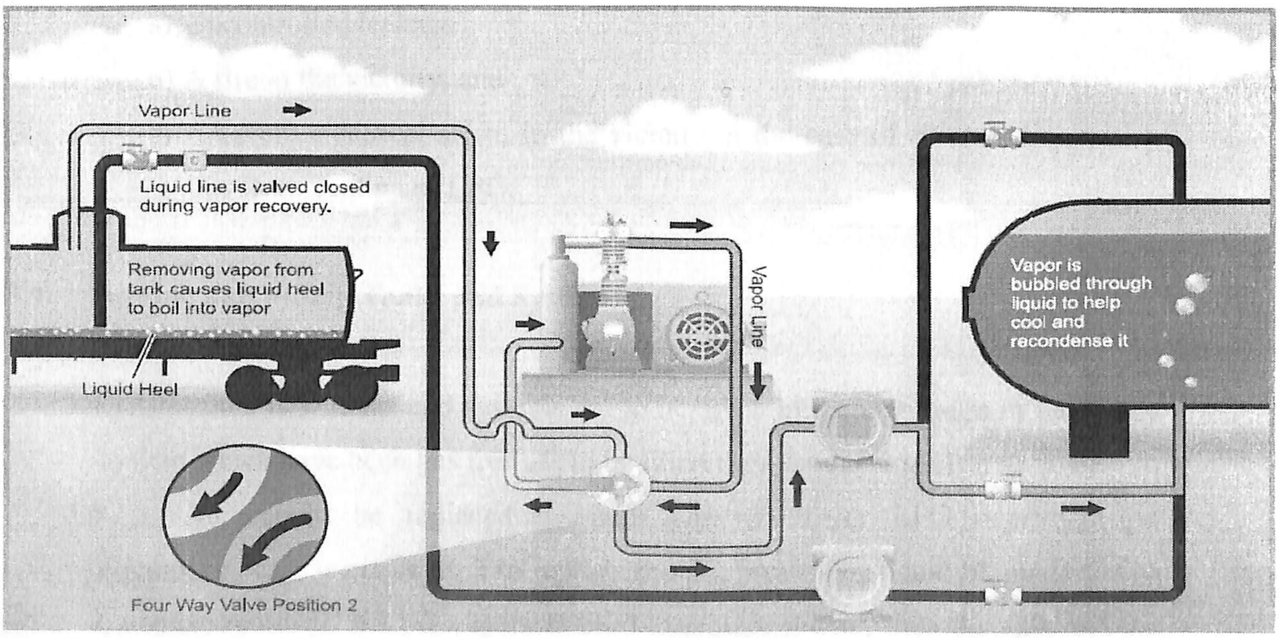


Figure 6.0

3.3. Attendance during Operation

3.3.1. A competent person remain in attendance during all transfer operations and should ensure that when transfer take place outside a petroleum or other protected area, the necessary warning notices against smoking and the use of naked lights are displayed and that the requirements of above

3.3.2. No drain valve, bleed valve, pipeline etc the LPG system which communications directly to the outside sir should be left open without an operator in attendance unless positive measures have been taken to prevent escape of product.

3.3.3. If it is necessary to discontinue temporally a vehicle loading operation and return later to complete it, the loading operation and return later to complete it, the loading hose should be disconnected from the vehicle for the period of absence.

3.3.4. The person in charge of operations should ensure that transfer operation s are stopped and all valves closed in the event of the following occurrences.

a) Uncontrolled leakage
b) A fire in the vicinity, and
c) A severe electrical storm in the vicinity in the case of an operation which involves venting of LPG.

3.4. Purging and Filling Tanks and Systems.

3.4.1. When new tanks and systems are to be taken into commission or tanks and system which have been gas free are to be filled they should first cleared of air.

3.4.2. Air should be replaced by inert gas, water, or LPG dependent on circumstance. If water is used to replace the air, provision should be made for its complete removal. If LPG vapour is used to replace the air, then the tank and the system will contain, for a period of time, a flammable mixture will be vented from the tank and the system adequate precautions to prevent its ignition are therefore essential.

3.4.3. In the case of air removal by means of an inert gas or LPG vapour, sampling and testing of the tank contents and the mixture determine the completeness of the air removal and the flammability of the issuing gas.

Static charge hazard: This aspect is covered under OISD-110.

Pipeline bonding (See clause 7.4 of OISD-110): Flange bonding needs to be of Copper strip. At present the jumpers are of Steel as informed.

ii. End flanges at the unloading point are not bonded and these may be bonded.

ii. Rubber hoses used for unloading need to be wound with coiled round with thick Copper wire and joined to the end flanges on either end to discharge any static charge formed during unloading operation.

