Fire Risks and Safety Measures in Road Transport of LPG Tanker Trucks.

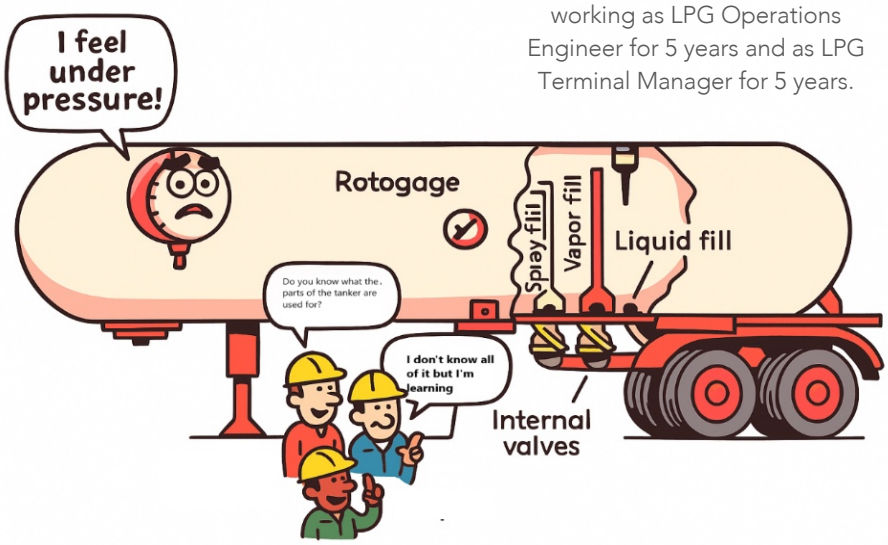
Liquefied Petroleum Gas (LPG) plays a critical role in energy supply chains, especially in countries heavily reliant on road transportation. The widespread use of LPG in residential, industrial, and automotive sectors necessitates a robust logistics network, where road tankers serve as the backbone for inland transport. However, the flammable nature of LPG introduces significant fire and explosion hazards that require careful management.

Fire incidents involving LPG road tankers, although infrequent, can have catastrophic consequences. High temperatures, intense thermal radiation, and potential BLEVE (Boiling Liquid Expanding Vapor Explosion) events make such accidents particularly dangerous for both drivers and surrounding communities. These risks underscore the importance of understanding, preventing, and effectively responding to fire hazards in this sector.

This article focuses on identifying the fire risks associated with road LPG tankers and outlines the technical, procedural, and regulatory safety measures implemented to mitigate these dangers. It emphasizes the need for comprehensive fire prevention strategies tailored to the unique challenges of road-based LPG transport.

1. Technical Features of Road LPG Tanker Trucks

Technical Specifications and Safety Equipment of Road LPG Tanker Trucks. Tanker trucks that transport LPG by road are designed and manufactured in accordance with national and international regulations regarding the transport of hazardous materials (e.g. ADR - European Agreement Concerning the International Carriage of Dangerous Goods by Road). These transport vehicles must meet special engineering criteria in order to transport liquefied petroleum gas (LPG) safely under pressure.



