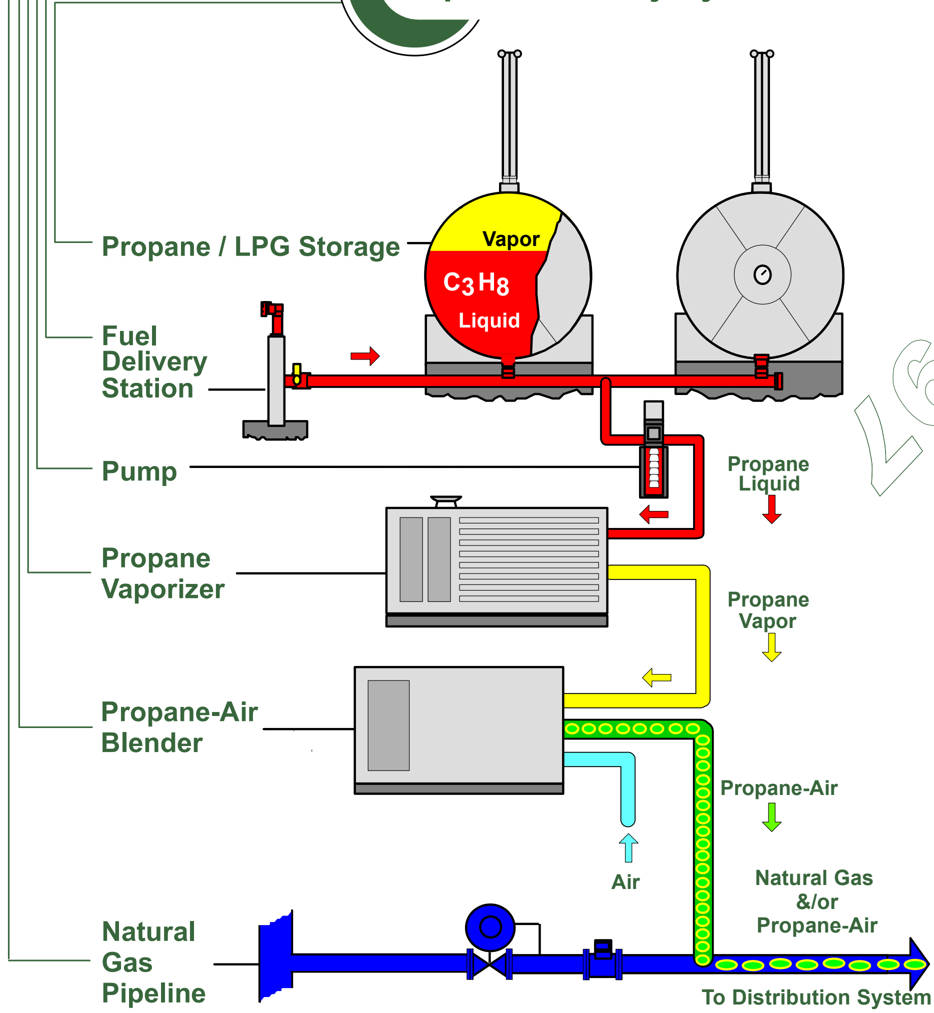
Propane Standby Systems ...an overview



Standby Systems inc.

...about Standby Systems, Inc.

Standby Systems, Inc. is a total resource for propane peak shaving and standby systems. We provide a full range of engineering, equipment, project management and customer support.

Since 1975, we've been serving needs of natural gas utilities and energy consumers, including:

- natural gas "city-gate" systems for heating, metering and control;
- industrial / commercial gas distribution systems, process burners and safety audits;
- SCADA and other control, communications, safety systems and software;
- metering for gas, electric, water and steam systems;
- training for operators, technicians and facility managers.

We hope you find ***Propane Standby Systems ...an overview*** informative.

