A report about

LPG system requirements for domestic uses, expected problems, and precautions

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Contents

Introduction

Liquefied petroleum gases are made up of hydrocarbons refined from crude oil, typically from propane, butane, or a combination of the two (Farouq and Al-Obaidi, 2022). Propylene, butylene, and other hydrocarbons are frequently present as additional components, but they are not the primary ones. Homes typically use cylinders to store and transport liquid petroleum gas (LPG) for ease of movement. Cylinders were too heavy to transport up multiple stories of buildings; therefore, they were not practical. In order to use liquefied gas for cooking, water heating, and other purposes, it was necessary to construct a system that transfers gas over a network into buildings' floors. Due to its practical benefits—clean combustion and being cleaner—liquefied petroleum gas (LPG) is regarded as suited for home heating and cooking. It has the benefit of lowering air pollution. Gas leaks within homes or structures, which can cause fires or explosions, are one of the drawbacks or risks of LPG. Also, all components, including joint compounds, gaskets, valve seats, and packing, must withstand the effects of liquefied petroleum gas. The goal of this report is to understand the LPG system and precautions.

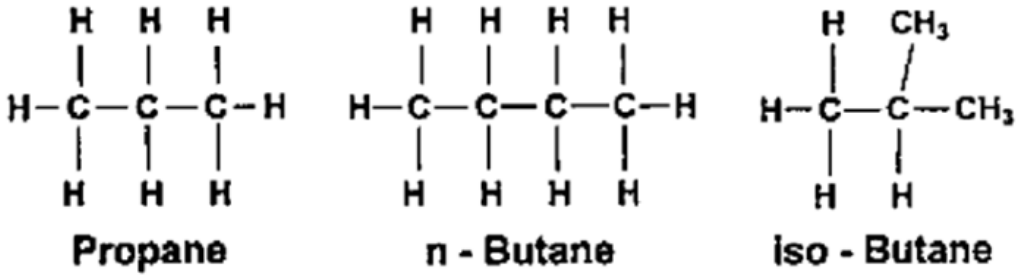


Figure 1: Commercial LPG mixtures (Hazlehurst, J, 2009)

Properties of LPG (National Fire Protection Association, 2008)

1- It weighs more than air. (PALGRAVE MACMILLAN LTD, 2005; HSE, 2020)

2- LPG lacks all characteristics of color, taste, and smell, but an odorizing chemical called ethyl mercaptan is added to give it a strange smell so that any leak can be immediately discovered.

3- Natural rubber is dissolved by LPG. Therefore, it is crucial that all materials used in LPG installations be LPG- resistant. If there is LPG in the air and the concentration is below the flammability threshold, it will ignite. When combined with air, the flammability ranges from 2% to 9% of the total volume.

4- LPG reacts to temperature changes by expanding and contracting like any other liquid. One gallon of LPG will expand to a greater volume when the temperature is 10 degrees Fahrenheit. LPG canisters are never entirely filled since there is a need to account for the expansion of the liquid within.

5- LPG is neither hazardous nor poisonous. However, because it is heavier than air when it is vaporized, it pushes the air out of the room, which results in a lack of oxygen and might kill everyone present.

6 - When stored in its container, LPG exists in liquid form, but as soon as the liquid is discharged, it rapidly transforms into a gas. It is liquefied to make transportation and storage more convenient and affordable. If it were to be kept in the form of vapor instead of liquid, a gallon of liquid LPG that was contained in a container would need a vehicle that was 270 times bigger.

7- For LPG to burn, the appropriate amount of air and fuel must be combined. LPG has a two percent to nine percent (2% - 9%) flammability limit. This indicates that for the LPG mixture to burn, the LPG content must be between two percent and nine percent.

8- The temperature at which boiling takes place when the pressure above the liquid is atmospheric, or 14.7 psig, is known as the boiling point of a liquid. LPG has a boiling point of 10°F, or -12°C.