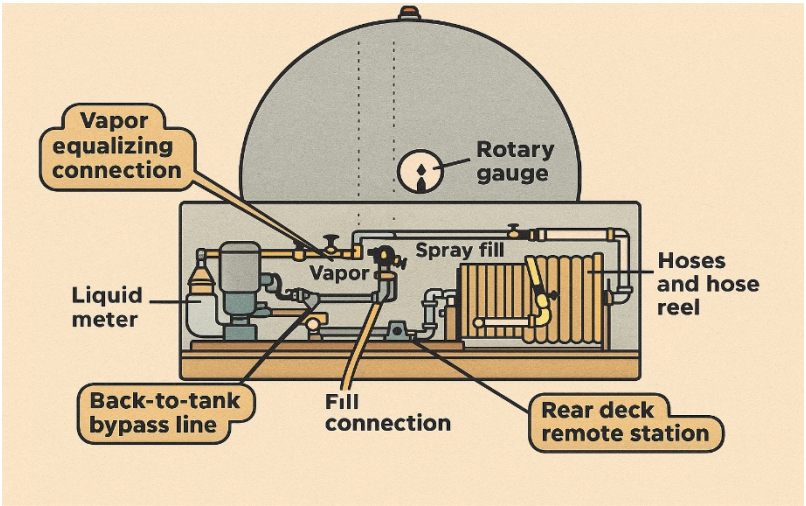
I was born in Ankara, Türkiye in 1987, I have been living in Türkiye/Hatay for many years. I graduated from Akdeniz University in 2010 as a Mechanical Engineer, and in 2012 I completed my master's degree in heat transfer & fluid mechanics at Mustafa Kemal University. I have been working as a mechanical engineer in the sector for 13 years. I worked in the field of production and manufacturing for the first 3 years of my profession, and then for 2 years, I worked in project-based maintenance-repair and capacity increase works in Oil&LPG terminals. I have been working at Milangaz for the last 8 years. I have been working as LPG Operations Engineer for 5 years and as LPG Terminal Manager for 5 years.

a. **Tank Structure and Material Properties**: LPG tanks used in tankers are generally cylindrical in section and horizontally positioned and are manufactured using high-strength alloy carbon steel. The tank body is tested with non-destructive testing (NDT) methods to provide resistance against both internal and external effects (radiographic testing, penetrant testing, hydrostatic testing, etc.). In addition, the outer surfaces are protected with paint against corrosion.

b. **Pressure Relief Valves (PRV)**: When the pressure in the tank exceeds a certain pressure set value, it automatically opens and provides a controlled discharge. Pressure safety valves are activated in over-pressure conditions such as fire or overfilling and are very critical equipment for the integrity of the tank.

c. **Emergency Shut-Off Valves (ESV)**: These valves, usually integrated into the tanker's bottom or inside connections of the tank, are closed remotely or automatically in the event of an accident or leak, cutting off the LPG flow. They must be closed position while the vehicle is moving on the road.

d. **Level Indicators**: These are systems that allow the LPG level in the tank to be monitored. The level on the tank can be monitored with systems called Rochester or Rotogauge.



e. **Pump and Transfer Systems**: The pumps used during LPG transfer are mounted on the tanker and are used to supply gas to customers. Transfer hoses used during supply are special hoses resistant to LPG that comply with the relevant standards.

f. **Excess Flow Valves**: In the event of a connection line break or unexpected high flow rate, it automatically cuts off the LPG flow in the line.

2. Causes of Fire and Risk Reduction Methods in LPG Tanker Accidents

Liquefied Petroleum Gas (LPG) tankers used in transportation pose serious safety risks because they carry highly flammable products. Traffic accidents involving these tankers are one of the most important causes of LPG-related fires. Mechanical damages that occur in such incidents can lead to leaks in the tank or pipe system where the LPG is located. Impact forces, especially in accidents, can damage the structural integrity of pipes, fittings, valves or the tank, causing the gas to spread uncontrollably into the environment. Leaking LPG starts to burn rapidly when it comes into contact with a suitable ignition source and can cause explosions.

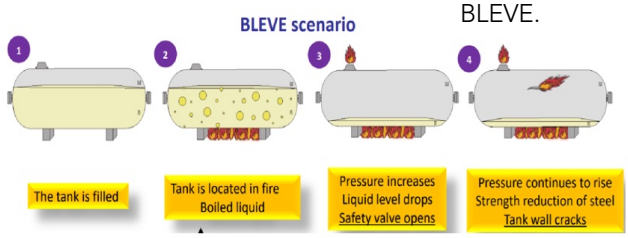
Not only traffic accidents, but also operational errors made during the loading and unloading operations of tankers are important factors that create a fire risk. Negligence such as incorrect connections, damaged or incompatible use of hoses in these processes can cause LPG leaks. In addition, factors such as aging of equipment used in tankers, lack of regular maintenance or technical malfunctions also increase the risk of leakage and fire. Errors related to human factors, such as non-procedural operations, carelessness or inadequate training, can further increase these risks.

