PROPANE
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Good Practices for the Care and Custody of Propane in the Supply Chain

A Report From
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Glossary

Batch system – a pipeline system where more than one product is moved, in series, through the line. Buffers or batching pigs are used to separate the products.

Batching pigs – a plastic or foam bullet placed between product batches.

Buffer – the use of normal butane or iso-butane in a pipeline to reduce product intermixing by separating propane from other products that may be transported through the same pipeline.

Commercial propane – a hydrocarbon product for use where high volatility is required. Commercial propane is suitable for heating applications and most engine applications.

Dedicated system – a pipeline system where propane is the only product moved through the line.

Gas chromatography – process in which a mixture of gases or vapors are separated by their differential adsorption by a stationary phase. Gas chromatography is used as an analytical method to determine the composition of a mixture, including the concentration of individual species.

HD-5 propane – a high quality product defined by GPA 2140 that is composed predominantly of propane, which exhibits superior antiknock characteristics in high-output engines when used as an internal combustion fuel (equivalent to special-duty propane defined in ASTM D-1835).

Heavy-ends – non-volatile liquid or solid material left in tanks or piping systems after propane is vaporized.

Liquefied petroleum (LP) gas – a mixture of hydrocarbons, mainly propane, propene (propylene), and butanes.

Odorant fade – the depletion over time of the odorant content in odorized propane, due to various complex processes.

Passivate – action taken to eliminate or reduce the occurrence of propane odorant fade caused by certain complex processes which can take place on the active metal surfaces of new containers and tanks.

ppm – parts per million, which is a measure of concentration. Parts per million (ppm) can be expressed on either a volumetric or weight basis.

Special-duty propane – a high quality product defined by ASTM D-1835 that is composed predominantly of propane, which exhibits superior antiknock characteristics in high-output engines when used as an internal combustion fuel (equivalent to HD-5 propane defined by GPA Standard 2140).

1. Introduction

All stakeholders in the propane industry have a common interest in maintaining propane quality. There are many quality assurance practices that are required (by a facility's management or industry standard) or voluntarily followed by those that have custody of propane as it moves through the supply chain. However, propane quality can – and does – reach unacceptable levels if product control practices are not constantly monitored.

The objective of this document is to increase awareness of maintaining fuel quality for propane that is delivered as an odorized product. Maintaining fuel quality involves more than producing propane with the proper composition. Rather, all entities that have custody of propane throughout the supply chain need to follow good practices that will ensure that high quality propane is delivered to the final customer.

This guideline provides a basic foundation of the complex subject of fuel quality. In the United States, propane supplied by producers generally complies with one of the following specifications:

- HD-5 (GPA Standard 2140)
- Special Duty[1] (ASTM Standard D 1835)
- Commercial (GPA or ASTM standards)
- HD-10[2] (California Code of Regulations)

History and experience show that propane does not always meet one of these specifications. Further, meeting a specification does not necessarily mean that the product is fit for all applications that use odorized propane. Therefore, it is incumbent on those that produce, handle, transport, store, and deliver propane to monitor and maintain propane quality as it moves through the supply chain.

This guide is organized as follows:

- Chapter 2 – Background and overview of the propane supply chain
- Chapter 3 – Good practices related to pipelines and terminals
- Chapter 4 – Good practices for bulk plant storage and customer delivery
- Chapter 5 – Summary of good practices and fuel quality issues
- Appendix A – Summary of major propane contaminants

This report does not address safety issues and should not be used to replace or supersede any propane safety procedures or policies.

[1] Special-duty propane (D1835-03a Standard Specification for Liquefied Petroleum (LP) Gases) is identical to HD-5 propane (GPA 2140).
[2] The term "HD-10" is used in the propane industry, but there is no official "HD-10" specification.

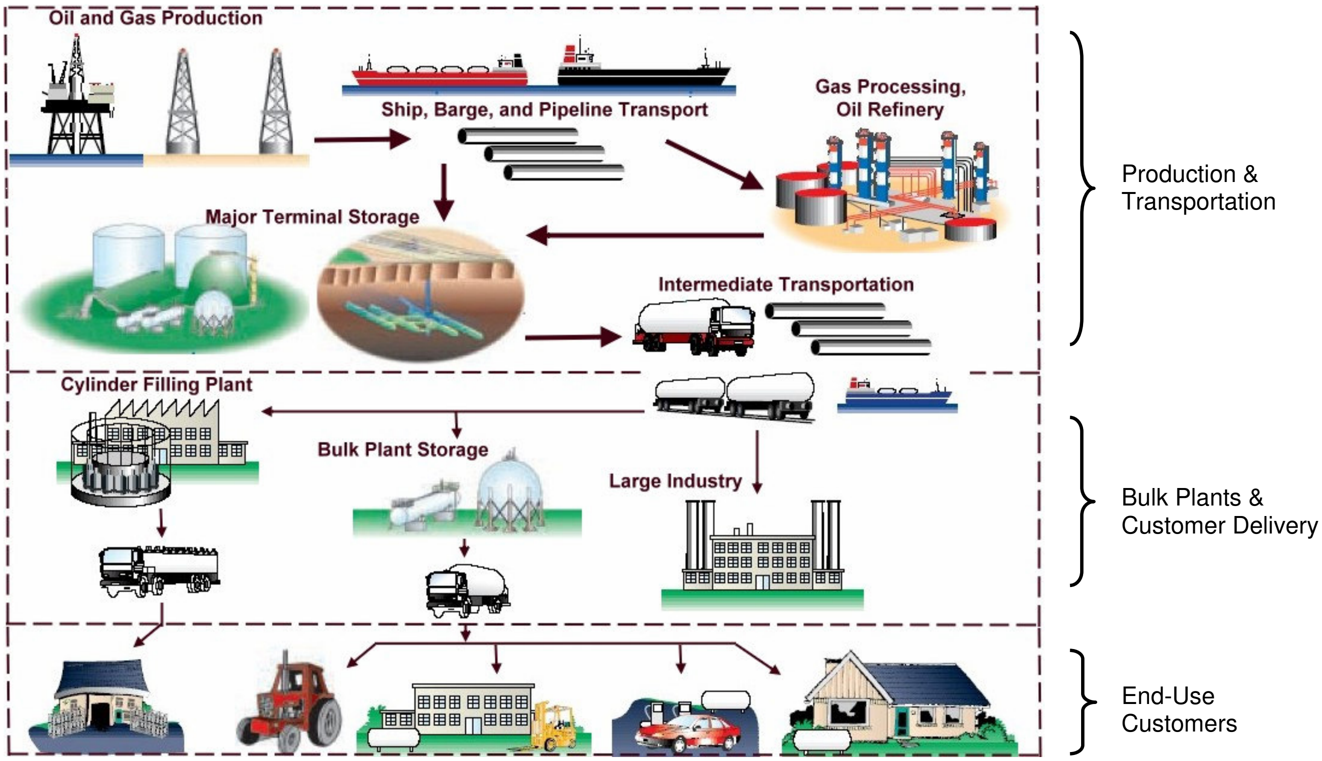
2. Background

Liquefied Petroleum Gas (LP-gas or LPG) is a mixture of hydrocarbons, consisting mainly of propane, propene (propylene), and butanes. In the United States, LP-gas is primarily propane (C_3H_8), and in this report the terms LP-gas and propane are used interchangeably.

2.1 Overview of Propane Supply Chain

A simplified schematic of the propane supply chain is illustrated in **Figure 1**. For this guideline, the supply chain is divided into three groups:

- Production and Transportation
- Bulk Plants and Customer Delivery (cylinder filling plants, bulk storage plants, and large industrial customers)
- End-Use Customers (final consumers of odorized propane)



Source: Adapted from the World LP Gas Association

Figure 1. Simplified Propane Distribution Chain

As indicated in **Figure 1**, there are many custodians that are involved in the multitude of paths that can be used to deliver propane from the production source to the end-use customer. All of these custodians play an important role in maintaining quality.