Fig.7

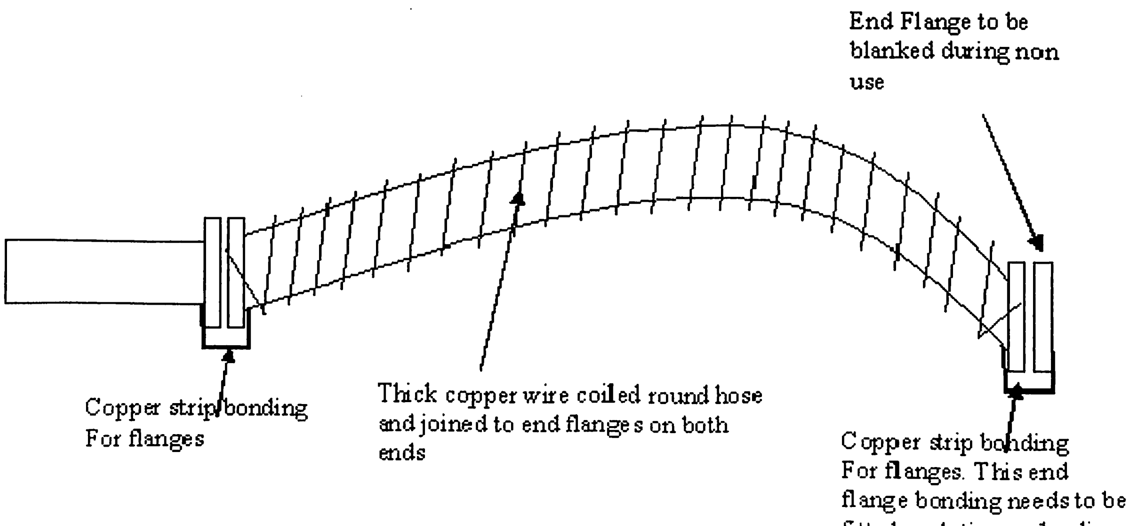


Fig. Bonding of hoses for LPG-Unloading

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

Recommendations: LPG-Storage facility should conform to the following OISD Standard:

Safety distances: OISD-144 gives various inter distances between various facilities in Petroleum installations. These may be found in Appendix-24. Table-1 of OISD-144 requires a min. distance separating LPG-bulk storage and other facilities. Following is a summary of the same:

Table 5.0 for minimum distance from other units

S.No	**Inter-distance between**	**Nearest equivalent**	**OISD-144 In meters**
1.	LPG-Process unit, Process control	Digester house	60
2.	LPG-A, B, C Class storages	Fuel Tanks	30
3.	LPG-Flares elevated, boilers	Boilers	90
4.	LPG-Flares ground	Furnaces	150
5.	LPG-Bulk loading	None	30
6.	LPG-Fire Station, First aid Center	Security at New gate	90
7.	LPG-Fire water and Pump house	Pond and Pump house	60
9.	Orientation of flares/furnaces (Major ignition sources to be up wind of HC-Storage	-	To be upwind wind of LPG Storage

Specific Recommendations for the Hazards of ignition sources within 90 m across the western boundary wall:

i. **Emergency response:** In the event of any major LPG-Leak immediate action needs to be taken to stop the traffic on the road nearest to the LPG-Storage to prevent ignition and explosion. Fogging of LPG-vapours needs to be carried out to prevent ignition of vapours till all gas gets dispersed. these requirements should be built in to the EMP and Mock drill procedures for preventing fire and explosions..

ii. **LPG-Detectors:** There shall be LPG-Detectors. It is necessary to provide detectors at least on the four corners of LPG-Bullet area and at the consumption area.

General Observations

1. 0 Knowledge and awareness of employees concerned with LPG-Storage and handling: Following Departments are involved in Storage and Handling of LPG in bulk:

i. **Engineering Department:** This department is responsible for all unloading, Storage and Handling of bulk LPG.

ii. **Safety Department:** This department is concerned in safety checking and advising of bulk LPG storage and handling.

iii. **Security Department:** This department is concerned with fire fighting and leakages of LPG.

iv. **Company:** This Company that has installed the facility and it is their property and are responsible for its inspection, maintenance.

Overall knowledge and awareness: There shall be fairly good and general knowledge and awareness of bulk LPG storage and handling in all the departments concerned. The knowledge and awareness is not confined to small leakages and small fires only. There is generally complete lack of knowledge and awareness of major hazards of leakages, fires, explosions, spill pool formations, flash evaporations, BLEVE etc. and their prevention and control methods.

Inspection, Testing and Maintenance of LPG-Facilities: This should be responsibility of organization that has set up the LPG-Facility

Maintenance Records: There should be systematic recording of inspections, testing and maintenance work done in a computerized data base form using advanced software application to enable processing the data for MIS-Reports for improving the systems.