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Propane Standby Systems ...an overview

Introduction

As the world transitions to a low-carbon energy future, demand for clean burning natural gas (composed primarily of *methane*) is rapidly growing as a better environmental choice than coal and most petroleum-derived fuels. In a global dynamic *gas-energy* marketplace, many gas utilities and consumers gain enhanced supply security and flexibility - while reducing energy costs - using propane **peak shaving** and **standby systems** to supplement natural gas deliveries. Most of these systems produce "propane-air" for direct replacement of natural gas during peak demand periods.

Glossary

LDC **L**ocal **D**istribution **C**ompany

LDCs operate natural gas distribution systems linking consumers & pipelines. LDCs may also provide gas storage & peaking services.

LNG **L**iquefied **N**atural **G**as

When cooled to about -260°F, methane becomes a liquid for storage or transport in insulated tanks, trucks and ships.

LPG **L**iquefied **P**etroleum **G**as

LPG or LP-gas refers to several gas liquids, including propane and butane.

NG **N**atural **G**as

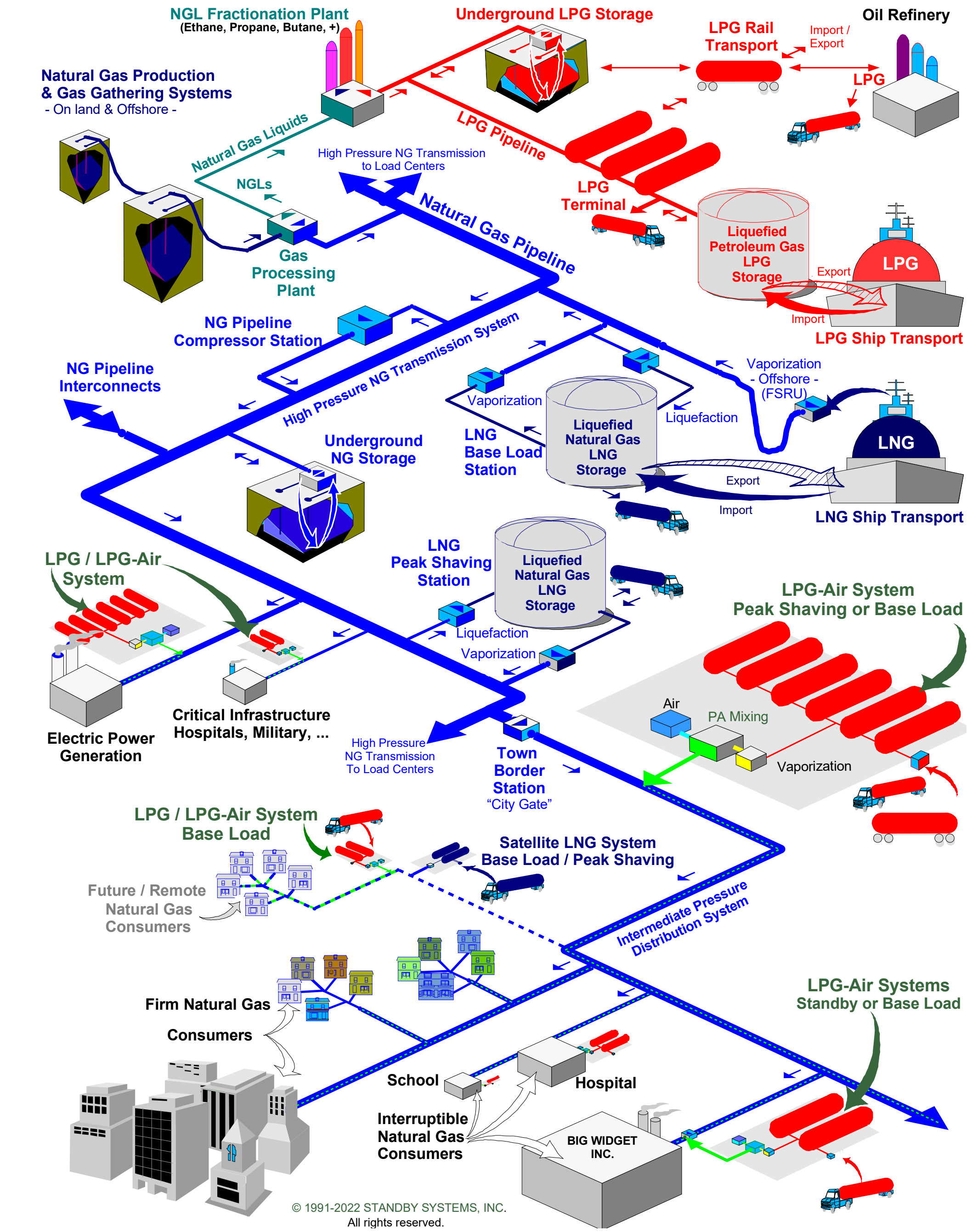
NG is a mixture of methane and various other hydrocarbons and inert gases.