2.2 Quality

Maintaining propane quality is more than just producing a product with the proper composition. After the product is produced within specifications, each custodian in the supply chain must handle the product properly to ensure that contamination does not occur. If there is a breakdown anywhere in the supply chain, serious problems can occur. Consider the following examples:

- A manufacturer of propane engines used for indoor applications reported a high incident rate of poor engine performance that was traced to oil in the propane. Analysis showed that the oil would build into a tar-like substance on the intake valves and keep the valves from closing completely. This situation caused loss of cylinder compression, which led to poor engine performance and high emissions of carbon monoxide (CO) and unburned hydrocarbons. One beneficial selling point for propane is low emissions for indoor engine applications. However, oil in the propane caused just the opposite result for this manufacturer – high engine emissions.
- A propane tanker from a refinery was contaminated with a common cleaning agent for steel tanks and piping systems. The tanker was off-loaded at a bulk plant and the contaminated propane was then delivered to approximately 300 customers. The problem was reported by end-users that experienced severe problems using the contaminated propane in water heaters, furnaces, and vehicles.
- Water contamination of propane delivered by rail car has been a significant challenge. One distributor received two rail cars on separate occasions contaminated with water. The contaminated propane was not immediately detected and was delivered to over 50 customers.
- A propane distributor purchased a secondhand propane storage vessel from a tank broker and put it into service without first doing an internal inspection. Unknown to the distributor, the vessel had been previously contaminated with sulfur. This situation resulted in the distribution of corrosive propane to end users.

These preceding anecdotal examples illustrate the undesirable impacts that poor quality control can have on customers. If unchecked, poor quality control affects the entire propane industry and can lead to the erosion of market share or the inability to move into new markets. For example, based on unfavorable warranty and service experience, some engine and vehicle manufacturers have expressed reluctance in producing new propane engine offerings without assurances that propane will not trigger future unwanted warranty claims. With engine applications, concerns include both on-road and off-road vehicles. For example, new emission regulations applicable to off-road equipment present opportunities for clean burning propane. However, control technologies require consistent fuel properties for satisfactory performance, and off-road vehicle manufacturers may be reluctant to develop propane engine alternatives if fuel quality is uncertain or highly variable.

Table 1 includes a list of common propane contaminants and potential problems related to these contaminants. In the following sections, the source of these contaminants in the supply chain is explored, and good practices are discussed that can be followed to mitigate the introduction of these contaminants.

Table 1. Possible Propane Contaminants

Contaminant	Problem
Water	Water promotes rust on internal surfaces of carbon steel storage tanks and black iron piping systems. Rust can result in odor fade, reducing the life of system components. Rust particles can also block small openings. In cold weather or during pressure reduction operations, water can freeze. Ice can impair the operation of, or even damage, valves, pumps, piping, and regulators.
Oil residues and heavy ends	Operational problems with end-use equipment and inability to meet emissions standards. May lead to the production of carbon monoxide.
Solid particulates	Operational problems with end-use equipment when not properly purged. May lead to the production of carbon monoxide.
Air and nitrogen	Operational problems with end-use equipment (improper fuel-air ratio, poor or no combustion). May lead to the production of carbon monoxide.
Ammonia	Failure of brass fittings through stress corrosion cracking.
High sulfur (S), hydrogen sulfide (H_2S), and other corrosive components	Corrosion and failure of copper containing materials.
High butane content[3]	Inadequate vaporization in cold weather.
High propylene content[4]	Increased emission production and inability to meet air quality standards.

[3] Butane is an acceptable component of propane. However, in high concentrations, butane can be regarded as a contaminant because the fuel will not perform as expected.
[4] Like butane, propylene is an acceptable component of propane but can be regarded as a contaminant in high concentrations.

3. Pipelines and Propane Terminals

Good practices for the care and custody of propane in pipeline distribution systems and propane terminals are discussed in this chapter. A detailed discussion of the production of propane is beyond the scope of this manual. However, a brief overview of propane production is provided for completeness.

3.1 Production

Propane is one of many hydrocarbons that are produced through the processing of natural gas and the refining of crude oil, both of which are found and extracted from underground reservoirs. A complex series of production and processing steps, such as field treating, transportation, desalting, desulphurization, fractionation, catalytic cracking, alkylation, separation, finished-product treating, storage, and quality assurance testing are utilized within gas plants and refineries. These steps must be properly conducted to produce propane that meets required specifications and is suitable for pipeline, truck, rail or marine delivery to propane terminals, distributors, and end-users.

3.2 Transportation to Terminals

Propane is delivered from refineries and gas plants to propane terminals (or directly to some retailers) by transporting the propane, in liquid phase, either through liquid pipeline grids located in the central and eastern United States, or by truck, ship, barge, or railcar.

Pipeline transportation utilizes pumping stations positioned along the pipeline grid to provide the energy needed to move the product. Some pipelines are "dedicated" propane systems, in which propane is the only product moved in the line. Others are "batch" systems, in which more than one product is moved, in series, through the pipeline. In batch systems, propane is typically isolated from other products in the pipeline by separating the propane batch either with a product of different density before and after the propane, by the use of normal butane or iso-butane buffers, or the use of batching pigs placed between product batches – see **Figure 2**.

Source: Girard

Figure 2. Product Separation Pig for Batch Shipments in Liquid Pipelines

3.3 Receipt at Terminals

Figure 3 illustrates a propane and refined products terminal. A large propane storage sphere is shown on the left side of the photo (many terminals use horizontal storage vessels for propane storage, rather than spheres). Propane dehydration equipment and propane truck loading facilities are located below and left of the sphere. Several atmospheric (non-pressurized) refined product tanks are also shown, along with the refined product truck loading rack (the large, covered structure at the lower right of photo).

Operators at terminals should pay close attention to the following general activities, based on management's instructions, in order to maintain and protect product quality during receipt of propane into terminal storage:

- Proper valve line-up to terminal propane storage to ensure that the propane being received is routed to the correct terminal storage without cross-contamination by other products.
- Proper sampling, testing, frequency of testing, and interpretation of results on the propane as it is being received into terminal storage.
- Proper action plan followed if an off-spec test result occurs.

Figure 3. Propane and Refined Products Terminal

3.3.1 Pipelines

Propane received by pipeline into terminals should be sampled and undergo oversight testing for quality just prior to the start of the receipt into the terminal and periodically during delivery, based on the facility management's requirements. A sampling point located in the pipeline just upstream of many terminals remotely monitors the density (specific gravity) of the pipeline product as it approaches the terminal. This information gives the terminal operator guidance on the timing of the arrival of the propane at the terminal. Once the propane reaches the terminal, it is typically sampled and undergoes

oversight testing for density (specific gravity), volatile and non-volatile residues, and oily contaminants before it is routed to the appropriate storage vessel or cavern within the terminal. Terminal operators continue to test the propane at the facility management's required frequencies throughout the pipeline receipt. In some cases, the propane composition is analyzed on a continuous basis. Key items at pipeline terminals include:

- Careful timing on opening the pipeline propane into terminal storage on batch systems to avoid possible contamination with the products on either end of the propane batch.
- Close coordination with the pipeline scheduler/controller throughout the receipt operation.

If any quality control oversight tests are found to be out of compliance, then some or all of the following actions should be considered:

- The pipeline receipt into the terminal should be shut down immediately until further confirmation testing can be done.
- The terminal supervisor should be notified.
- The propane storage to which the receipt was originally lined-up should be isolated, tested, and confirmed to be on-spec before delivering from it.
- If any propane transport vehicles were loaded with suspect or off-spec propane, follow-up testing should be done on that material and corrective action taken, if needed.

Propane found to be off-spec in terminal storage should, with facility management review and approval, either (1) be blend-adjusted at the terminal, retested, and confirmed to meet the required quality specifications before delivery, or (2) be removed from the terminal for off-site quality correction, reprocessing, or other approved disposal action. For large batches, on-site treating and dehydration may be considered. The delivery of off-spec fuel could be in violation of contract terms and some laws or regulations.

3.3.2 Ships and Barges

Propane receipts into marine terminals can be by barge or ocean-going vessels (barge shown in **Figure 4**). The relative size of the cargos can range from 8,000 to 600,000 barrels for some of the world's largest propane vessels. Quality control of propane is a critical component due to the expense and logistics associated with handling product that does not meet specifications. Marine cargos are typically tested for ammonia, corrosion, composition by chromatographic analysis, freeze valve (on barges only), density (specific gravity), and vapor pressure. Prior to loading ships or barges, the previous cargo transported must be considered to ensure the propane cargo will meet specifications after loading. In some cases, this may require flaring, purging with nitrogen, and/or sweeping with propane vapors to ensure a sufficient amount of the previous cargo has been removed such that the propane will meet contractual specifications.

Large ocean-going vessels deliver propane into marine terminals, and this propane is then either delivered directly into the wholesale propane market or stored in underground caverns or refrigerated tanks. Typically, propane transported and received from ocean-going vessels is refrigerated to approximately –40 °F. At this temperature, onboard tank pressures are less than 1 psig. This refrigerated product must be warmed before it is delivered into trucks, railcars, underground storage, or pipelines to avoid thermal stresses.

Source: Dynegy Midstream Services, L.P.

