CONTENTS

2015

INTRODUCTION

A housewife looks forward to the fancy of cooking gas, at the tap similar to the ease at which other utilities such as water, electricity, cable TV, Broadband Internet Network are available. The conventional system of packed cylinder being ordered and delivered to the housewives shall be out of vogue in times to come. The availability of natural gas and city grids of piped natural gas (PNG) shall further challenge LPG as a domestic fuel. We have to provide an efficient distribution network for LPG as well. We have to reorient our marketing strategies and provide LPG as a Reticulated System.

Reticulation is defined as the supply of LPG to multiple consumers via a piped distribution network, from centralised bulk storage facilities. The minimum number of consumers, which can be connected into a reticulated system, is two and the maximum is unlimited.

This USER Manual reviews design criteria's, Marketing Modules, Specifications, Operations, Safety Measures and work practices employed as laid down in codes of practice formulated by the LPG Association worldwide and the guidelines issued by The Chief Controller of Explosives for India.

This USER Manual discusses the basic parameters in evaluating the requirement of design so as to provide a continuous uninterrupted flow of LPG. This is achieved through a series of pressure regulations and vapourisation system. Adequate precautions have to be incorporated so as to function in a safe manner.

Finally, Reticulated LPG System is evolving and shall pose numerous questions and challenges with every new job. A feedback to the Head Quarters shall be highly appreciated.

PROPERTIES OF LPG

## PHYSICAL AND CHEMICAL PROPERTIES

CHEMICAL FORMULA

A chemical formula indicates the number of atoms of the various elements (Carbon & Hydrogen) in the molecule and to the chemist also gives some indication of their arrangement. As an example, the chemical formula for Propane is $CH_3CH_2CH_3$. If the arrangement of the atoms are disregarded then, in its simplest form, the formula may be expressed as C_3H_8.

The hydrocarbons found in LPG may be paraffins or olefins. The basic paraffin fourmula is C_nH_{2n+2} whereas the basic olefin formula is C_nH_{2n}. In the case of propylene (propene) the formula is $CH_2CH\ CH_3$ OR C_3H_6.

FORMULA
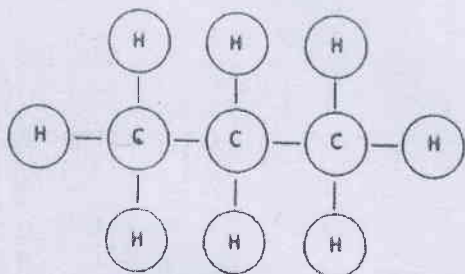
EACH PROPANE MOLECULE CONTAINS:
3 ATOMS OF CARBON
8 ATOMS OF HYDROGEN
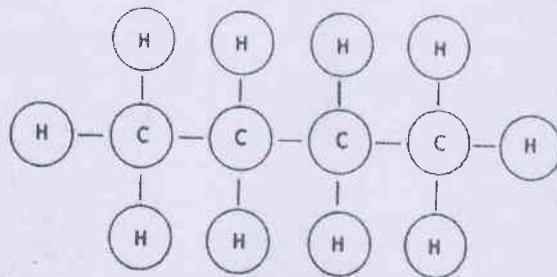
EACH BUTANE MOLECULE CONTAINS :
4 ATOMS OF CARBON
10 ATOMS OF HYDROGEN

GENERAL

Liquefied Petroleum Gases produced and distributed in India are a mixture of commercial Butane and Propane. .HPC Refineries produce straight run to virgin LPG (HP-Gas Special) which has a vapour pressure of 70 PSIG at 100° F and cracked LPG (HP-Gas Special) which has a vapour pressure of 8 kg/cm²(g) at 37° C. Refer Characteristic table – HPC Gas and HPC Gas Special.

247

PROPERTIES OF LPG

DENSITY

Density means mass or weight per unit volume. The unit used is gm/cm^3 for liquids and kg/cm^3 for gases.

Since the density of the liquid varies slightly with temperature, the latter must be indicated in an extract statement of density. Normally density is expressed at $15°$ C or $60°$ F.

Since the density of water is 1.0 gm/cm^3 and the density of liquid LPG is about 0.5 gm/cm^3, the latter is about half as heavy as water.