9- Even though a tank that once held LPG is now "empty," LPG still exists in the form of vapor and could still be dangerous. The explosion danger will increase if a valve leaks or is left open,

allowing air to enter the container and creating a volatile mixture. The internal pressure is nearly atmospheric in this state. LPG has the capacity to spread into the atmosphere as well.

10- The temperature drops quickly when the LPG liquid is ejected, and if it comes into contact with the body, it can cause serious frost burns.

11- It is kept under pressure (6.9 bar/100 psi) as a liquid. Liquid leakage will cause far greater volumes of combustible gas to be produced.

12- The two basic types of explosions that can be distinguished are physical and chemical explosions. Chemical explosions, like gas explosions, are the outcome of oxidation reactions that produce large amounts of heated gas. When a sealed container ruptures owing to vessel failure or an increase in internal pressure, it is referred to as a physical explosion.

Table 1: LPG Properties (UNEP, 2018)

Typical Properties of LPG			
Property	Propane	Iso-Butane	n-Butane
Boiling point at 101.3 kPa (°C)	-42.1	-11.8	-0.5
Liquid density at 15 °C (kg/ m3)	506	561.5	583
Absolute vapour pressure at 40 °C (kPa)	1510	530	375
Flash Point (°C)	-104	-83	-60
Upper flammable limit (% vol. in air)	9.5	8.5	8.5
Lower flammable limit (% vol. in air	2.3	1.9	1.9
Volume vapour per volume liquid	269	221	235
Relative vapour density (air = 1)	1.55	2.07	2.07
Coefficient of expansion (liquid) per 1°C	0.0032		0.0023
Minimum air for combustion (m3/m3	24		30
Kinematic Viscosity (centistokes) @ 20°C	0.2	0.29	0.3
Latent Heat of Vapourisation (kJ/kg) @ 20°C	352		368
Specific Heat (kJ/kg/°C) @ 20°C - liquid	2.554		2. 361
Specific Heat (kJ/kg/°C) @ 20°C - vapour	1.047		1. 495
Minimum ignition temperature (°C) in oxygen	470 - 575		380 - 550
Specific Energy (gross) kJ/kg	49.83		49.4

LPG distribution system for many users

Figure2: LPG systems for use in residential and commercial buildings (National Academy of Sciences, 2018)

Advantage and disadvantage of LPG

Advantages

Due to its practical advantages, such as clean combustion and economical characteristics, liquefied petroleum gas (LPG) is appropriate for residential heating and cooking.

Disadvantages

Gas leaking inside buildings or dwellings, which can result in fires or explosions, is one of LPG's drawbacks or hazards. For instance, at least fifteen people were murdered and approximately fifteen others were injured in a residential section in Sulaimani city in 2022, and at least five people were killed and scores of people were injured in Duhok.

Problem Statement

Gas tank and pipes has a number of issues, including the potential for gas to seep through the pipes and cause fires or explosions in LPG storage and distribution tanks; thus, safety precautions were made during the design and implementation process.

Solve the issue

The gas leak detector demonstrated a quick response to gas leakage, so sense, so it is advised to position the device 0.6-2 meters away from the gas source and 0.2 - 1 meters above the ground.

Mechanical Test

Every sample container must undergo the following tests:

Weld Inspection (Agreement concerning the Adoption..., 1958)

The manufacturer must guarantee that the welds exhibit uninterrupted penetration without any departure from the weld seam and that they are devoid of any faults that may compromise the secure use of the container.

Container consisting of 3 parts joined together with longitudinal and circumferential welds. (Agreement concerning the Adoption..., 1958)

- Conducting a single tensile test on the original material of the bottom;
- Conducting a tensile test in a direction perpendicular to the longitudinal weld;
- Conducting a tensile test in a direction perpendicular to the circumferential weld;
- A one-bend test will be conducted on the longitudinal weld, specifically focusing on the inner surface under stress.
- Perform a single-bend test on the longitudinal weld, with the outside surface subjected to stress.
- A one-bend test will be conducted on the circumferential weld, with the inner surface subjected to stress.
- Performing a single bend test on the circumferential weld with the outer surface subjected to stress.
- One test to evaluate the circumferential weld at a macroscopic level.
- A single macroscopic examination of the longitudinal weld.