Figure 4. Propane Barge (capacity of 16,600 barrels)

Propane is transported in barges at ambient temperatures, thus barge tanks are designed for a maximum working pressure of 250 psig at 100 °F, the same pressure as land-based tanks. Some cargoes are transported on ships that are neither fully pressurized like barges nor fully refrigerated like large ocean-going vessels. These semi-refrigerated vessels have tanks with a design pressure lower than barges, but higher than fully refrigerated ships, and usually have capacities ranging up to approximately 100,000 barrels.

3.4 Treating and Conditioning at Terminals

Propane terminals use a variety of methods for treating and conditioning the propane they receive and store, prior to delivery to distributors and end-users. The methods employed are dependant on the condition of the propane at that location and on facility equipment and capabilities.

3.4.1 Water

Although not allowed in either commercial grade or HD-5 grade specifications, some terminals receive propane containing free water and/or dissolved water which, if left in the propane, may cause freeze-up problems at piping low points, valves, or pumps during cold weather or at pressure reduction steps. Propane with a water content of approximately 26 ppm or higher has a tendency to freeze-up, and is considered “wet.” Dissolved water is not visibly evident in liquid propane. A freeze valve test is used to determine if propane containing dissolved water is “wet” or not. Free water is water that physically settles out of the propane or is carried along with the propane and accumulates at the bottom of vessels or containers or in piping. If free water is present in propane, the propane is water saturated and the amount of dissolved water in that propane will cause it to test “wet.” Propane is usually “wet” when it has been stored in underground caverns in which water or brine is pumped into the bottom of the cavern to deliver (displace or push) the propane from the cavern. To remove moisture from propane, terminals typically employ the use of one or more of the following processes:

- Coalescing filter
- Dryer (dehydrator)

- Particulate filter
- Methanol injection

Coalescing Filter

A coalescing filter physically removes free water from wet propane, but may not remove enough water to pass a dryness test. It typically consists of a water knockout vessel containing a polymer (plastic) or metal-mesh pack or pad located near the vessel's outlet, which helps coalesce and separate any free water from the propane. The separated water then settles into a water drop-out pot and is periodically drained into a holding tank for treatment and disposal, based upon local regulations.

A good practice to maintain proper filter operation is for the terminal operator to check the level in the water drop-out pot at regular intervals and drain as necessary to prevent water carry-over into the propane stream.

Dryers (Dehydrators)

Dryers are typically located downstream of the coalescing filter. Dryer vessels can be of the salt-dryer type, in which salt is used to remove moisture by the formation of brine (salt water), which is then removed from the propane. The salt is consumed in the process and normally replaced when moisture begins to be indicated by the freeze valve test. It is also a good idea to "heat trace" the system to prevent the brine from freezing at low temperatures.

A good practice to maintain proper salt-dryer operation is for the terminal operator to run a freeze valve dryness test at regular intervals on propane downstream of the dryer. This practice will help avoid the delivery of wet propane, which may occur due to a low salt bed level or channeling of the propane in the salt bed. A particulate filter downstream of the dryer can be equipped to sound an alarm if water is present.

Dryers can also be of the regenerative type, which contain a desiccant material such as activated alumina or silica gel or are constructed with molecular sieves. Regenerative dryers remove dissolved water from wet propane as it passes through the dryer bed and may also remove free water if so designed. These dryers are periodically regenerated by passing hot propane vapor through the dryers after the desiccant or molecular sieve has reached near-saturation with water. The need for dryer regeneration is typically determined by routine freeze valve testing for moisture content in the propane downstream of the dryers, but may be continuously monitored with online moisture analyzers.

A good practice to maintain proper regenerative dryer operation is to run a freeze valve dryness test at regular intervals or use online moisture detectors on propane downstream of the dryer. This practice will prevent the delivery of wet propane caused by water saturation of the alumina or mole sieve bed.

Particulate Filter (final filter)

A particulate filter is often utilized downstream of the dryers and just upstream of the loading dock to remove any particles (e.g., rust, desiccant dust, debris, etc.) in the propane. Some particulate filters "swell" if water is present in the propane, increasing the pressure differential across the filter which, in turn, can be equipped to sound an alarm in the terminal control room and shut down the propane loading pump until the situation can be investigated.

The following are good practices to maintain proper particulate filter operation:

- A terminal operator and instrument technician should regularly check pressure differential readings, the condition of instrumentation and alarms, and the general condition of the particulate (final) filter.
- A freeze valve dryness test should be run at regular intervals or online moisture detectors should be used downstream of the particulate (final) filter.

Methanol Injection

Propane terminals that do not have dehydration equipment typically use methanol injection to control moisture. Methanol helps prevent the formation of ice crystals (freeze-ups) when water is present in propane. The amount of methanol added should be recorded on the bill of lading (BOL) or loading ticket so as to guard against subsequent additions of methanol after delivery from the terminal. Facility equipment and capabilities determine the specific methods used to deal with water at a particular terminal. Methanol is sometimes injected into individual transport trucks and railcars during propane loading if small amounts of moisture are detected.

3.4.2 Odorant Injection

Propane is an odorless gas, and for safety reasons an odorant is added for most applications.[5] Odorant is typically injected into un-odorized propane during the first bulk loading process at propane terminals. Experience has shown that ethyl mercaptan in the ratio of 1.0 pounds per 10,000 gallons of liquid propane has been recognized as an effective odorant[6]. However, a standard practice in the propane industry is to inject 1.5 pounds per 10,000 gallons of propane to provide an extra margin of safety. Excessive odorant addition (additions significantly above the 1.5 pounds per 10,000 gallons level) may in some circumstances cause problems in sulfur-sensitive end-use equipment, and may cause complaints of strong odor in cooking and heating appliance use. Odorant is commonly transferred from a storage vessel into the loading line, often through a metering system, during propane loading. Metering systems often employ a fail-safe mechanism which shuts down the propane loading pump if an odorant injection malfunction occurs. The odorant injection systems should be checked and calibrated on a routine basis to maintain accurate injection rates and consistent operation. While not required, the amount of odorant that has been injected into a load of propane is normally printed (or hand written) on the BOL or loading ticket when the propane loading has been completed.

A good practice to maintain proper odorant injection system operation is to have qualified terminal personnel make regularly scheduled checks on the odorant injection system to ensure proper operation of odorant storage, transfer, and metering equipment.

3.5 Shipment from Terminals

Propane is delivered from propane terminals to distributors and re-sellers via truck, railcar, ship or barge, and sometimes by pipeline. The previously sampled and tested propane is transferred from storage vessels (“sales tanks”) to the loading dock where odorant is injected into the propane as it is being loaded into transport vehicles. Periodic freeze valve testing for moisture is typically done at terminals, either by terminal personnel or, at some facilities, by the vehicle drivers as the vehicles are being loaded. Freeze valve test results, time of test, vehicle identification, and tester’s name are typically required to be logged on a form at the loading facility. Transport vehicles are normally loaded with propane using

[5] The requirement to add odorant can be waived in special-use applications, such as aerosol propellants and food and drug products where the odorant has a detrimental effect on the final product.

[6] NFPA 58, Appendix A, A.1.3.1, 2001.

temperature-compensating meters, by weighing in and out, or by container outage gauge reading and calculation using product gravity, temperature and the container volume (strapping) data. A bill of lading (BOL) or loading ticket is printed, showing load date, time in and out, customer and carrier identification, and the gross and net gallons of propane loaded. In most cases, the amount of odorant injected will also be shown on the BOL. The results of any freeze valve tests are not included on the BOL but may be requested. Copies of the BOL or loading ticket are sent with the carrier vehicle, and are typically sent to the purchasing customer and retained at the terminal and/or supplying company's home office.