In order to prevent all these risks, first of all, potential hazards and possible risk scenarios must be systematically analyzed.

In this context, risk assessment methods such as HAZOP (Hazard and Operability Analysis) and FMEA (Failure Modes and Effects Analysis) can be used. It is of great importance to establish appropriate technical and organizational barriers against the identified risks. These barriers include safety valves and emergency shut-off valves. In addition, the implementation of periodic maintenance programs, regular training of personnel, emergency drills and the establishment of an effective safety culture also play a critical role in minimizing risks.

3. Fire Scenarios in LPG Trucks

One of the most dangerous fire scenarios encountered in LPG (Liquefied Petroleum Gas) facilities is known as BLEVE (Boiling Liquid Expanding Vapor Explosion). BLEVE typically occurs when an LPG tank is exposed to external heat, especially fire. In such cases, the liquid LPG inside the tank rapidly vaporizes, causing a sudden and dramatic increase in internal pressure. If the tank's pressure relief systems are inadequate or out of service, the pressure may exceed the tank's structural limits, resulting in rupture or explosion.



The effects of a BLEVE are extremely destructive. Upon explosion, fragments of the tank are propelled at high speed into the surrounding area, causing severe injuries and secondary damage. The intense thermal radiation released after the explosion poses a fatal risk to human life and can ignite surrounding equipment and structures. Additionally, BLEVE can damage nearby tanks and facility components, triggering a domino effect that may escalate the situation.

Another critical fire scenario involves fires that occur during the transfer of LPG. These incidents are often caused by mechanical failures such as hose rupture, loosening of flange or coupling connections, seal wear, or assembly errors. Although the initial leak may appear minor, the low flash point and wide flammability limits of LPG make it highly susceptible to ignition from any spark or static discharge in the vicinity. When pressurized LPG is released and vaporizes, it can ignite rapidly, resulting in a jet fire. The presence of open flames, hot surfaces, or electrical equipment near the transfer line can significantly increase the speed and intensity of fire spread.
Fires involving transportation vehicles also pose serious risks. In LPG tankers, a fire that begins in the engine compartment or one caused by overheated brake systems can quickly spread to the tank area. If the fire is not brought under control swiftly, the tank may heat up, creating the risk of a BLEVE.

Such incidents present a major threat to driver safety and can have severe environmental consequences.

4. Emergency Management for LPG Tanker Accidents (Overturned)

The process of rescuing an LPG tanker that has been involved in a collision or has overturned is a highly dangerous undertaking. In order to ensure the safety of the individuals involved, as well as the safety of the operation, it is essential that those involved in the rescue are adequately trained, equipped, and that there is effective coordination with the emergency services.
In the event of an emergency, it is imperative that the relevant authorities, namely the LPG Emergency Services, encompassing both the fire department and the police, are informed without delay. It is of the utmost importance to emphasise that the management of such incidents should be entrusted exclusively to trained professionals, as their expertise are essential in ensuring the safety.

The primary concern is invariably the safety of individuals in the vicinity. In order to ensure the immediate security of the scene, it is imperative to implement a comprehensive evacuation protocol, encompassing all individuals within a designated safe perimeter, which is typically a minimum of 500 metres away.

Furthermore, it is crucial to ensure that all ignition sources are meticulously removed from the immediate vicinity of the site, and all potential leak points on the tank are meticulously examined. The inspection process entails the use of auditory perception from a safe distance, in addition to visual confirmation of any indications such as frost or vapour clouds. In the absence of any leaks, the tanker is approached and detailed gas leak checks are conducted. In addition, a thorough inspection of the piping and valves is imperative to ascertain the functionality of the tanker's emergency shut-off valves. It is imperative that the damage status of the tanker is thoroughly and accurately assessed, as this will inform the subsequent response actions of the emergency response team. A series of actions must be taken prior to the tanker being returned to its standard position. Prior to the execution of the lifting operation, it is imperative that the liquid LPG contained within the tanker be meticulously transferred to an alternative, secure tank. Secondly, the LPG vapour contained within the tank must be transferred to an alternative tank by means of a compressor.