Burst Test (Agreement concerning the Adoption..., 1958)

The burst test under hydraulic pressure necessitates the use of equipment capable of incrementally increasing pressure until the container ruptures, while simultaneously documenting the temporal fluctuations in pressure. The test must verify that the rate of flow remains below three percent of the container's capacity per minute. So, the goal of the burst test is to analyze the tear and the form of its edges.

Fire experiment (Agreement concerning the Adoption..., 1958)

The bonfire test is intended to verify that a container equipped with the fire protection system, as defined in the design, would effectively prevent container rupture when subjected to the prescribed fire conditions. The manufacturer is required to provide a detailed description of the performance of the whole fire prevention system, including the intentional decrease in pressure to atmospheric levels as intended.

Ultra-violet (UV) test (Agreement concerning the Adoption..., 1958)

Exposure of the container to direct sunlight, even when it is placed behind glass, might result in the degradation of polymeric materials due to UV radiation. Hence, the producer must demonstrate the durability of the outer layer material in withstanding UV radiation over a period of 20 years.

Coating of the surface and coloration (Bhavan et al., 2000)

The corrosion protection of the surface coating will be achieved by the application of a primer consisting of zinc, lead, or iron oxide, followed by a top coat of synthetic enamel paint. The total thickness of the coating will be at least 75 microns, or as mutually determined between the manufacturer and the customer. Applying a surface coating to stainless steel is not mandatory. The color scheme will adhere to the specifications set by the governing authorities.

Pneumatic Leak Test (Bhavan et al., 2000).

After drying and equipping each container with all necessary accessories, as agreed upon by the buyer and the manufacturer, a suitable jointing material will be used. The container will then be

tested for leakage by immersing it in water and subjecting it to an air pressure of at least 2 MPa for one minute. During this test, there should be no leakage from the container body or the valve pad joint. This test should be conducted after securely attaching the safety cap to the valve(s) fittings, if appropriate.

Identification symbols or patterns (Bhavan et al., 2000)

Every container must have a marking plate that is securely affixed and displays the following information in a visible manner:

- A distinct identification number,
- The minimum or standard water capacity, measured in liters,
- The weight of the container without any attachments, in kilograms,
- The label indicates that the container is designed for Liquefied Petroleum Gas (LPG),
- The pressure at which the container was tested, measured in megapascals (MPa),
- The statement indicates that the container should not be filled beyond 80 percent of its total capacity.
- The year and month when the container was tested,
- An official mark of the authority responsible for inspecting and approving the container.
- Manufacturer's name and trademark,
- Specification number,
- Adequate space for the requalification mark,
- Maximum working pressure in megapascals (MPa)

Testing of pipework (Architectural Services Department, 2012)

Prior to being put into service, every piece of pipework must undergo testing to verify its structural integrity and gas impermeability. Precautions must be taken throughout the test to safeguard against any potential hazards that may occur in the event a pipe failure.

The pressure testing procedure for all piping is as follows: - (Architectural Services Department, 2012)

(a) The hydraulic testing of all liquid lines should be conducted at a pressure that is 1.1 times the normal operating pressure.

(b) Vapour lines with high pressure must be examined using either pneumatic or hydraulic methods, with a minimum pressure of 1034 kPa.

(c) Vapor lines with medium and low pressure must undergo testing using either pneumatic or hydraulic methods. The minimum pressure for the test is 103 kPa for medium- pressure lines and 69 kPa for low-pressure lines.