The following good practices may help maintain product quality when shipping propane:

- The terminal operator should conduct dryness testing on propane whenever a change in sales tank line-up is made, based on facility management's requirements.
- At facilities where propane transport drivers do freeze valve dryness testing during propane loading, proper training and demonstration of acceptable testing techniques should be conducted. Pertinent vehicle/driver identification and freeze valve test result information should be routinely logged and proper action taken in the event propane fails the freeze valve test.
- At a minimum, periodic analysis for composition using gas chromatography (GC) or the 95 percent evaporated test, residue and oil stain, copper strip corrosion, and vapor pressure testing should be performed on propane that will be supplied to the loading rack. Testing often includes the 95 percent evaporated test, residue and oil stain, copper strip corrosion and vapor pressure test. If a propane sample is analyzed for composition using gas chromatography, the results and subsequent calculations are often used in place of the 95 percent evaporated test and the vapor pressure test. (See a detailed discussion on contaminant testing options in **Appendix A**.)
- Routine testing of propane that has been loaded into each individual truck or railcar may not be needed unless a problem is noted by an operator, driver, or customer. Although not required, some facilities may recommend additional testing.
- Some facilities are equipped with an automatic loading-pump shutdown feature on their odorant injection system, which shuts down propane loading in the event of an odorant injection malfunction. In addition, the operator or driver can perform a "sniff test" to confirm the presence of odorant in the propane.
- Replace product transfer-line caps tightly to prevent connector and hose contamination.
- Use hoses that are lined with proper materials.[7]

3.5.1 Transport Truck Loading

Transport trailers that have been to a repair shop for unscheduled service or pre-scheduled five-year hydrostatic testing should be hand wiped and purged with nitrogen to remove water vapor and oxygen prior to release and subsequent loading with propane. Also, the loading terminal (see **Figure 5**) should be advised that the trailer is coming from a repair shop for an initial load of propane. The carrier may need to remove any excess nitrogen pressure and pressurize the vessel with propane vapor before loading the transport truck with propane. Some terminal operators will add additional odorant to the first load of propane to passivate the internal walls of the transport tank and minimize the potential for odorant

[7] All hoses used for propane transfer are lined, but there are concerns that some lining materials may cause contamination.

fade in the propane. While not a requirement, the additional odorant should be noted on the bill of lading.

Figure 5. Propane Terminal Loading Rack and Transport Trucks

Many propane loading terminals are not attended on a 24-hour basis. For the most part, the transport truck driver is responsible for loading propane. Therefore, the transport trucking company must be responsible for ensuring the transport truck meets all DOT requirements for propane transportation. In most instances, the terminal operator completes product oversight testing on propane receipts, and these tests can include:

- Length of stain tube for moisture, ammonia, odorant, or hydrogen sulfide (H_2S)
- Lead acetate paper to test for presence of hydrogen sulfide (H_2S)
- Red litmus paper to test for ammonia
- Freeze valve test for dryness of propane
- Copper strip test for corrosive contaminants
- Reid vapor pressure test for vapor pressure
- 95 percent evaporated temperature test for volatile residue
- Oil stain observation for oily residue
- Residue on evaporation of 100 milliliters of propane to test for non-volatile residue
- Gas chromatography to measure fuel composition, odorant concentration, and the presence of other chemical species

The level and frequency of testing will depend on the types of deliveries into a terminal (pipeline, common carrier truck, ship, barge, railcar), the methods used to store the propane (above ground vessels, refrigerated storage, caverns), other equipment and processes specific to the terminal (type of dehydration equipment, if any, other products handled in the terminal, and the degree of product isolation), and the contractual product specifications required by the customer.

3.5.2 Rail Car Loading

Rail cars that have been to a repair shop for unscheduled tank repairs, cleaning, or pre-scheduled five-year hydrostatic testing should be hand wiped and purged with nitrogen to remove water vapor and oxygen prior to release and subsequent loading with propane. The amount of purging required at the repair shop is dependent upon reaching an oxygen content of less than 2 percent, and a moisture content of less than 1,000 ppm in air, so that when the tank is filled with propane, the moisture content remains less than the maximum allowed. The receiving terminal should be advised that the railcar is coming from a repair shop. The terminal operator may need to remove any excess nitrogen pressure before loading the railcar with propane. Also, some terminal operators will double stench the first load of propane to minimize the potential for odorant fade in the propane. Although not required, the additional odorant should be noted on the bill of lading.

When a terminal operator receives a railcar, the terminal operator should perform an inspection of the rail car prior to loading. This inspection should include looking for expired dates, mechanical defects, leaking valves, and missing fittings to ensure the railcar can be loaded.

Once the railcar has been deemed fit to load, the terminal operator will estimate the volume to be loaded on the railcar to ensure leaving sufficient outage for liquid thermal expansion while the railcar is in transit. Product testing is performed by the terminal operator prior to loading, and these tests can include some or all of the following (same list as that used for transport truck loading discussed in preceding section):

- Length of stain tube for moisture, ammonia, odorant, or hydrogen sulfide (H_2S)
- Lead acetate paper to test for presence of hydrogen sulfide (H_2S)
- Red litmus paper to test for ammonia
- Freeze valve test for dryness of propane
- Copper strip test for corrosive contaminants
- Reid vapor pressure test for vapor pressure
- 95 percent evaporated temperature test for volatile residue
- Oil stain observation for oily residue
- Residue on evaporation of 100 milliliters of propane to test for non-volatile residue
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The level and frequency of testing will depend on the types of deliveries into a terminal (pipeline, common carrier truck, ship, barge, railcar), the methods used to store the propane (above ground vessels, caverns), other equipment and processes specific to the terminal (dehydration equipment, if any, other products handled in the terminal, and the degree of product isolation), and the contractual product specifications required by the customer.

3.6 Propane Sampling and Testing for Quality Assurance

In the United States, refineries and gas plants generally comply with the sampling and testing requirements of GPA Standard 2140 for HD-5 Grade Propane, and ASTM D 1835 – Standard Specification for Liquefied Petroleum (LP) Gases for Special-Duty Propane (these are equivalent standards). However, some refineries in certain areas of the country comply with the GPA and ASTM

specifications for Commercial Propane, and some may comply with what is commonly called the "California HD-10" specification (California Code of Regulations Title 13, Motor Vehicles, Section 2292.6, "Specifications for Liquefied Petroleum Gas"). The propane production stream in the operating units of refineries and gas plants is commonly sampled and tested at regular intervals, typically one or two test series per eight-hour shift. Some of the more time-consuming tests, such as total sulfur analysis and laboratory gas chromatography, may be run once or twice per week. However, in some plants composition and moisture analyses may be performed on a continuous basis. The propane in final storage is usually sampled and tested again prior to or during delivery to pipelines, trucks, railcars, ships, and barges.

Propane terminals that receive product only directly from refineries and gas plants typically sample and test the propane product on a more limited basis (oversight testing), due to the propane having already been fully tested by the supplying refinery or gas plant and, in some cases, due to limited manpower and testing equipment at some propane terminals. The tests that are typically run on propane received by propane terminals are as follows:

- 95% evaporated temperature (ASTM D 1837) for volatile residue
- Residue on evaporation of 100 milliliters (ASTM D 2158) for non-volatile residue
- Oil stain observation (ASTM D 2158) for oily residue
- Copper strip corrosion (ASTM D 1838) for corrosive contaminants
- Freeze valve test (ASTM D 2713) for dryness

Larger terminals with additional laboratory resources often perform testing beyond those listed above.

4. Bulk Plant Storage and Customer Delivery

The bulk plant is a key segment in the propane distribution system. Collectively, bulk plants account for the greatest number of personnel, trucks, tanks, and piping systems within the propane industry. At a typical bulk plant, liquid propane is received in tanker trucks, railcars, and/or barges from large terminals, gas plants, or refineries. Bulk plants typically have storage capacities in the range of 10,000 to 100,000 gallons. There are approximately 13,500[8] bulk plants in the United States with at least one storage tank. These bulk plants deliver propane to thousands of wholesale and retail customers.

Bulk plants generally represent the interface with the end-user. If a propane customer suspects a propane quality problem, the customer generally contacts the bulk plant. For many propane customers, the bulk plant operation is the only segment of the propane industry that they see. For many customers, their knowledge of propane comes from the information they receive from delivery truck drivers or bill stuffers included with mailings from bulk plants.

4.1 Bulk Storage Tank and Piping System

Bulk plants typically have one to five storage tanks with individual tank capacities of 10,000 to 30,000 gallons. Propane quality can be affected during routine operation or maintenance of existing storage tanks or during the commissioning of new tanks.

4.1.1 Operations

A major source of potential contamination is open flexible hoses that can allow water or solid debris to enter storage tanks. Water in a carbon steel tank or black iron piping system causes rust, and rust can cause odor fade or create rust particles that can plug regulators or burners. Flexible hoses with metal end fittings are used during unloading of tanker trailers and rail cars into bulk storage tanks as well as when filling bobtail trucks that are used to deliver propane to distributors and end-users. Good practices that help keep connecting hoses free of contamination include:

- Placing plastic screw-on caps at the hose ends whenever they are not in use.
- Using racks that keep the hoses off the ground.
- Covering the ground with concrete or crushed rock to eliminate dust and dirt from the immediate vicinity of the hose ends.
- Use hoses that are lined with suitable materials.[9]

4.1.2 Maintenance

The bulk storage tank and piping system maintenance can have undesirable effects on propane quality if not properly maintained. Maintenance items that are good practices include:

- Regularly cleaning strainers in piping systems to ensure that any solid particles that pass through piping systems are collected and removed. By installing a 1/2” ball valve in the plugged fitting on the strainer, it can then be blown-down with high-pressure propane periodically to remove any accumulation of solid debris. At the same time, the integrity of the strainers can be checked, and if needed, replaced. Deteriorating strainers can themselves

[8] Facts About Propane – America’s Exceptional Energy, NPGA #3026, April 10, 2001.
[9] All hoses used for propane transfer are lined, but research shows some lining materials cause contamination.

be a source of contamination and should be thoroughly inspected at least annually or whenever the propane flow appears to be impaired. A thorough inspection involves removing the strainer from the housing, cleaning the strainer, and inspecting for holes.