NGLs **N**atural **G**as **L**iquids

NGLs are hydrocarbon components of natural gas other than methane, including ethane, propane and butane.

Propane is derived during both natural gas production and crude oil refining. Common trade names include LPG, LP-gas and HD-5 Propane.

North American Gas Energy Grid: Natural Gas and Propane (LPG)



What is SNG? ***Synthetic*** Natural Gas commonly refers to the output of 'coal gasification' plants or refinery and petrochemical process streams. SNG may also be used to indicate a mixture of propane or other LPGs and air. ***Substitute*** Natural Gas and ***Supplemental*** Natural Gas almost always refer to 'LPG-air' mixtures - and '**propane-air**' is the most common form.

Propane Standby Systems ...an overview

Propane Standby Systems ...an overview offers a brief look at consumer-owned standby systems, including general design considerations and equipment types.

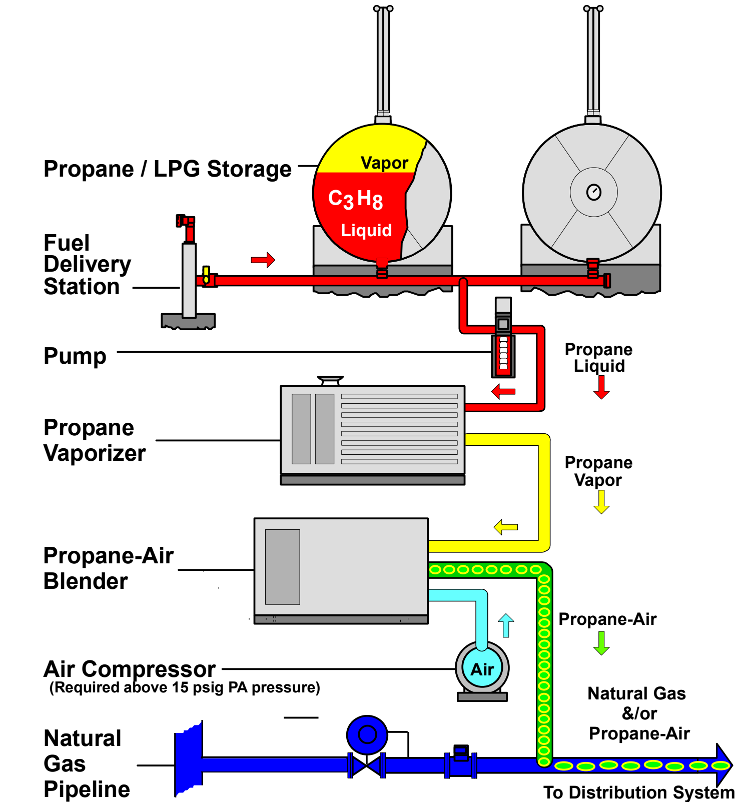
For further information, contact ***Standby Systems, Inc***.
Internet: **www.standby.com** Telephone: **612.721.4473** Email: **LPG@standby.com**