Concurrently, the remaining LPG gas within the tank must be inertised with nitrogen. The mobile gas flares can serve as an effective solution if there is safe distance. It is imperative that a comprehensive and meticulous lifting plan is devised for the overturned tank, with the objective of averting any potential damage to the tank's equipment, including pipes and valves. The overturned tanker should be transferred to a designated safe area by a rescue vehicle that is appropriately equipped for the task.

Emergency LPG Transfer from a Damaged LPG Tanker Following an Accident

Emergency transfer of LPG from a damaged tanker should only be carried out by authorized, experienced, and trained LPG professionals. During the entire process, continuous coordination and communication must be maintained with fire departments, police, and relevant environmental authorities.

The accident site must first be secured with an extended safety perimeter. Wind direction should be identified to establish the hazard zone, and personnel should be positioned accordingly.

The damaged tanker must be thoroughly inspected for potential leaks using visual examination, acoustic listening, gas detectors, and foam tests. Particular attention should be paid to identifying any cracks, dents, protrusions, or structural deformations on the tank surface or valves.

Tank integrity is critically important. Under no circumstances should the tanker be lifted or moved using cranes or other lifting equipment before it is completely emptied, as this could lead to further damage or create additional hazards. If the conditions are deemed safe for LPG transfer, preparations can commence. To eliminate the risk of static electricity, both the damaged and receiving tankers must be individually grounded.

All transfer equipment used must be spark-proof and comply with ATEX standards.

If the operation is conducted at night, sufficient ATEX-certified lighting must be provided, and all personnel must be equipped with appropriate Personal Protective Equipment (PPE).

The receiving tanker should be positioned on level ground, preferably at a lower elevation than the damaged tanker, and placed upwind to minimize exposure to any potential LPG vapors. Hoses used for the transfer must be suitable for LPG service and equipped with breakaway couplings for additional safety.

Before initiating the transfer, tank pressures must be checked and adjusted if necessary. If a compressor is used, the vapor phase from the damaged tanker can be utilized to push the liquid LPG into the receiving tanker. However, using compressed nitrogen is considered a safer method. In this approach, the damaged tanker is pressurized with nitrogen, and the liquid LPG is transferred to the receiving tanker. During the entire process, the pressure in both tanks must be constantly monitored, and precautions must be in place to prevent over-pressurization.

Once the transfer is complete, it must be ensured that all liquid LPG has been removed from the damaged tank. If any liquid remains, the nitrogen inside the tank must be carefully vented, as nitrogen is a non-condensable gas and can cause a dangerous increase in internal pressure. If the product cannot be salvaged or transferred safely, the LPG inside the damaged tanker should be destroyed in a controlled manner using mobile flare units to render the tank safe.

Mobile Gas Flare: In emergencies involving liquefied petroleum gas (LPG) truck accidents, a mobile gas flare system plays a crucial role in ensuring safety. When such accidents occur, the potential for gas leakage poses a severe threat of explosions or fires if left unattended. To mitigate this risk, the mobile gas flare system is swiftly deployed to the accident site. Its purpose is to safely burn off the LPG in a controlled manner, minimizing the possibility of uncontrolled ignition. This proactive measure not only safeguards emergency responders but also protects the surrounding community from potential harm.

Emergency Management for LPG Tanker Accidents (During LPG Leaks)

A leaking LPG tanker accident poses a great danger due to the highly flammable and potentially explosive nature of liquefied petroleum gas (LPG). The first and foremost priority is to ensure the safety of all people in the vicinity. Since the risk of exposure to LPG vapors is serious, it is imperative to immediately evacuate the incident area and retreat to a safe distance. Evacuation areas should be determined in the opposite direction of the wind direction and the distance should be carefully adjusted according to the weather conditions and the amount of LPG released. All ignition sources that may increase the risk of fire and explosion, such as open fire, electrical equipment and smoking, should be eliminated immediately.

The use of personal protective equipment (PPE) is mandatory for all team members performing emergency intervention. The gas density of the environment should be carefully measured with gas detectors before the intervention, and only trained and equipped personnel should approach the leak.