Regulators and relief valves

The goal of accessories is to control the LPG system. An LPG's actual heart is its regulator. This pressure must be supplied by the regulator, and two-stage regulation ensures that the appliance receives a pressure that is nearly constant. Additionally, internal relief valves are utilized along with appropriately selected regulators to offer NFPA 58-compliant overpressure protection.

First Stage High Pressure Regulator

It is a high- pressure regulator that is enclosed and situated close to the tank area. Heavy-duty aluminum or steel sheets should be used to build this enclosure, and certified locks and lockable doors are required.

The enclosure should contain the following parts:

• Shutoff valves

Over-pressure shut-off (OPSO)/ under-pressure shut off (UPSO)

First Stage Pressure Regulator (Outlet Max. Up to 1.2 Bars);

• Solenoid valves that are normally closed

Medium/Low Pressure Regulator, Second Stage

The second-stage vapor pressure regulator should be sized to reduce the high gas pressure to the necessary pressure level (range of 0.030 to 1 bar) to handle the equipment. Installing the second-stage regulator and any associated fittings is necessary to shield them from the elements and stop water from entering the vent. According to project specifications, an enclosure must be created since it will serve as a pressure-reducer station for equipment in many kitchens, for example. Additionally, each piece of gas cooking equipment must be linked to a specified regulator, which must be either medium or low pressure, using a ball valve and an authorized hose.

First Stage regulators Second Stage Regulators

Figure3: First and second-stage regulation

System for Detecting Gas

Installing a gas control panel with a detector will increase safety by enabling you to respond appropriately when an alert sounds, with the detector acting to shut off a solenoid valve in the event of a gas leak.

It should install a permanent gas detection system that can keep an eye on the building or specific regions of the building where flammable gases might unintentionally collect. To begin one or more of the following activities, either automatically or manually, the detecting system should be able to communicate an early warning of an inadvertent accumulation of flammable or hazardous gases and the location:

Proper firefighting techniques;

• Safe evacuation of the building;

• Shutting down the process or facility;

• Ventilation control in accordance with local government requirements

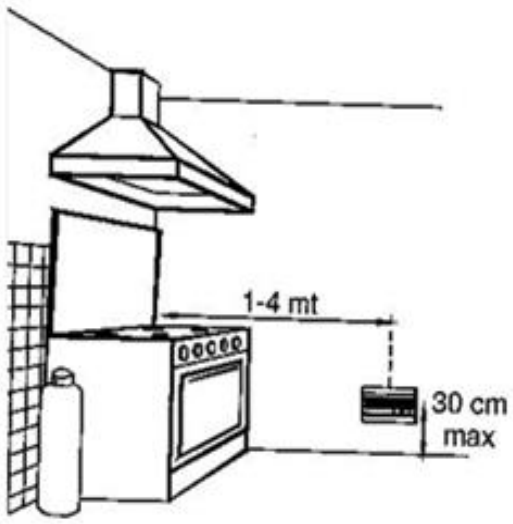


Figure 4 : Detector LPG and Placement in the Kitchen.

The following factors influence the choice of pipe type

1- Location, with an interior or outdoor entry.

2- Gases can be found as liquids or vapors. – Pressure.

3- Mechanical damage might possibly occur. Iron/Steel Pipe Design, Installed in Compliance with ASME B31.3, Welded in Compliance with ASME V111

3- High -density pipe made of copper; Type K or L seamless tube or pipe; PE. (30 psig pressure) (outside + underground).