1 Propane Standby System Operation

Propane standby systems generally work as follows:

- Liquid is withdrawn from the storage tank and, if required, the pressure is raised via motor-driven pump.
- The liquid is heated in a vaporizer and converted to a super-heated vapor.
- Vaporized propane is sometimes piped directly to consuming appliances that are each equipped for dual-fuel (NG & LPG) firing. Most often, propane vapor is first diluted with air to produce a **"propane-air"** mix. Propane-air is then distributed via the natural-gas piping for use without changes to individual burners.

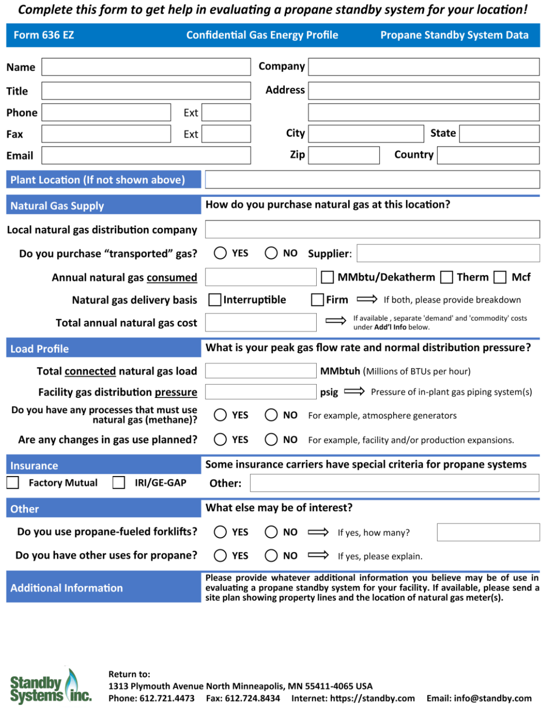
Typical Propane-Air System - Flow Diagram



2 Gas-Energy Profile

While not addressed here, the costs and terms of natural-gas supply for an individual consumer need to be understood. Of special interest are projected savings and flexibility associated with interruptible service, balancing requirements, storage options, etc. **Propane-system size and configuration** depend on several factors. These include:

*Use **Form 636EZ in Appendix** to get help with **your** standby system needs.*



Complete this form to get help in evaluating a propane standby system for your location!

Form 636 EZ | Confidential Gas Energy Profile | Propane Standby System Data

Name | Company
Title | Address
Phone | Ext
Fax | Ext | City | State
Email | Zip | Country

Plant Location (If not shown above)

Natural Gas Supply — How do you purchase natural gas at this location?
Local natural gas distribution company
Do you purchase "transported" gas? YES NO Supplier:
Annual natural gas consumed — MMbtu/Dekatherm | Therm | Mcf
Natural gas delivery basis — Interruptible | Firm ⟹ If both, please provide breakdown
Total annual natural gas cost ⟹ If available , separate 'demand' and 'commodity' costs under **Add'l Info** below.

Load Profile — What is your peak gas flow rate and normal distribution pressure?
Total connected natural gas load — MMbtuh (Millions of BTUs per hour)
Facility gas distribution pressure — psig ⟹ Pressure of in-plant gas piping system(s)
Do you have any processes that must use natural gas (methane)? YES NO For example, atmosphere generators
Are any changes in gas use planned? YES NO For example, facility and/or production expansions.

Insurance — Some insurance carriers have special criteria for propane systems
Factory Mutual | IRI/GE-GAP | Other:

Other — What else may be of interest?
Do you use propane-fueled forklifts? YES NO ⟹ If yes, how many?
Do you have other uses for propane? YES NO ⟹ If yes, please explain.

Additional Information — Please provide whatever additional information you believe may be of use in evaluating a propane standby system for your facility. If available, please send a site plan showing property lines and the location of natural gas meter(s).