TABLE - 1

Temperature ° C	Density	
	Commercial Propane	Commercial Butane
0	0.522 to 0.531	0.587 to 0.596
(+) 10	0.508 to 0.517	0.576 to 0.585
(+) 15	0.500 to 0.510	0.570 to 0.580
(+) 20	0.492 to 0.502	0.564 to 0.574
(+) 30	0.476 to 0.487	0.552 to 0.562
(+) 40	0.458 to 0.470	0.539 to 0.550
(+) 50	0.440 to 0.454	0.526 to 0.537

In an exact statement of the density of the gas it is necessary to indicate not only the temperature but also the pressure.

The usual form is to state the density of 1 m^3 of the gas at $0°$ C and 760 mm hg (normal atmospheric pressure), this being known as a normal cubic meter, abbreviated to m^3_n.

Relative density is used to indicate the density of a gas in relation to that of air at the same temperature and pressure.

If the relative density is greater than unity, the gas is heavier than air. LPG is about 1-1/2 to 2 times as heavy as air.

248

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PROPERTIES OF LPG

TABLE – 2

Temperature ° C	Vapour Density at a Pressure of 760 mm of Merc (10.33 m water) Kg/m³	
	Propane	Butane
0	1.8 to 2.0	2.40 to 2.7
(+) 15	1.7 to 1.9	2.30 to 2.6
(+) 20	1.7 to 1.9	2.25 to 2.5
(+) 30	1.6 to 1.8	2.20 to 2.4

COEFFICIENT OF VOLUMETRIC EXPANSION

The coefficient of volumetric expansion indicates the change in volume per unit volume liquid for each degree of temperature change.

Its value varies slightly with temperature, and the table therefore states the coefficient for two temperature ranges that may be encountered in practice.

The rate of expansion or contraction also varies depending upon the composition of product.

In the case of propane, the expansion rate between 0°C and +40°C is approximately 8.0%

In general, it may be said that the lower the density of the liquid the greater the rate expansion or contraction.

VOLUMETRIC EXPANSION OF LP-GASES

Since the coefficient of volumetric expansion of LPG is about 100 times that of steel it w be realized that this must be taken into account when a tank is being filled with LPG.

In consequence, a LPG tank must only be filled to a certain volume in order to leave sufficient expansion volume, which varies with the temperature and density of the liqu LPG.

When filling a LPG container or when measuring a specific volume of LPG liquid, it may b necessary to determine the volume of the liquid at a temperature other than which exists the time of filling.

Through the use of volume correction factors, the volume of the product may be pre determined at a base temperature or may be projected to a volume at some other temperatur to which the container is likely to be exposed.

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2 LP 8

PROPERTIES OF LPG

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249

PROPERTIES OF LPG

MELTING OR FREEZING POINT

LPG can exist as a liquid over a wide range of temperature. The lowest temperature is that at which the liquid assumes the solid state. This is known as the melting point and is such a low temperature that it is without practical interest.

CRITICAL TEMPERATURE

The highest temperature at which a substance can exist as a liquid is known as the critical temperature. Above this temperature the substance is gaseous, whatever pressure is applied.

CRITICAL PRESSURE

To obtain the substance in liquid form at the critical temperature a certain minimum pressure is required, this being known as the critical pressure.

At temperature below the critical temperature the substance can exist either as a gas or as a liquid.

When the substance exists as gas and liquid simultaneously we say that there is a state of equilibrium between gas and liquid. At any given temperature there will, under these conditions, be a definite pressure.