- Hoses at bulk plants should be given a brief examination every time they are used and thoroughly inspected monthly. Regular inspection of hoses for deterioration reveals if hoses have begun to break down, which can result in a safety hazard and a source of contamination if hose material flakes off and enters the propane system.

- Hoses at bulk plants should be inspected in accordance with the requirements of NFPA 58. Replacing hoses after they have been in service for a period of time – whether or not they show visible signs of deterioration – is a good practice that can prevent unwanted propane contamination. To implement this practice, bulk plant operators need to make sure all hoses have labels clearly stating the date when the hoses were placed in service.

> **Note:** Flexible hoses commonly used in propane distribution have been identified as possibly having detrimental effects on propane quality by potentially leaching hose materials into the propane. Studies are in progress to assess any possible effects that flexible hoses have on propane quality and possible methods to mitigate any problems that are identified.

4.1.3 New Equipment Design, Construction, and Installation

The design, construction, and commissioning of bulk plant tanks and piping systems is an important consideration. Bulk plants often operate for an extended time with few changes, and the bulk plant systems must function properly to avoid propane contamination. There are several aspects of the design, construction, and commissioning of new equipment that can affect propane quality and these include:

- All bulk plant rigid piping and storage tank systems need strainers, filters, or some other means installed to collect and remove solid contaminants before propane leaves the bulk plant.

- Bulk plants need to use only materials that are acceptable for propane service. In general, materials that comply with NFPA 58 Liquefied Petroleum Gas Code are acceptable.

- During construction, care should be taken to ensure that foreign material, such as dirt, scale, and oil from pipes, fittings, and components, is kept from the system prior to assembly. Also during construction it is important to prevent excess joint sealing material such as pipe dope or Teflon tape from contaminating the piping system and eventually getting into the propane.

- When construction is complete, prior to commissioning, it is important to clean out any welding and cutting slag from the piping assembly. One approach is to pump 200 gallons of propane at a high rate through the piping assembly and then through a portable 80-mesh strainer, and finally into a propane storage tank to be used exclusively for vapor service.

- When a storage tank is being installed for service, the tank must be purged if it was opened to air or was used to store any gas or liquid other than propane. Supplemental odorant may also be required to passivate the tank walls and minimize odor fade.

- Tanks that are taken out of bulk plant storage service may have contaminants such as rust, water, methanol, heavy ends and debris in them, and these tanks should be checked, and if necessary, cleaned and purged before being reused. Material removed from tanks that have been in service may be hazardous, and should be disposed of properly.

- When a storage tank is entering new service, whether the tank itself is new or used, the tank and associated piping needs to be checked by the supplier or installer prior to commissioning, to ensure that all foreign material has been cleaned from the interior of the tank. The foreign material may include rust, mill scale from manufacturing, or any accumulation of heavy-ends left from previous use. When propane tanks are opened for internal inspection, or to have other work carried out, the vessel needs to be cleaned to remove dust or other material that may accumulate on inside surfaces of the vessel.

4.2 Bobtail Delivery Truck

The bobtail delivery truck (**Figure 6**) is the last link in the distribution of propane from its source to the end-use customer. Any propane quality problems that originated upstream will likely be passed to the propane in the bobtail truck and then on to the end-use customer. However, there are aspects of quality that are under the control of the bobtail truck driver; specifically the liquid loading procedures at the bulk tank and unloading procedures at the customer's site.

Figure 6. Bobtail Delivery Truck

4.2.1 Operations

Similar to the loading or unloading of large tanker trucks, a source of contamination for bobtail tank trucks is the potential for getting water or debris into the open ends of flexible hoses. Standard practices that help keep connecting hoses free of contamination include:

- Placing plastic screw-on caps at the hose ends whenever they are not in use.
- Using hose racks on the truck that keep the hoses off the ground when delivering propane at a customer site.
- Covering the ground with concrete or crushed rock to eliminate dust and dirt from the immediate vicinity of the hose ends at the bulk plant.
- At the delivery site, the bobtail driver faces many of the same possibilities for contamination as during loading. However, the conditions during filling and the position of the customer tank can vary widely. The hose nozzle is especially susceptible to dirt and water when

reeling the hose back to the bobtail. A recommended good practice is to screw a plastic cap on to the hose nozzle to protect it from contamination before reeling the hose back. It is also important that the plastic end caps are not cracked.

4.2.2 Maintenance

The bobtail truck tank and piping system maintenance can have an important effect on propane quality. Maintenance practices that help maintain propane quality include:

- Regular cleaning of strainers in piping systems to remove solid particles that may have been collected. At the time strainers are cleaned, the integrity of the strainers should be checked. Strainers can deteriorate or plug and thus become ineffective. Each strainer in a bobtail truck tank should be removed from its housing, cleaned and inspected for holes and plugging annually. Likewise, each strainer in a bobtail truck tank should be cleaned and inspected for holes when the tank is hydro-tested.
- Placing a magnet at the tank outlet before the pump and in the meter strainer to collect steel fragments.
- Giving hoses a brief examination every time they are used, and examined thoroughly every month in accordance with the requirements set forth by the U.S. Department of Transportation (DOT) in HM-225A. Regular inspection of hoses should reveal deterioration that could lead to hose fragments entering the propane system or other hose breakdowns that may pose a safety hazard.
- Replacing hoses after they have been in service for a pre-determined length of time – whether or not they show any signs of deterioration – can prevent unwanted propane quality problems. To institute a hose replacement practice requires that all hoses have labels stating when they were placed in service, which is required by DOT HM-225A.
- Using hoses that are lined with suitable materials.[10]

4.2.3 New Equipment Design, Construction, and Installation

As with any propane piping, storage, or delivery system, the design, construction, and commissioning of bobtail propane delivery trucks can have an effect on propane product quality. Manufacturers of bobtail trucks should have careful housekeeping and cleanup practices to eliminate possible contaminants. Most bulk plant operators rely on the bobtail truck supplier to deliver a well designed unit with a clean tank and piping. If a used bobtail truck is purchased, the operator needs to be assured that the piping system and tank are clean before placing the truck in service. To be confident of the bobtail's cleanliness, one approach is to flush the bobtail with 200 gallons of propane. The propane should be pumped at a high rate through the bobtail truck (tank and piping), then through a portable 80-mesh strainer, and finally into a storage tank to be used exclusively for vapor service.

4.3 The Customer Storage Tank, Piping System, and End-Use Equipment

Propane quality problems are typically reported by the end-use customer, even though the source of the problem could have occurred anywhere in the propane supply chain – including the customer's storage tank, service piping, or end-use equipment (burner tip or engine).

[10] All hoses used for propane transfer are lined, but research shows some lining materials cause contamination.

4.3.1 Storage Tanks

The customer's storage tank can be a source of propane contamination and is not always under the control of the bulk plant that is delivering propane to the storage tank. Some customers own their tanks, which may have been purchased new or from a previous owner. Recommended good practices include:

- New customer tanks are generally shipped from the manufacturer with the air evacuated (vacuum sealed) and plastic shrink-wrap around the valves. It is a good practice to leave the plastic shrink-wrap in place until the tank is ready to be filled and the hose has been connected. This practice will reduce the possibility of inadvertently admitting air or water vapor into the new tank.
- If new tanks are delivered pressurized, it is a good practice to leave the tanks pressurized until just before being placed in service. At that time, the tanks should be de-pressurized and re-pressurized five times to purge any air or other non-propane gases.[11]
- Assure that a tank is purged of air and other non-propane gases if it is new or has been open to the atmosphere.
- Tanks may be delivered from the manufacturer containing moisture. The water should be removed, and it may be necessary to add supplemental odorant to passivate the tank walls and reduce the possibility of odor fade.
- When a customer's storage tank is filled for the first time, the driver should be alert to the possibility of contaminants in the tank. This may be accomplished by checking appropriate documentation, talking directly with the personnel who installed the tank, or by inspecting the tank.
- Tanks that are taken out of customer storage service, or used tanks entering customer storage, may have contaminants such as rust, water, methanol, heavy ends and debris in them, and should be checked, and if necessary, cleaned before being returned to service. The material removed may be hazardous, and should be properly disposed.
- If a service valve is taken out of a tank in the yard for repair or replacement, insert a plug or replacement valve or cover the fitting immediately. Waiting until there is time to complete the work may be too late because it may rain or other contaminants may get into the tank.
- A fixed liquid level gauge (80 percent valve) is frequently used to depressurize a tank, and once the pressure is relieved, the valve is frequently left open. By leaving the valve open, the tank is exposed to the atmosphere and moisture can get into the tank. Thus, it is a good practice to double check that all valves have been closed after depressurizing a tank.