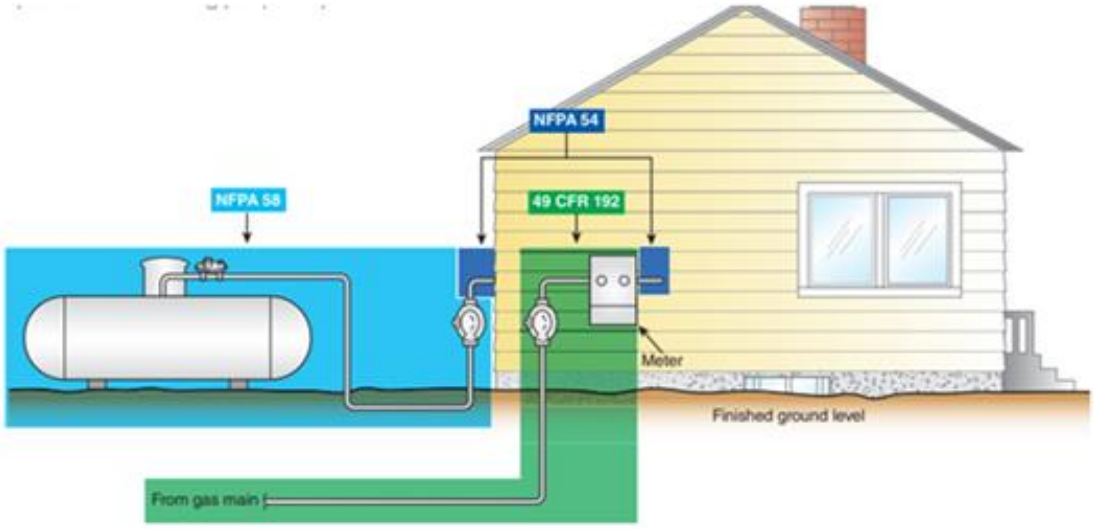


Figure 5 : Inside the home, NFPA 54 is used, and outside the home, NFPA 58.

Flow meter

The gas meter is a tool used to measure the quantity of supply of vapor gas consumed in terms of volume measurements in cubic meters. A general gas meter should be computed in cubic meters per hour (m3/hr), which will meet the typical needs of each individual outlet. NFPA 54, Section 5.7, and NFPA 58, Section 6.17.5, should be consulted. The gas meter box should include the following fittings:

- The gas meter's flow rate (m3/hr)
- UPSO/OPSO pressure regulator
- Attaching the meter connection bracket
- A ball valve that shuts down
- Connection for meter compensation

This machine computes fluid flow rates. In order to quantify the amount of liquid that is accessible, greater flow rates provide bigger tube gaps and higher pendulums.

Different kinds of tanks are used to store LPG.

There is a wide variety of liquefied petroleum gas (LPG) storage tanks, each of which is designed for a specific use and comes with a unique capacity. The following types of LPG storage tanks are among the most common and widely used today. (Dey, A. K., 2022).

1- Above-ground LPG storage tanks are large containers that are typically used for the purpose of warehousing huge amounts of liquefied petroleum gas (LPG), which are then utilized in commercial and industrial applications.
2- Underground LPG storage tanks: These tanks, which are constructed underground, are widely used to store liquefied petroleum gas (LPG) in residential areas that have a shortage of available space.

3- LPG storage tanks that are installed horizontally: These tanks, which are capable of storing LPG in both commercial and industrial environments, may be erected horizontally.

Figure 6: Horizontal tank

4- LPG storage tanks that are vertical. These tanks were designed to be positioned vertically since that is how they are most often used to store LPG in residential areas and in smaller commercial settings.
5- Tanks for the storage of LPG that are mounds: In most commercial and manufacturing environments, these tanks are used to hold liquefied petroleum gas (LPG). They are set on a raised platform or mound made of concrete.

6- Cylinders of propane gas: These are portable, small tanks that have been utilized to store LPG for use when camping and cooking outside.
7- Tanks that are cylindrical
8- Storage tanks that are spherical.