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- **size of the connected gas-consuming load**,
  - maximum/minimum **instantaneous flow rates**
  - maximum **consumption** per **hour** and per **day**;
- **pressure** used for natural-gas distribution;
- **form of standby fuel** (undiluted propane, propane-air, or both) suited to the task;
- **special gas applications**, if any, requiring *methane* exclusively, such as atmosphere generators or CNG;
- **expected changes** in gas use (e.g., plant expansion);
- **insurance requirements**;
- **volume of propane storage needed** - depending on:
  - maximum consumption rate and "number of days" backup desired;
  - requirements, if any, of natural gas utility or other supplier;
  - available space and code or insurance constraints;
  - LP-gas sources and delivery vehicle size.

Other uses for propane - such as forklifts or vehicle fleets - should be evaluated to determine propane supply requirements and system hardware.

3 System Layout

A variety of codes and technical standards (*See 12, Standards)* may affect the configuration and construction of a specific propane system. The type of vaporizer and gas-air mixer selected can also affect the basic layout, as can other activities at the site.

NFPA 58

In the U.S., the National Fire Protection Association publication NFPA 58, *Liquefied Petroleum Gas Code*, represents a common minimum standard for commercial and industrial LP-gas installations. (Note: NFPA 59 addresses *LP-Gases at Utility Gas Plants.*) (See also: *12, Standards*.)

Minimum Distances

Minimum distances are required between LPG systems and various exposures.

For storage containers (tanks), minimum separations are needed from other tanks, important buildings, adjoining property which may be built upon (See e.g., *NFPA 58, Table 6.4.1*) and from other exposures.

NFPA 58 Table 6.4.1.1 (Partial Data, 2020 Ed.)

Water Capacity per Container (Gallons)	Minimum Distances Between Containers, Important Buildings and Other Properties feet (meters): Mounded or Underground Containers	Aboveground Containers
501 to 2,000	**10** (3)	**25** (7.6)
2,001 to 30,000	**50** (15)	**50** (15)
30,001 to 70,000	**50** (15)	**75** (23)
70,001 to 90,000	**50** (15)	**100** (30)
90,001 to 120,000	**50** (15)	**125** (38)
120,001 to 200,000	**50** (15)	**200** (61)
200,001 to 1,000,000	**50** (15)	**300** (91)
>1,000,000	**50** (15)	**400** (122)

Propane vaporizers and most fuel transfer stations (truck or rail delivery) also require separation from each other and from other exposures, including storage tanks, buildings and property lines.

Third-Party Review

Review of a proposed LPG facility by state and local agencies is often required. Guidelines have also been developed by property and liability insurers.

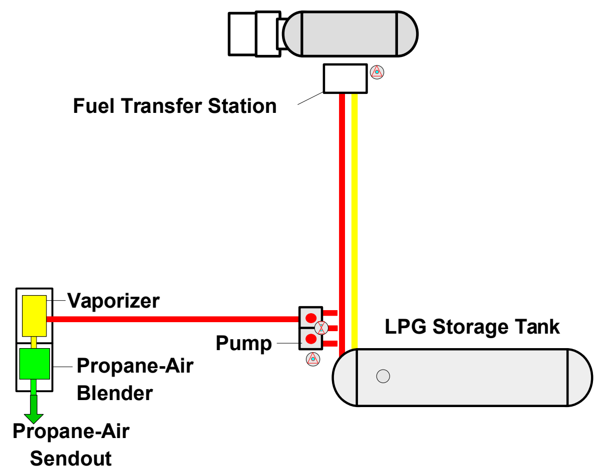
Other Propane Uses

If other uses of propane are likely at a site (e.g., forklift or vehicle fuel), requirements should be evaluated in initial plant design.