4.3.2 Propane Deliveries

It is the responsibility of the propane distributor to use reasonable care in providing acceptable quality propane to the customer's tank. Quality issues that should be addressed by bobtail delivery truck drivers include:

- Visually inspect customer tanks and associated piping prior to every filling, specifically looking for:

[11] This publication does not cover fugitive emissions. However, when purging tanks, operators must take care to comply with prevailing emissions regulations for propane.

- Leaks
- Modifications to the tank
- Damage to the tank
- Anything unusual
- The belly of the tank to not be touching the ground, which can cause rust

- Keep dirt and water from tank connections by ensuring that the fill connections are always covered with a plastic cap when not in use.

- Be aware of changes in the storage tank and piping that might indicate a possible quality problem related to system modifications. Signs of potential problems include a different tank location, piping that has been changed, or indications of major construction activity at the site.

- Listen to customers to find out if there are any problems or concerns related to propane quality.

4.3.3 Piping Systems and End-Use Equipment

Besides the customer's storage tank, contamination to propane at the customer's site can occur from the piping, regulators, valves, and end-use equipment. Issues that distributors should consider when confronting these contamination problems include:

- In order to fully investigate possible problems with propane quality, the distributor needs to have service technicians available (in house or by independent contractor) and capable of understanding and working on the customer piping and end-use equipment.

> **Note:** Black iron pipe is the most common material used for propane systems. In recent years, polyethylene (PE) pipe has become common, particularly for low pressure (less than 30 psig) underground vapor service applications. PE has excellent corrosion resistance properties and is not subject to rust, which can occur with black iron. In addition, compared to black iron, PE pipe is manufactured without any oil coatings and no paint is applied to prevent corrosion. Therefore, in low pressure vapor applications, PE is a good choice that results in a clean piping system that presents minimal risks for contamination from the pipe material. Use only PE pipe rated for hydrocarbon service.

- End-use equipment that is not operating properly can indicate a problem with propane quality and can also indicate a problem with equipment maintenance or operating procedures that is not related to propane quality.

- Keeping new regulators and other parts sealed in original boxes keeps foreign material out of system components.

- Keeping a minimum of parts and using good storage methods in service vehicles minimizes damage and deterioration. Another good quality practice is to keep coils of copper tubing and hose ends capped to avoid contamination.

- Some end-use equipment is more sensitive to propane contaminants. Examples of sensitive equipment include internal combustion engines and other systems where heated external vaporizers are used to produce propane vapor.

> **Note:** Like black iron pipe, galvanized (hot dipped zinc coated) pipe is approved for use in propane systems (NFPA 58). There are concerns that the galvanized coating may flake off and block small orifices, regulators, or burner tips. However, galvanized pipe has been used in the propane industry for many years with no unusual reports or problems attributed to the galvanized piping.

- When setting a tank for a construction heater or similar system, it is a good practice to use a first stage regulator located near the tank that is set at 10 to 30 psig. It has been found that if high pressure vapor is allowed to sit in long flexible hoses and re-condenses during cold weather, an unusually large amount of oily residue can be carried over to the burner regulator, orifices, and piping. A small amount of oily residue is usually not a problem. However, large amounts of oily residue can cause problems with regulators and burners.
- Use a sediment trap downstream of vapor regulators to catch oil and heavy-ends. A sediment trap is used on some appliances as required in NFPA 54 (Section 8.5.7, 2002).

4.3.4 Quality Oversight

It is important for propane distributors to maintain proper propane quality oversight, including:

- Fully investigating customer questions about propane quality and poorly operating end-use equipment. Do not dismiss the customer as a one-time exception or a complainer.
- Keeping records of propane quality complaints, investigations, and the results of those investigations so that patterns can be noted and actions taken to solve recurring quality problems.
- Maintaining regular communication with other distributors and the greater propane industry to learn about other quality problems, responses to those problems, and ongoing research that is aimed at solving industry-wide problems.
- Keeping detailed records of all propane received including the source, the transporter, the driver, in addition to the quantity and all relevant information relating to quality.

4.4 Bulk Plant Personnel Training

The training of a propane distributor's personnel plays a crucial role in maintaining propane quality throughout bulk plant operations. Training can be a key factor in responding in a positive way to customers who have valid issues with propane quality. Training can have a positive impact on personnel attitudes toward propane quality, and can provide personnel with examples of how actions can affect propane quality – in a negative or positive way. Personnel training related to propane quality can include the following items:

- An explanation of the company policy towards propane quality. To maintain a high quality product everyone in the organization needs to be aware of the importance of ensuring propane quality.
- Hold regular product quality meetings where employees discuss propane quality issues, develop solutions, and ask questions. Report concrete examples of propane quality problems from within the organization or from the industry.

The following types of personnel training at bulk plants can help maintain or improve quality:

- Quality practices for liquid transfer by personnel in bulk plant operations.
- Housekeeping at bulk plants – for the sake of propane quality.
- Quality considerations in bobtail deliveries.
- What to look for at customer sites that may cause problems in propane quality.
- Recommendations for preventing contamination of propane at bulk plants.

- Quality procedures for filling cylinders.
- Quality issues to be addressed when new equipment is installed at bulk plants.
- Quality issues when using propane as an engine fuel.
- Procedures for responding to a customer who claims to have a problem with the quality of their propane.
- Training drivers, service personnel and every person answering the telephone to be aware of and carefully listen for possible issues of propane quality.
- Procedures for investigating a possible problem with propane quality.

5. Summary

Several propane quality problems have been evaluated in this report, and a summary of common contaminants is listed in **Table 2** (each contaminant is discussed in more detail in **Appendix A**). This table provides an overview of possible problems and the possible sources for these contaminants.

Table 2. Summary of Propane Quality Issues

Contaminant	Problem	Possible Source
Water	Causes rust on surfaces of storage tanks and piping systems. Rust can result in odor fade, reduces life of system components. Rust particles can block small openings. In cold weather or during pressure reduction operations, water can freeze, leading to impaired operation (or damage) of valves, pumps, piping, and regulators.	Water sources include propane processing, pipelines, tank trucks and railcars, open hose ends, filling a tank during rain or snow, hydrostatic testing, and leaving a tank open to the atmosphere.
Oil residues and heavy ends	Operational problems with end-use equipment and inability to meet emissions standards. May lead to the production of carbon monoxide.	Oily residue sources include propane handling, pipelines, pumps, compressors, piping systems, flexible hoses, and pumping out (emptying) older, in-use vapor tanks.
Solid particulates	Operational problems with end-use equipment. May lead to the production of carbon monoxide.	Debris (dirt, dust, rust, welding slag, Teflon tape, or liquid-thread sealants) occurs during construction and manufacturing of equipment and through unprotected hose ends.
Air and nitrogen	Operational problems with end-use equipment (improper fuel-air ratio, poor or no combustion). May lead to the production of carbon monoxide.	Nitrogen is used to prevent corrosion in empty tanks or piping systems. Nitrogen is also used to purge railcars of oxygen at a tank car repair shop. Air is introduced when a system is opened to the atmosphere.
Ammonia	Failure of brass fittings through stress corrosion cracking.	Anhydrous ammonia and propane may be stored or transported in the same equipment, and if not cleaned properly, the propane will be contaminated.
High sulfur (S or H_2S) and other corrosive species	Corrosion and failure of copper containing materials.	Improper propane processing and un-inspected secondhand bulk storage tanks. Excessive odorant.
High butane content[12]	Inadequate vaporization in cold weather.	Inadequate propane processing, pipelines and terminal handling, rail car and transport service changes.
High propylene content[13]	Increased emission production and inability to meet air quality standards.	Inadequate propane processing, pipeline, and terminal handling.

[12] Butane is an acceptable component of propane. However, in high concentrations, butane can be regarded as a contaminant because the fuel will not perform as expected.
[13] Like butane, propylene, is an acceptable component of propane, but can be regarded as a contaminant in high concentrations.