Figure 7: Above ground Spherical LPG pressure storage tank (WEEN Consult Limited, 2020)

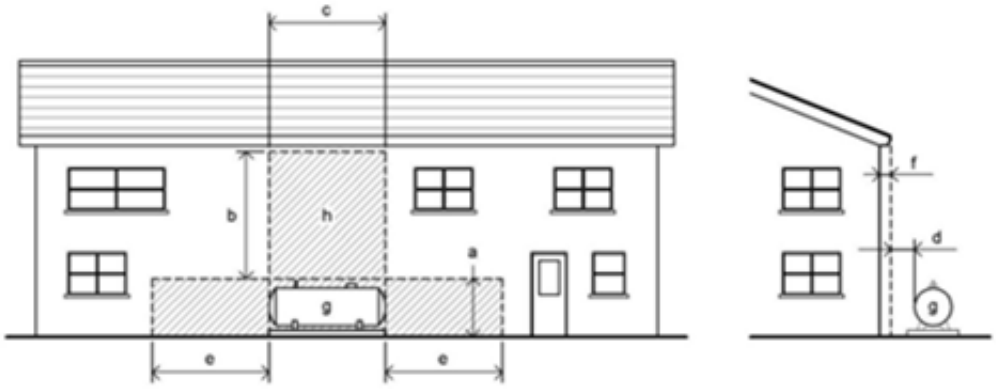
Both the specific use and the quantity of LPG that must be stored in the tank should be taken into consideration before making a decision. Every configuration of LPG storage tank comes with its own set of advantages and disadvantages. Installation and maintenance practices that are up to par are essential to ensuring that LPG storage tanks can function in a manner that is risk-free.

The most common form of storage tank used for LPG is the horizontal cylindrical type, sometimes known as the "bullet type." The spherical variations are used for capacities that are bigger, while the horizontal cylindrical variants are often used for capacities that are smaller or for installations that are located underground. The design of the high-pressure LPG storage tank is essential. When creating anything, a number of considerations need to be taken into account.

Guidance on where to locate LPG tanks

1- The LPG tank has to be outside.
2- Tanks must not be positioned in flood-prone locations.

3- Storage tanks may not be positioned adjacent to or directly underneath power cables.
4- Avoid flammable objects, such as woodpiles, dry grass, leaves, or other combustibles, away from the tank's surroundings. To stop fires, keep the area clean.
5- Tanks should never be put in open pits or buildings.
6- Build up a security fence or wall around the tank to prohibit anyone from entering.
7- Tanks shouldn't be positioned beneath branches or trees.



Key:

a	Height of top of Pressure Relief Valve (PRV)
b	9m
c	Length of vessel
d	0.3m for vessels up to 500 litres 1.5m for vessels > 500 litres to 2,500 litres
e	2.5m for vessels up to 500 litres 3.0m for vessels > 500 litres to 2,500 litres
f	Roof overhang
g	LPG vessel
h	60 minutes minimum fire resistance & imperforate

Figure 8: Small bulk vessel adjacent to a building (Building Regulation 2014)

Components for Liquid Petroleum Gas Tanks

There is a wide range of materials that may be used to construct LPG storage tanks; the specific kind of tank that is needed is determined by the application. The following components are commonly included in the construction of tanks for the storage of LPG. (Dey, A. K., 2022).

1- Steel: Because of its long lifespan, high strength, and resistance to corrosion, steel is the material of choice for the construction of LPG storage tanks. Steel tanks may be installed either above or below ground, and they can be painted or coated to give further protection against corrosion.
2- Aluminum: Tanks for storing LPG might also be made out of aluminum, which is a different material altogether. Because aluminum tanks are both lightweight and resistant to corrosion, they are an excellent alternative for applications that need portability as well as locations with high humidity or salt air.
3- Stainless steel: In the construction of cryogenic LPG storage tanks, stainless steel is one of the most common materials employed. It is not susceptible to corrosion even when exposed to low temperatures, and it is sturdy and long-lasting.
4- Nickel alloys: Tanks that are used to store cryogenic LPG may be fabricated out of nickel alloys such as Inconel or Monel. They have a high resistance to embrittlement and corrosion, even when temperatures are rather low.
5- Composite materials: Carbon fiber or fiberglass-reinforced plastic (FRP) are examples of composite materials that may be used to create LPG storage tanks. These materials are lightweight, impact-resistant, and corrosion-resistant.
6- Concrete: Underground LPG storage may be accomplished with concrete tanks. Large-scale industrial applications suit concrete tanks because they are robust and able to withstand high pressure.