If the source of the leak can be detected and controlled, the priority is to close the valves or isolate the damaged section with clamps or another method. The type of leak is also a critical factor; liquid LPG leaks can have a cooling effect, so special methods such as wet cloths can be used. In addition, tools that have a risk of sparking should definitely be avoided and non-sparking equipment should be used.

In cold regions, it is generally not recommended to apply water directly to liquid LPG, because water can cause LPG to evaporate and spread more quickly. However, moistening the leak area with pulverized water can reduce the LPG concentration in the air and reduce the risk of fire.
After the leak is completely controlled, ongoing gas level monitoring in the environment should be carried out and possible risks should be followed meticulously. These comprehensive measures are essential to minimize the effects of the accident and protect human life.

5. Emergency Management for LPG Tanker Accidents (During Fires)

In the event of a fire involving an LPG tanker, rapid, coordinated, and structured emergency response is critical to minimize risks to life, property, and the environment. The first step is to immediately activate the emergency response plan and notify local fire departments, emergency services, and relevant authorities. Establishing a safety perimeter around the tanker to prevent unauthorized access and protect responders from potential explosions is essential. Firefighting efforts should focus on preventing BLEVE (Boiling Liquid Expanding Vapor Explosion) by continuously cooling the LPG tanker with large amounts of water applied to exposed surfaces. If flames are not directly impinging on the tank body, especially the vapor space, the situation is more manageable. However, if flames contact the tank body and sufficient cooling cannot be maintained, the emergency zone must be evacuated immediately, as a BLEVE could occur at any moment.

In LPG tanker fires, warning signs and time for evacuation are often minimal. Classic indicators such as bulging, discoloration, or metallic ringing may not be visible or may appear too late. BLEVE events progress very rapidly; a tank may look intact one moment and be shattered and engulfed in a fireball the next.

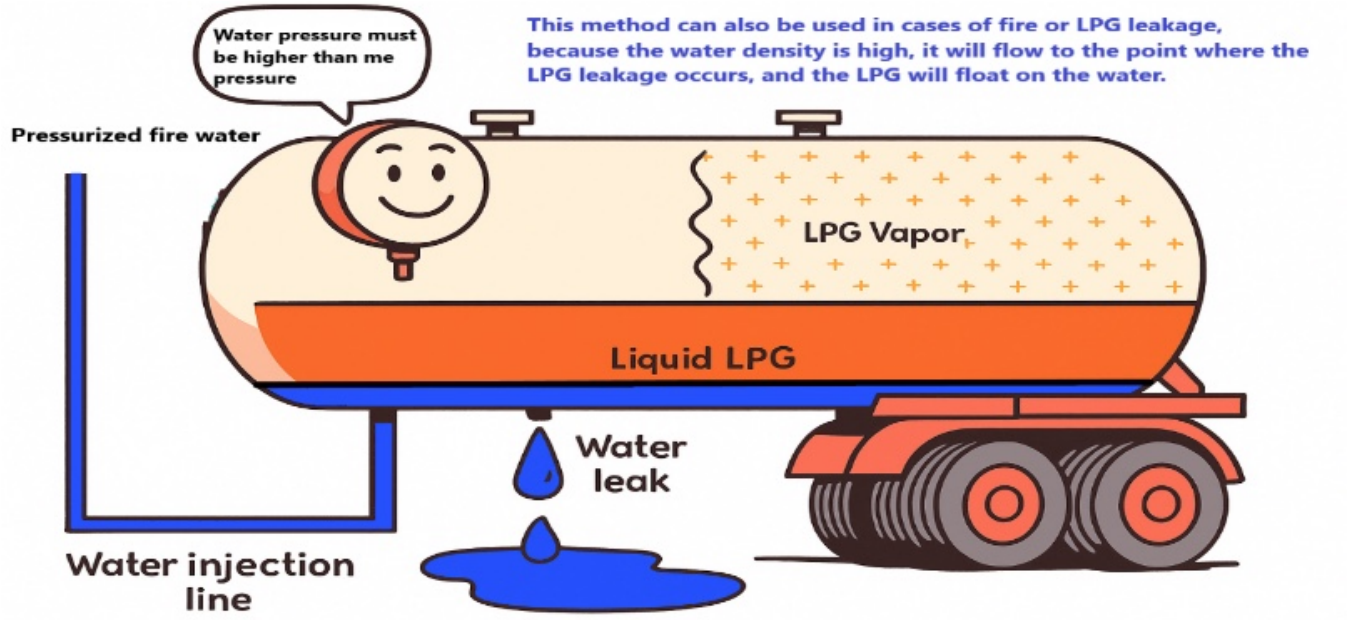
A critical early warning sign is the activity of the pressure relief valve (PRV or PSV). Initially, the PRV may open and close intermittently depending on where and how the fire affects the tank. If the PRV continues to cycle for a while, it may indicate limited fire exposure or that the fire has reached the liquid level both dangerous conditions.