In this report, good practices have been identified that address the contaminants listed in **Table 2**. These good practices, and several other recommendations for maintaining propane quality, have been discussed, and can be summarized as follows:

Good practices for production, pipelines, and terminals

- Proper valve line-up to terminal propane storage to ensure that the propane being received is routed to the correct terminal storage without cross-contamination by other products.
- Proper sampling, testing, frequency of testing, and interpretation of results from propane tests.
- Proper action plan followed if an off-spec test result occurs.
- Careful timing when routing pipeline propane into terminal storage on batch systems to avoid possible interface contamination.
- Close coordination with the pipeline scheduler/controller throughout the receipt operation.
- Qualified terminal personnel should make regularly scheduled checks on the odorant injection system to ensure proper operation of odorant storage, transfer, and metering equipment.
- Terminal operator should do freeze valve dryness testing on propane prior to methanol injection whenever a change in sales tank line-up is made, based on facility management's requirements.
- At facilities where propane transport drivers are required to do freeze valve dryness testing during propane loading, proper training and demonstration of acceptable testing techniques should be conducted. Pertinent vehicle/driver identification and freeze valve test result information should be routinely logged and proper action taken in the event of a failed test.
- Periodic copper strip testing and analysis for composition using gas chromatography, or 95% evaporated test and vapor pressure testing should be performed on propane that is being supplied to the loading rack.
- The routine testing of propane that has been loaded into each individual truck or railcar is not usually needed unless a problem is noted by an operator, driver, or customer. Although not required, some facilities may recommend additional testing.
- Some facilities are equipped with an automatic loading pump-shutdown feature on odorant injection systems, which shuts down propane loading in the event of an odorant injection malfunction. In addition, the operator or driver can perform a "sniff test" to confirm there is odorant present in the propane.
- Replace product transfer-line caps tightly to prevent connector and hose contamination.
- Propane terminals will typically run the following tests as propane is received into the terminal (larger terminals with additional laboratory resources often perform testing beyond those listed below):
  - 95% Evaporated Temperature (ASTM D 1837) – for volatile residue
  - Residue on Evaporation of 100 ml (ASTM D 2158) – for non-volatile residue
  - Oil Stain Observation (ASTM D 2158) – for oily residue
  - Copper Strip Corrosion (ASTM D 1838) – for corrosive contaminants
  - Freeze Valve Test (ASTM D 2713) – for dryness

Good practices for bulk plants

- Using caps to keep water and dirt out of hose ends where liquid is transferred from tanker trucks to bulk storage tanks.
- Design system piping to prevent debris from contaminating the system using strainers or other means.
- Keeping all propane piping systems sealed from contamination of air, water, dust and debris.
- Ensuring that new construction piping at the bulk plant or customer site has been thoroughly cleaned prior to introducing propane for the first time.
- Making every effort to keep rain and snow out of tank service valves.
- Preventing moisture from entering empty tanks by keeping them pressurized.
- Purging new tanks of non-propane vapor by following documented good practice procedures.
- Perform independent routine field tests that help determine the presence of contaminants such as moisture, oil residue, and ammonia before the propane is received into bulk storage. Document any tests that are run. If contamination is indicated by a field test, immediately stop the transfer, isolate the bulk tank, and contact the propane supplier to arrange confirmation testing. Copper strips and stain tubes can be purchased commercially.
- Be alert to signs of contaminants, including solid particles, moisture, and heavy-ends that may be in the customer tanks.
- If a customer vapor-service tank is pumped out in preparation for moving or cleaning, the material pumped out should be checked for contamination (heavy-ends) and if found, undergo proper disposal. The material should not be transferred to a bulk storage or delivery tank for future sale.
- Respecting the customer by carefully investigating complaints about propane quality.

The good practices discussed in this report are intended to help custodians of propane in the supply chain maintain quality. These good practices can benefit the entire propane industry. By providing customers with a consistent fuel free of contaminants, the propane industry can expect increased opportunities to capture market share in existing markets and lower barriers for entering new markets.

Resources

This section includes a representative (not all inclusive) list of publications related to propane quality that are publicly available. Resources no longer in print or not publicly available are not included.

ASTM DS 4B, "Physical Constants of Hydrocarbon and Non-Hydrocarbon Compounds"

ASTM D 1265, “Practice for Sampling Liquefied Petroleum (LP) Gases (Manual Method)”

ASTM D 1267, “Test Method for Gage Vapor Pressure of Liquefied Petroleum (LP) Gases (LP-Gas Method)”

ASTM D 1657, “Test Method for Density or Relative Density of Light Hydrocarbons by Pressure Hydrometer”

ASTM D 1835-03a, “Standard Specifications for Liquefied Petroleum (LP) Gases”

ASTM D 1837, “Test Method for Volatility of Liquefied Petroleum (LP) Gases”

ASTM D 1838, “Test Method for Copper Strip Corrosion by Liquefied Petroleum (LP) Gases

ASTM D 2158, “Test Method for Residues in Liquefied Petroleum (LP) Gases”

ASTM D 2163, “Test Method for Analysis of Liquefied Petroleum (LP) Gases and Propane Concentrates by Gas Chromatography”

ASTM D 2420, “Test Method for Hydrogen Sulfide in Liquefied Petroleum (LP) Gases (Lead Acetate Method”

ASTM D 2598, “Practice for Calculation of Certain Physical Properties of Liquefied Petroleum (LP) Gases for Compositional Analysis”

ASTM D 2713, “Test Method for Dryness of Propane (Valve Freeze Method)”

ASTM D 2784, “Test Method for Sulfur in Liquefied Petroleum Gases (Oxy-Hydrogen Burner)”

ASTM D 3700, “Practice for Obtaining LPG Samples Using a Floating Piston Cylinder”

ASTM D 6667, “Test Method for Determination of Total Sulfur in Gaseous Hydrocarbons and Liquefied Petroleum Gases by Ultraviolet Fluorescence”

Australian Liquefied Petroleum Gas Association, “Draft LP Gas Supply Chain Guidelines,” December 2001

California Code of Regulations (CCR) Title 13, Motor Vehicles, Sec. 2292.6, “Specification for Liquefied Petroleum Gas”

Gas Processors Association (GPA) Standard 2140, “Liquefied Petroleum Gas Specifications and Test Methods”

NFPA 58, “Liquefied Petroleum Gas Code,” 2004

NFPA 54, “National Fuel Gas Code,” 2002

NPGA, "Propane Safety and Technical Support Manual," NPGA #0001

NPGA, “Facts About Propane – America’s Exceptional Energy,” NPGA #3026

PERC, "Certified Employee Training Program," PERC Resource Catalog

PERC, “Basic Principles and Practices (1.0)”

Appendix A. Contaminants

There are a number of potential contaminants in propane that when present in sufficient quantities have been shown to cause problems. This appendix provides a brief overview of just a few common contaminants, including:

- Water
- Oil residues and heavy hydrocarbons
- Solid particulates
- Air and nitrogen
- Ammonia
- High butane, propylene, sulfur, hydrogen sulfide, or sodium hydroxide content

For each contaminant, the following topics are covered:

- Description – describes the characteristics of the contaminant
- Source – identifies likely sources of the contaminant
- Potential Problems – explains possible problems caused by the contaminant
- Testing Methods – laboratory and field methods of testing for the contaminant
- Prevention – discusses how to prevent the contaminant from entering the propane distribution system

Water

Description: Free and dissolved water.

Source: Water can contaminate propane at several points in the supply chain. Examples include transportation or storage tanks that have been open to the atmosphere or steam cleaned, open hose ends, filling uncovered tanks in the rain or snow, or valves exposed to weather.

Potential Problems: Moisture in propane at a level of approximately 26 ppm or more may cause freeze-up problems in tanks, valves, pumps and piping during cold weather or during pressure-reducing operations.

Testing Methods: The laboratory tests include Gas Processors Association (GPA) Propane Dryness Test (Cobalt Bromide) or ASTM D 2713-91 (Freeze Valve Test). The recommended field tests for moisture in propane are the Freeze Valve Test, the Needle Valve Freeze-up Test (as described in NPGA #T151, 1991, Suggested Field Tests for Contamination in Propane[14]), and the Stain Tube Test.

Prevention: The following steps may prevent or reduce the occurrence of water in propane:

- Eliminating water in propane at major terminals.
- Keeping propane piping systems and tanks that are not currently in use sealed and under pressure at all times.

[14] This NPGA guideline was last published in 2003.