BOILING POINT

The temperature at which the vapour of a liquid becomes equal to the external pressure is the boiling point.
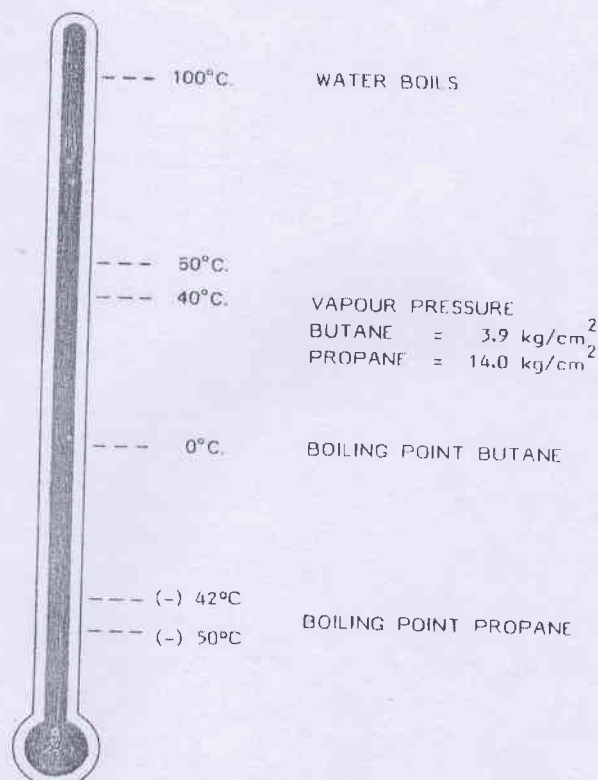
This temperature differs for the same liquid under different pressures.

The normal boiling point is the temperature at which the vapour pressure reaches 760 mm of mercury or 1 atmosphere.

250

PROPERTIES OF LPG

BOILING POINT – VAPOUR PRESSURE

- - - 100°C.   WATER BOILS

- - - 50°C.
- - - 40°C.   VAPOUR PRESSURE
                BUTANE   =   3.9 kg/cm^2
                PROPANE =   14.0 kg/cm^2

- - - 0°C.   BOILING POINT BUTANE

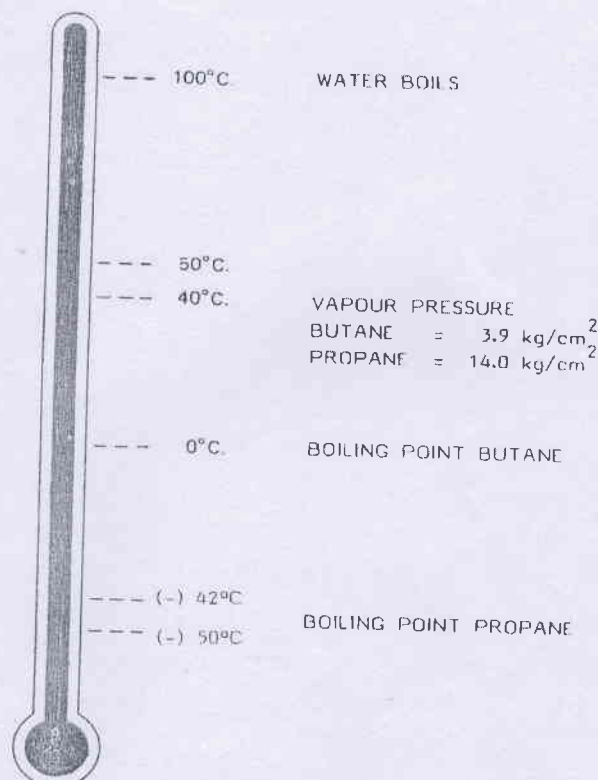- - - (-) 42°C   BOILING POINT PROPANE
- - - (-) 50°C

Considering liquid in an open container exposed to the atmosphere, a pressure equivalent to atmospheric pressure (one atmosphere) is applied to the surface of the liquid. As the temperature of the liquid increases, its vapour pressure approaches atmospheric pressure.

At the temperature at which vapour pressure equals atmospheric pressure the opposition to evaporation exerted by the atmosphere is neutralized and boiling takes place.

From a practical standpoint, it is the liquid temperature at which evaporation is rapid enough to produce noticeable formation of vapour bubbles within the liquid.