Emergency Management Plan (EMP) and Mock drills: There shall be an Emergency Management Plan.

Mock drills have to be conducted on one of MCAS.

Legislations, Standards and codes of practices: All LPG-Related legislations, standards and codes of practices should be obtained and used.

2.0 Design of the LPG-Storage and Handling facility: The design of the storage and handling facility for LPG has to be examined with reference to all the relevant legislations, rules, standards and codes no practices namely: Factories Act and Rules, MSIHC-Rules, Explosives Act and Rules, OISD-Standards, Pressure vessel rules.

References:

1. “Joshi M V, Mahajani M M, Process Equipment Design, Macmillan India Ltd. Third edition 1996”
2. “Hamsagar R S, Risk Assessment in Petroleum Industry, journal 2007”.
3. “Moss Deniss, Pressure Vessel design manual, Gulf Professional Publishing, Uk, 2004”.
4. “OISD 144 Design and Construction of LPG Installations” from Oil Industry Safety Directorate
5. “Indian Standard Liquified Petroleum Gases-Specification (second revision) IS 4576:1999 edition 3.1 (2003-05) by Bureau of Indian Standards”
6. “Indian Standard Code of Practice for Liquified Petroleum Gas Storage Installations Part-2 Commercial, Industrial and Domestic Bulk Storage Installations (First revision) IS 6044(part-2):2000 by Bureau of Indian Standards”
7. “OISD Standard 118 on "Layouts for Oil & Gas Installations" and OISD Standard 144 on "LPG Bottling Plant Operations". Oil Industry Safety Directorate.
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9. www.corken.com
10. “Singh Sadhu, Strength of materials, Khanna Publication , Nai sarak ,New Delhi., 2003”

ANNEXURE I

CAPACITY OF SAFETY VALVES(IN CUBIC METERS PER MINUTE OF AIR WITH RESPECT TO SURFACE AREA OF THE PRESSURE VESSELS)

Surface area in m2	Flow Rate in m3/Min of Air	Surface area in m2	Flow Rate in m3/Min of Air	Surface area in m2	Flow Rate in m3/Min of Air
(1)	(2)	(1)	(2)	(1)	(2)
2.0	19	15.5	102	56	292
2.5	23	16.0	106	61	315
3.0	27	16.5	108	66	335
3.5	31	17.0	111	71	356
4.0	34	17.5	114	76	377
4.5	37	18	116	81	398
5.0	42	19	121	86	418
5.5	44	20	126	91	437
6.0	46	21	132	96	459
6.5	50	22	137	101	476
7.0	54	23	142	106	495
7.5	56	24	147	111	513
8.0	58	25	152	116	533
8.5	62	26	158	121	550
9.0	65	27	162	126	570
9.5	68	28	166	131	589
10.0	71	29	174	136	607
10.5	75	30	178	141	625
11.0	77	31	183	146	644
11.5	81	32	187	151	662
12.0	83	33	192	156	680
12.5	86	34	195	161	698
13.0	88	35	200	166	715
13.5	91	36	204	171	733
14.0	94	41	227	176	751
14.5	97	46	250	180	765
15.0	99	51	272		

Annexure 2

MATERIAL SAFETY DATA SHEET OF LPG (As given in OISD-114)

CHEMICAL IDENTITY

Chemical Name : LIQUEFIED PETROLEUM GAS Chemical Classification : Hydrocarbon Mixture	
Synonyms: LPG, Propane, Butane, Propylene, Trade Name : LPG Purofax, Bottled Gas.	
Formula C_3H_8, C_4H_{10} (Mixture) C.A.S.NO. 68476-85-7 UN. No. 1075	
Regulated Shipping Name: Petroleum Gases, Liquefied. Identification Codes/Label : Flammable, Class 2 Hazardous waste I.D. No: 5 HAZCHEM Code : 2 W E	
HAZARDOUS INGREDIENTS	**C.A.S.NO.**
1. Propane	74-98-6
2. Butane	106-97-8
3. Propylene	115-07-1

2. PHYSICAL AND CHEMICAL DATA

Boiling Point/Range	°C	> -40	
Physical State :	Gas at 15 °C		
Appearance :	Colourless		
Odour:	Mercaptan added as an odouriser		
Vapour Density		1.5	
Solubility in water @ 30°C			
Specific Gravity		0.51-0.58	(Water = 1) at 50°C
pH	Not pertinent		

3.FIRE AND EXPLOSION HAZARD DATA

Flammability (OC)	Yes	LEL	1.9%	Flash Point °C	-
TDG Flammability (CC)	2	UEL	9.5%	Flash Point °C	- 104.4
Auto ignition Temperature °C			466.1 Propane, 405 Butane		
Explosion Sensitivity to Impact			Not established		
Explosion Sensitivity to Static Electricity			May explode.		
Hazardous Combustion products			Emits CO, CO_2		
Hazardous Polymerization			Does not occur		
Combustible Liquid	No				
Explosive Material	No				

Corrosive Material	No
Flammable Material Oxidiser	Yes No
Pyrophoric Material Organic Peroxide	No No

4. REACTIVITY DATA

Chemical Stability Incompatibility with other material.	Stable Strong Oxidisers.
Reactivity oxidising materials. Hazardous Reaction Products	No reaction with common materials but may react with Not available.