- Checking all propane storage vessels prior to use to ensure that water is not present.
- Making sure that caps are used for filling hoses and service valves on tanks and transfer stations.

Oil Residues and Heavy Hydrocarbons

Description: This type of potential contamination can vary from very light oil to a very viscous tar-like substance. Sometimes it is a waxy material like paraffin, or it may be similar in consistency to axel grease. Sometimes it is transparent (no apparent color) while at other times it is light brown, dark brown, or even black. It usually has a strong odorant smell, as the ethyl mercaptan used as an odorant in propane appears to concentrate in the oily residues.

Source: The oils in propane can come from many sources; from processing, pipelines, pumps or compressors, piping systems, and flexible hoses. Heavy-ends usually appear when the liquid propane is vaporized for end-use applications. When external heat is used to vaporize propane, like in a propane powered vehicle vaporizer or industrial water-bath vaporizer, heavy-ends tend to deposit in greater volumes.

Potential Problems: Oils and heavy-end contaminants can cause operational problems with many types of end-use equipment, such as internal combustion engine fuel systems, microturbines, and fuel cells. Dissolved oils and heavy ends can also accumulate in vapor service tanks (customer tanks) and eventually cause an odor problem (oily smell) with propane heating and cooking appliances.

Testing Methods: The laboratory test is Residues in Liquefied Petroleum (LP) Gases (ASTM-2158). Field test methods include the Weathering Test (NPGA #151, 1991, Suggested Field Tests for Contamination in Propane[15]) and the Stain Tube Test for Oil Mist.

Prevention: The following steps may prevent or reduce the occurrence of oily residues and heavy-ends in propane:

- Investigate and develop processes and procedures to help identify and eliminate the sources of oil.
- Use filters in the propane liquid or vapor lines (such as a coalescing filter) to remove oil prior to the end-use equipment.
- Use inspection and remediation procedures to ensure that empty storage tanks and piping are free of oils and heavy-end contaminants before being filled with liquid propane.
- Use oil traps to collect and remove any oils downstream of all externally heated vaporizers.

Particulates

Description: Solid particulates cover a wide range of potential contamination such as dirt, dust, rust, welding slag, Teflon tape, or liquid thread sealants.

Source: The most obvious source for solid debris is during construction and manufacturing of propane equipment and systems. Another common source is from hose ends that are not protected from dirt, dust and sand through the use of end caps and hose racks. In forklift and other engine-fuel applications,

[15] Last publication was 2003.

oxides such as black powder can flake off from the steel.

Potential Problems: Solid particles can clog small openings in regulators and burner orifices which can lead to malfunctioning end-use equipment.

Testing Methods: Visual inspection of a propane sample that is allowed to evaporate under ambient conditions, or inspection of strainer, orifices, and regulators.

Prevention: The primary approach to prevent solid debris from contaminating propane is to clean all new or modified storage tanks and piping systems prior to introducing propane for the first time. Use of aluminum or composite cylinders will eliminate sources of rust particles. The use and frequent inspection of filters and screens can be helpful in protecting pumps, meters, regulators and other equipment in the propane distribution system.

Air and Nitrogen

Description: Any common non-condensable gas, such as air or nitrogen, that is found in propane storage tanks and piping systems.

Source: These non-condensable gases are usually found in storage tanks and piping systems that have been opened to the atmosphere during manufacturing, construction or during maintenance or refurbishment. Some new storage tanks and cylinders are filled at manufacturing plants with a dry, non-corrosive gas, such as nitrogen, to prevent corrosion. The storage vessels are kept sealed until they are put into service.

Potential Problems: Air and nitrogen can cause increased pressure in tanks being filled unless the air or nitrogen is vented-off during filling. Air and nitrogen can also cause improper fuel-air ratios and retard or prevent combustion of propane in vapor service end-use equipment. The oxygen in the air can also oxidize ethyl mercaptan odorant causing odor fade.

Testing Methods: Analysis of vapor sample composition by gas chromatography or a vapor pressure test.

Prevention: The standard method for eliminating air and nitrogen in tanks and piping systems is to follow well developed and documented purging methods, where propane vapor is used to flush out all traces of air and nitrogen prior to filling a tank or piping system with propane.

Ammonia

Description: Anhydrous ammonia is widely used as an agriculture fertilizer. As with propane, anhydrous ammonia is stored and transported as a pressurized liquid and used as a vapor.

Source: Anhydrous ammonia and propane are sometimes used in the same storage and transportation equipment, alternating on a seasonal basis. If ammonia equipment is switched to propane use and the storage tank or transport truck is not cleaned properly, ammonia contamination of the propane occurs.

Potential Problems: Ammonia contaminated propane can cause brass and bronze fittings to fail in a process known as “Stress Corrosion Cracking”. This failure may occur on the brass fittings of a propane storage tank or throughout a gas distribution system that has been contaminated with ammonia. If steam cleaning is used to clean tanks after being in ammonia service, water and rust may result unless all water is eliminated.

Testing Methods: An acceptable field test is the "Red Litmus Paper Test for Ammonia in LP-Gas" as described in NPGA #122, Recommendations for Preventing Ammonia Contamination of LP-Gas. An alternative test is the "Stain Tube Method" of testing.

Prevention: When switching from anhydrous ammonia to propane service, the storage tanks or transport trucks should be emptied and purged. The procedures include steam cleaning, water flooding or a combination of the two as outlined in NPGA #122, Recommendations for Preventing Ammonia Contamination of LP-Gas.

High Butane, Propylene, Sulfur, or Sodium Hydroxide Content

Description: Butane, propylene, sulfur, and sodium hydroxide are grouped together because they generally originate at the upstream end of the supply chain (e.g., gas fields, refineries, gas plants).

Source:

High Butane or Propylene: Commercial propane supplied throughout the United States frequently contains more than 90% propane, with the remainder being non-propane hydrocarbons, including, butanes or propylene. These non-propane hydrocarbons are all LP-gases, but they can be regarded as contaminants if levels become too high. ASTM specifications limit butanes and heavier components to 2.5 liquid volume percent for Commercial and Special-Duty Propane (same as HD-5).

Sulfur: Sulfur is contained in crude oil and raw natural gas that is recovered from oil and gas fields. ASTM specifications limit sulfur to 185 ppm for Commercial and 123 ppm for Special-Duty Propane (same as HD-5).

Sodium Hydroxide: Sodium hydroxide is used to treat propane in some processes and is a contaminant if it enters the propane stream.

Potential Problems: While butane is similar to propane in many respects, end-use equipment that is adjusted to operate on propane may not operate properly when using propane containing excessive amounts of butane. Butane has a lower vapor pressure than propane, and during cold weather butane does not vaporize as readily as propane, which can lead to conditions where butane-rich liquid accumulates in a storage tank or cylinder. Excessive propylene content can alter combustion characteristics and create high combustion emissions.

If the sulfur content is higher than the specified limit, it can lead to corrosion and failure of copper containing materials such as copper tubing and brass or bronze valves.

Sodium hydroxide can cause severe corrosion to steel surfaces in equipment and piping throughout the distribution chain and in end-use applications.

Testing Methods: The following tests may prevent or reduce the occurrence of these contaminants in propane:

- *High Butane or Propylene:* The laboratory tests for LP gas include analysis by gas chromatograph, testing for specific gravity (ASTM D 1267), the Reid Vapor Pressure (ASTM D 1267), and Volatile Residue Tests (ASTM D 1837 and D 2163). The field test is to compare the temperature of the propane liquid with the gauge pressure of the propane vapor,

using a pressure-temperature chart for propane. An extreme variance from the chart could indicate a product composition problem.

- *Sulfur:* The laboratory test for sulfur includes the Total Sulfur Test (ASTM D 2784) and the Test Method for Determination of Total Sulfur in Gaseous Hydrocarbons and Liquefied Petroleum Gases by Ultraviolet Fluorescence (ASTM D 6667). The field test for hydrogen sulfide includes the Lead Acetate Paper Test and the Copper Strip Test (NPGA #151, 1991, Suggested Field Tests for Contamination in Propane[16]), and the Stain Tube Test for Hydrogen Sulfide. The Copper Strip Test is one of the most practical and useful tests for detecting problems with propane. It is not to be confused with the various Stain Tube Tests.

- *Sodium Hydroxide:* Sodium hydroxide can be detected through laboratory analysis. Since sodium hydroxide is contained in a water solution, all of the problems associated with water contamination are also a concern when sodium hydroxide is detected.

Prevention: Prevention of these contaminants requires appropriate equipment, processes, and quality control procedures at the refineries and gas processing plants where propane is produced.

[16] Last publication was in 2003.