PROPERTIES OF LPG

BOILING POINT – VAPOUR PRESSURE


```
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                 BUTANE   =  3.9 kg/cm²
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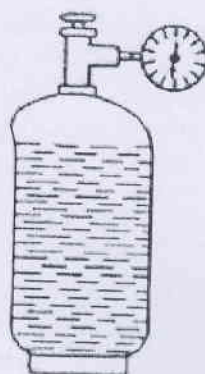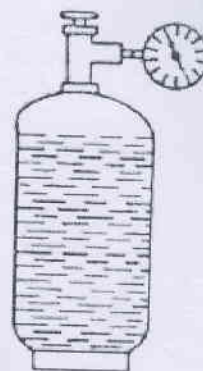
251

PROPERTIES OF LPG

VAPOUR PRESSURE

PROPANE
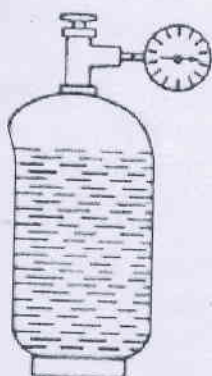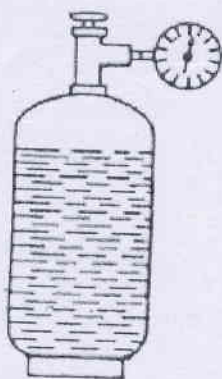

0°C – 4.8 ATA   +20°C – 8.3 ATA   +40°C – 14.0 ATA

BUTANE
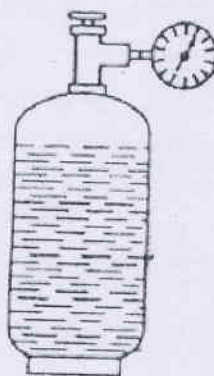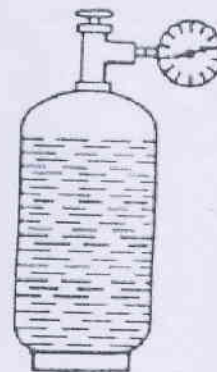
0°C – 1.04 ATA   +20°C – 2.1 ATA   +40°C – 3.7 ATA

VAPOUR PRESSURE

Vapour pressure is the pressure developed over a liquid in a closed container. The vapour pressure of LPG depends upon the temperature of the liquid and the composition in terms of primary hydrocarbons present.

If the liquid is heated in an open container the molecules (collectively called vapour) move away from the liquid and the liquid is said to evaporate.

252

PROPERTIES OF LPG

If, on the other hand, the liquid is in a closed container the motion of the escaping molecules is confined to the vapour space above. As an increasing number strike and re-enter the liquid, a point of equilibrium is eventually reached when the rate of escape of molecules from the liquid equals the rate of return to the liquid.

The pressure exerted by the escaping vapour at this point of equilibrium is vapour pressure. The volume of liquid within a LPG container does not effect the vapour pressure if product in liquid from remains, after equilibrium has been reached. Considering an identical product and identical temperatures, when equilibrium is reached in a container with 5% liquid and 95% vapour, the vapour pressure will be the same as that found in the same container with 85% liquid and 15% vapour.

From a practical standpoint, equilibrium will only be reached in a container when vapours are not being withdrawn and the amient temperature remains constant. Whenever product is being withdrawn from the container it is anticipated that the internal pressure will be depressed below the true vapour pressure which would be observed if equilibrium did exist.

Vapour pressure is usually stated in kg/cm^2. This unit can also be written "at", being then known as a technical atmosphere, to distinguish it from the normal atmosphere, atm (1 atm = 1.033 at).

Since the vapour pressure is independent of the pressure of the air or atmosphere it is usually stated as the "absolute" pressure, e.g. in absolute technical atmosphere = ata. If LPG is to be obtained in gaseous form from a container the temperature must be such as to give a vapour pressure at least as great as the pressure of the air.

Accordingly, vapour pressure can also be stated as overpressures in relation to the normal pressure of the air, usually called "gauge" pressures. For information relating to vapour pressure of commercial products and mixtures or blends see Appendix "L".

HEAT VAPOURIZATION
The quantity of heat absorbed by a unit mass when changing from the liquid to the gaseous phase while remaining at the same temperature.

In addition to the heat required to change or increase the temperature of a liquid, the is an additional heat requirement to cause actual vapourization.

This quantity of heat is referred to as the heat of vapourization or the latent heat of vapourization. The term is expressed in kilocalories per kilogram of the substance. The temperature should also be stated since the value decreases somewhat with an increase in temperature. As an example, the heat of vapourization of propane at (–) 20°C is 96 kcal/kg and at +20°C the value is 82 kcal/kg.

SPECIFIC HEAT
Specific heat is defined as the quanity of heat required to raise unit mass of a material through a unit temperature interval.

Specific heat may also be expressed as the amount of heat required to warm a substance in the solid, liquid or gaseous state.