However, a PRV that remains continuously open is a severe red flag. It indicates falling LPG liquid levels, loss of internal cooling, weakening steel strength, and vapor space heating conditions that set the stage for BLEVE.

Listen also for increasing PRV noise or prolonged flames, as these signal rising internal pressure. Keep in mind, though, that in real incidents these cues can be subtle or missed entirely. The harsh reality is that there may be no second chance. When in doubt, keep a safe distance.

Emergency Water Injection of LPG Leak

When something happens and you're faced with an uncontrollable liquid LPG leak you have very few options. Depending on the size of the tank and the volume of the release, a liquid LPG leak can quickly create a large hazard area requiring large area evacuations, limit your ability to safely extricate trapped accident employees or identify the location of a leak. In this situation you can use water injection method if all conditions are proper.



Injecting water into a LPG tank is a leak management option that most responders and operators have not considered. Water injection, just like all response tactics, requires special knowledge, identified tactical objectives, the proper tools and training. When a leak occurs in the tank, especially in the nozzle flange gasket, weld seam or valve body, the LPG leak cannot be stopped by emergency shut-off valves. In such cases, it will be necessary to flood the tank. When water is injected into the tank, since water will down to the bottom of the tank due to the density difference and the LPG will be displaced upwards. With this operation, the LPG leak will be replaced by a water leak. Thus, the LPG leak will be replaced by a water leak. LPG leakage will be end. While designing such a system, should be attention, the water pressure should be higher than the vapor pressure of the LPG inside the tank. Water injection is the process of forcing water into a tank using a water supply capable of producing more pressure than the LPG tank's internal pressure. Also a check valve should definitely be used in the water injection lines.

Otherwise, LPG can flow to water line and the situation may become more dangerous. As a result, with this method, LPG leakage can be prevented and stopped when water is injected into the tank. If there is a fire, it can stop fire, thus It is one of the most basic barriers that can prevent BLEVE.

CONCLUSION

The transportation of LPG by road tanker trucks carries inherent risks due to the highly flammable nature of the product and the complexity of operations involved. While such incidents are relatively rare, their potential consequences ranging from large-scale fires to catastrophic BLEVE events demand a rigorous and multidimensional approach to safety. Technical integrity, operational discipline, and regulatory compliance must work in harmony to reduce fire-related hazards in LPG logistics. This study demos that fire scenarios in LPG tanker incidents often stem from mechanical failures, human errors, or inadequate maintenance practices.

Components like pressure relief valves, emergency shut-off valves, and level indicators play a pivotal role in early risk detection and mitigation. However, even with advanced safety equipment, the effectiveness of risk control measures is ultimately dependent on the human factor adequately trained personnel, emergency preparedness, and situational awareness are essential to preventing escalation. Response strategies must be designed with flexibility, competency, and rapid execution in mind. Interventions such as mobile gas flaring, inerting with nitrogen, and, in critical cases, water injection into tanks are powerful tools to control hazards and prevent BLEVE. These methods underscore the importance of not only preventive strategies but also active incident management. The safe transportation of LPG by road hinges on a combination of engineered safety systems, proactive risk assessment, and well-coordinated emergency management. Continuous training, technological investment, and knowledge-sharing among stakeholders can significantly enhance the safety culture within the industry. In doing so, both operational continuity and public safety can be upheld even under the most challenging conditions.