Security features

There are several safety features available at the terminal, including:

1- Water sprinklers, a deluge system, and firefighting.

Figure 9: water sprinkler on the LPG tank (T Roberts, I Buckland and H Beckett, 2001)

2- System to detect gas leaks.
3- Asset management software.
4- High-quality design.
5- Comprehensive safety measures.
6- Tank gauge device to avoid unintentional overfilling.
7- A warning signal will be sent by the high- level alarm system as soon as the percentage of capacity in the tank reaches 85%.
8- Valves designed specifically for safety purposes are installed in storage tanks.
9- Excess flow check the valves installed on each outlet to prevent an unsafe release of LPG in the event that a rupture occurs farther downstream.
10- Protective mechanism against very high temperatures.
11- Protection mechanism against high- pressure systems
12- An apparatus for the detection of flames
13- There are emergency stop switches installed at important locations.
14- Alarm system, both audible and visible, covering the whole of the facility.

Precaution (Crystal Flash, 2023)

The following are the main precautions:

1-Take precaution if there is a gas smell.

2- None of the fire or sparks: Remove any smoking items and any other open fires as soon as possible. No lights, appliances, telephones, or mobile phones should be turned on at any time. An explosion or a fire may be caused by sparks or flames that originate from these sources.

3- Evacuation of the area without delay: Get everybody out of the location or the area if you think there may be a gas leak.

4- Turn off the gas supply at the tank: If it is safe to do so, you should turn off the primary gas supply valve that is located on your propane tank. Rotate the valve in a clockwise direction to the right in order to shut it.

5- A report about the leak: Immediately after you have moved away from the gas leak in a safe location, you should contact your propane seller. If you are unable to get in touch with your propane company, you should phone a firefighter in your area.

6- Do not go back to the building: Till your propane seller, emergency responder, or a licensed specialist is able to confirm that it is protected to return, you must not return.

7- Make sure that your propane system is inspected : Your propane merchant or a competent expert must do a thorough inspection of your complete propane system to guarantee that it is free of leaks before you try to use any of your gas appliances.

Maintenance

1- Every ten years, your gas cylinder must be retested and marked. **(**Fire and Rescue NSW, 2023)

2- In order to find a leak, never use a bare flame (Skovian , 2020). Spray soapy water on any connection or hose that you think could be leaking gas, and look for bubbles to detect any leaks.

3- Do not alter the safety valve or any other gas bottle fittings. Always be cautious rather than regretful. Call the local government or business and request the fire service if you notice a strong gas odor.
4- Inspection on a regular basis
5- Controlling Pressure, Check that the pressure regulators are operating properly to keep the system's gas pressure constant. If regulators are broken or old, replace them.
6- Regularly inspect each valve for corrosion or leakage.
7- Ventilation: to avoid gas fumes accumulating, make sure there is enough ventilation in locations where LPG equipment is used.
8- Systematic safety shutdowns check and keep up safety shutdown devices that, in the event of a leak or failure, will cut off the gas supply automatically.

Conclusions

Propane or butane, which are often used as fuels for cooking, heating, and other uses, can be transported and stored in LPG (liquefied petroleum gas) tanks. To guarantee safety and effectiveness, many important factors are routinely taken into account while designing an LPG gas tank. Such as a tank's composition, design of pressure vessel, size and shape of tank, safety features, system of valves and pipes, support and mounting, as well as regulatory compliance In addition, a review of earlier LPG investigations led to the following main conclusions:

1- Maintenance

2- Guarantee the safety of the population subject to these environments**.** Then**,** when working with LPG, always put safety first**.**

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