Specific heat is expressed as the number of kilocalories required to warm 1 kg of a substance through 1°C. Specific heat is dependent to a degree upon the temperature of the substance. For gases, moreover, it is necessary to indicate whether the pressure or the volume is constant. One kilocalorie is the quantity of heat required to raise the temperature of 1 kg of water through 1°C from 14.5 to 15.5°C.

253

PROPERTIES OF LPG

As an example, propane has a specific heat of 0.57 kcal per kg at 0°C. (Base 0°C).

TABLE – 3

TABLE OF VALUES

Description	LPG Components	
	Propane	Butane
Formula	C_3H_8	C_4H_{10}
Liquid Density @ 15°C	0.508	0.584
Coefficient of Volumetric Expansion Per Degree C Mean Value Between:		
(-) 20° and + 20°C	0.0028	0.0018
0 and + 40°C	0.0033	0.0020
Melting Point, °C	(-) 187	(-) 137
Critical Temperature °C	97	152
Auto Ignition Temperature	481°C	441°C
Critical Pressure ata. (kg/cm²)	43	39
Boiling Point at 760 mm Hg, °C	(-) 42.1	(-) 0.5
Vapour Pressure ata (kg/cm²)		
at -40°C	1.11	0.17
at -20°C	2.4	0.45
at 0°C	4.8	1.04
at +20°C	8.3	2.1
at +40°C	14.0	3.9
Heat of Vapourization kcal/kg		
at -20°C	96	96
at 0°C	90	92
at +20°C	82	87
Specific Heat at 0°C, kcal/kg/0°C	0.57	0.54
Relative Density		
Air = 1.00	1.561	2.091
Density kg/m³n	2.019	2.703
Specific Heat at 0°C		
C_p, kcal/kg/0°C	0.39	0.38
* C_p / C_v	1.15	1.11

* C_p -   Coefficient of expansion at constant pressure
* C_v -   Coefficient of expansion at constant volume

254

PROPERTIES OF LPG

TABLE – 4

LPG SPECIFICATIONS – Salient features as per IS 4576

Sr. No.	Characteristic	Requirement for Commercial Butane – Propane Mixture	Method of Test, Ref. To Page (P) of IS : 1448
1	Vapour pressure at 65 0 C kgf/cm2 g	16.87 Max	P 71
2	Volatility : evaporation temperature in 0C, for 95 percent by volume at 760 mm Hg pressure, Max.	2	P 72
3	Total volatile sulphur percent by mass, Max.	0.02	P 34
4	Copper strip corrosion at 38 0C for 1 hour	Not worse than No. 1	P 15
5	Hydrogen sulphide	Absent	P 73
6	Dryness	No free entrained water	P 74
7	Odour	Level 2	P 75

TABLE – 5

CHARACTERISTIC TABLE – HP Gas and HP Gas Special

Sr.	Tests	HP Gas Special	*HP Gas
1	Vapour Pressure psig @ 100 ^{0}F	100 Max. Typical 90	140 Max. Typical 120
2	Weathering test 95% Volume Evaporation, ^{0}F	36	44
3	Total Volatile Sulphur, ppm (Includes H_2S/RSH) Wt. %	Typical 8 – 15 0.0008 to 0.0015	
4	Residue	-	
5	Hydrogen Sulphide, ppm	Total 10 ppm Max. Typical H_2S=2-5	15 – 20 50 – 60
6	Mercaptan Sulphur, ppm	RSH=3-5	
7	Unsaturates	1 Max. Typical = Nil	30 – 40
8	Range of composition % by Volume		
	C_2 Hydrocarbons	0 – 0.5	0 – 0.5
	C_3 Hydrocarbons	20 – 26	40 – 45
	C_4 Hydrocarbons	74 – 80	55 – 60
	C_5 Hydrocarbons	0.5 – 1.0	1 – 4
9	Specific Gravity @ 15 ^{0}C	0.565 Typical	0.564 Typical
10	Calorific Value of LPG =11800 Kcals Kg		

Wherever specifications are not available values are typical and not amounts to specification.

* = Composition depends upon the feed

PROPERTIES OF LPG

GENERAL CHARACTERISTICS

SENSIBLE PROPERTIES

Sight

LP-Gases are colourless, therefore, they cannot be seen. However, when LPG, in liquid form, is released from a container or a pipe it vaporizes almost immediately. This produces a cooling of the surrounding air and may cause water vapour in the air to condense, freeze and become visible. In this way a LPG leak may be detected even though the gas itself is invisible. (Many gas leaks do not develop frost, therefore, other means of leak detection must be employed.)

Smell

LP-Gases are, in general, odourless and cannot be detected by human senses. There are, however, refinery products which may be included within a LPG product which do have definite odours. When odourization of LPG is required, a specific odourant is added to be product.

Taste

LP-Gases are tasteless and non-toxic, therefore the presence of LPG vapours in the atmosphere cannot be sensed by taste.

VAPOURIZATION

GENERAL

LPG is stored or contained as a liquid and then by a relatively simple process is converted into a gas or vapour for ultimate consumption.