5. HEALTH HAZARD DATA

Routes of Entry	Inhalation, Skin.
Effects of Exposure/	Concentration in air greater than 10% causes dizziness in few.
minutes. 1% conc	
Symptoms	Gives the same symptoms in 10 mts. High concentration
causes asphyxiation.	Liquid on skin causes frostbite.
Emergency Treatment	If inhaled, remove the victim to fresh air area. Provide
artificial resuscitation.	Skin: Remove the wetted clothes & wash the affected area
with plenty of water.	Eyes: Flush with plenty of water for 15 mins.
	Seek medical aid immediately.
NFPA Hazard Signals	Health Flammability
Reactivity/Stability Special	
1	4 0

6. PREVENTIVE MEASURES

Personal Protective Equipments	Avoid contact with liquid or gas. Provide hand gloves, safety goggles, gas mask, protective over-clothing and shoes.
Handling and Storage	Keep in tightly closed cylinders in a cool, well ventilated area, away from Precautions heat, flame, sparks.

7. EMERGENCY AND FIRST AID MEASURES

FIRE	Fire Extinguishing Media CO_2 , Dry Chemical Powder, Water Spray.
Special Procedure	Keep the containers cool by spraying water if exposed to fire or heat.
Unusual Hazards	If not cooled sufficiently, containers will explode in fire.
EXPOSURE	
First Aid Measures	If inhaled, remove the victim to open air area & artificial resuscitation may be provided if required. If skin is affected with the liquid, remove the clothing & wash the affected area with plenty of water. Seek medical aid.
Antidotes/Dosages	Not available.
SPILLS	
Steps to be taken	Shut off leaks if without risk. Warn everybody that air mixture is explosive.
Waste Disposal Method	Allow gas to burn under control.

Note: *CO_2 now not permitted as it produces high static charge. NFPA recommends that Flammable Gas fires should not be normally extinguished as it leads to explosive vapour cloud formation. It is desirable to shut off isolation valves and let the residual gas burn.*

8. ADDITIONAL INFORMATION

Avoid contact with oxidisers. Olefinic impurities may lead to narcotic effect or it may act as a simple asphyxiant. A very dangerous hazard when exposed to heat or flame. If fire is big, keep surrounding areas cool by spraying water.

Annexure 3

Liquefied Gas Transfer Compressor Worksheet

Model 691 Compressor on Propane

N = 1.13; RPM = 825; PD = 60.7; MAWP = 265 psia; Critical pressure = 619 psia; critical temperature = 666°R

Liquid Transfer Phase

Tank volume = 33,000 gallons, 30 psi drop in liquid transfer system; molecular weight = 44.1; total liquid volume to be transferred = 29,618 gallons or 89.8% of total tank volume

T1 (°F)	VP (psia)	P2 (psia)	T2 (°F)	CR	VE %	Gpm	Acfm (in)	Acfm (out)	Bhp	Time (min)	Lb/hour Liquid	Z (in)	Z (out)
0	38	68	32	1.8	85	216	51.8	28.9	12.3	137	55,229	0.92	0.89
10	46	76	38	1.7	87	238	52.7	31.9	13.1	124	60,864	0.91	0.88
20	55	85	45	1.5	88	258	53.4	34.5	13.9	115	65,938	0.90	0.87
30	66	96	52	1.5	89	278	54.0	37.1	14.8	107	70,841	0.89	0.86
40	78	108	59	1.4	90	294	54.4	39.3	15.6	101	75,048	0.88	0.85
50	92	122	67	1.3	90	309	54.8	41.3	16.6	96	78,903	0.86	0.83
60	107	137	75	1.3	91	322	55.1	43.0	17.5	92	82,154	0.85	0.82
70	124	154	83	1.2	91	333	55.3	44.6	18.5	89	85,064	0.83	0.80
80	144	174	92	1.2	91	344	55.5	46.0	19.6	86	87,748	0.81	0.79
90	165	195	101	1.2	92	353	55.7	47.1	20.7	84	89,966	0.80	0.77
100	189	219	110	1.2	92	360	55.8	48.2	21.9	82	91,969	0.78	0.75
110	215	245	119	1.1	92	367	55.9	49.1	23.2	81	93,687	0.76	0.73