This vapourization process or conversion form the liquid phase to the gaseous phase is accomplished through the addition of heat which is expressed in kcal per kg of LPG.

This term, heat of vapourization, has been defined earlier in this manual.

There are two basic methods of vaporizing LPG. The most common method is carried out within an LPG container, the product being withdrawn directly from the container in gaseous form.

In this method the heat is drawn primarily from the surroundings of the LPG container, although some of the heat comes from the LPG liquid and from the container. The amount of gas which can be generated by direct vapourization is limited by the size of the container, the quantity and composition of the product which it contains, the ambient temperature surrounding the container, the movement of air about the container and the exposure of the container ot direct sunlight. The quantity of gas which may be removed is also dependent upon the delivery pressure requirements.

The second method of vapourization employs a special apparatus called a vapourizer. In this process liquid product is removed from the storage container, delivered into a vapouriser where heat is applied to the liquid causing vapourization within the device.

The product is drawn from the vapourizer in gaseous form. Vapourizers are not considered within the manual since they are involved with the utilization of the product and are not normally found at a bottling plant.

256

PROPERTIES OF LPG

VAPOURIZATION IN LPG CONTAINER

As a practical explanation of the process of direct gas withdrawal from a LPG container and the vapourization process within the container, a comparison is made with the boiling of water within a boiler for the purpose of generating steam.

Since the boiling point of water is 100 ^{0}C, we must supply heat to the water by providing a fire in the firebox. When the water reaches 100 ^{0}C it boils but the steam exerts no pressure until the temperature of the water rises above 100 ^{0}C. As the temperature of the water increases above 100 ^{0}C the pressure of the steam or the vapour pressure will likewise increase.

When steam is withdrawn from the boiler the pressure will decrease. To prevent a reduction in pressure the firing must be stepped up in order to provide additional heat. By controlling the firing or regulating the amount of heat within the firebox it is possible to get a constant quantity of steam from the boiler which may be used to perform work.

From the standpoint of physics, the process of vapourization in the LPG container is identical with the process taking place in the boiler. The sole difference is in boiling points. LPG has a boiling point ranging from minus 48 ^{0}C to about zero degrees C depending upon its composition.

At temperatures above the boiling point of the LPG there will be a certain overpressure within the container.

If a valve is opened and LPG flows out of the container the liquid within will begin to boil developing new vapour to replace that which has flowed out of the container.

If the temperature is equal to or lower than the boiling point there can be no flow of gas from the container.

At temperatures below the boiling point the vapour pressure will be lower than the pressure applied by the atmosphere. In this case air will flow into the container when a valve is opened.

If the temperature is in excess of the boiling point so that gas can flow out through the container valve, the gas must be replaced by new vapour formed by boiling or vapourization. The heat required by this vapourization is supplied not by external heating, as in the case of the boiler, but by cooling or absorption of heat from the surrounding air.

If heat is to be supplied from the surroundings it is necessary for a temperature difference to exist. If no gas is withdrawn from the LPG container for some time, the liquid will have the same temperature as is surroundings.

Therefore, when withdrawal of gas begins, heat required for the vapourization, which begins at the same time, will be taken from the liquid LPG itself.

257