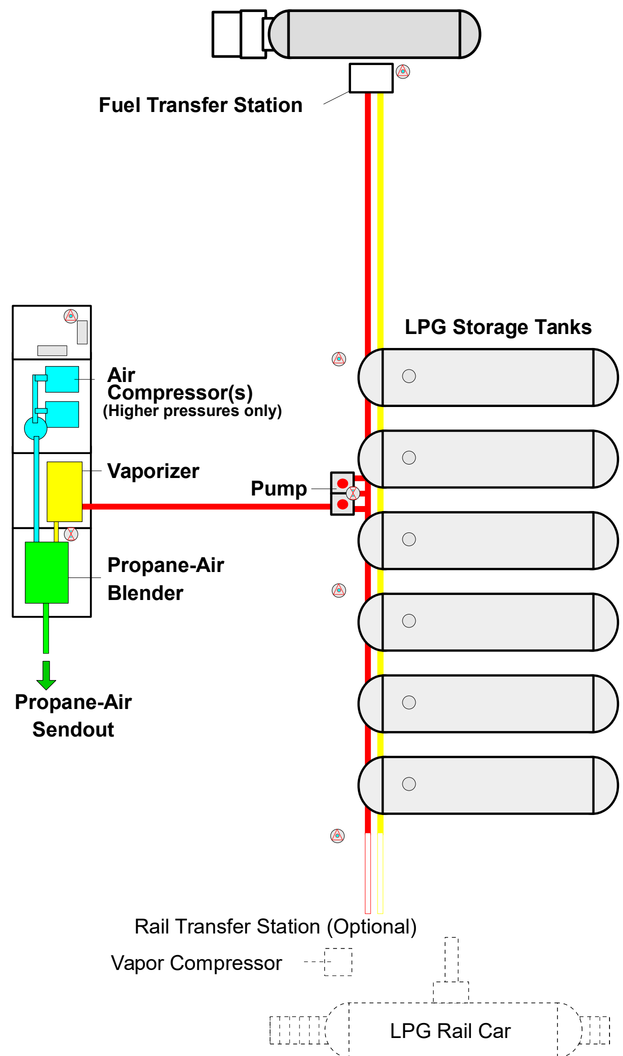
Expansions

Where appropriate, future expansion of either the standby system or the consuming plant should be investigated.

Small Industrial / Commercial Propane-Air System



Large Industrial Propane-Air System



4 Storage Tanks

Most LPG storage tanks in standby-plant service are steel, non-refrigerated pressure vessels. Tanks are available in many sizes for both aboveground and underground service. New propane tanks are built to ASME standards and are designed for at least 250 psig working pressure. Common tank sizes and approximate dimensions are shown in the chart below. Larger industrial and commercial applications generally use 18,000 gallon and larger tanks.

Tank Trim

Required tank trim includes relief valves, excess flow valves and gauges for temperature, pressure and liquid level. Remote / automatic valve features are often required or desired to provide enhanced product control and safety (See also: *9, Safety Systems.*)

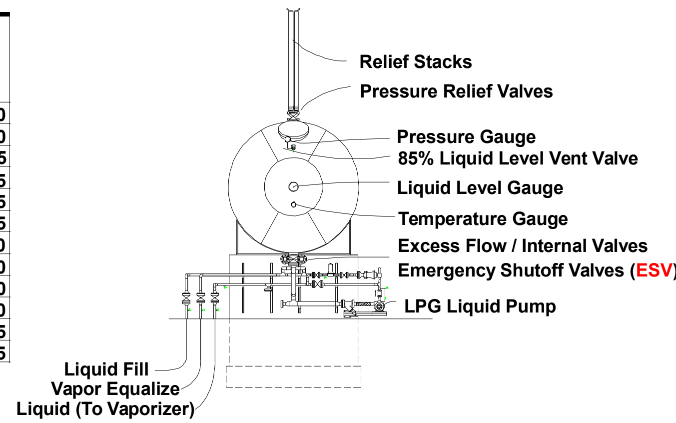
Fire Protection

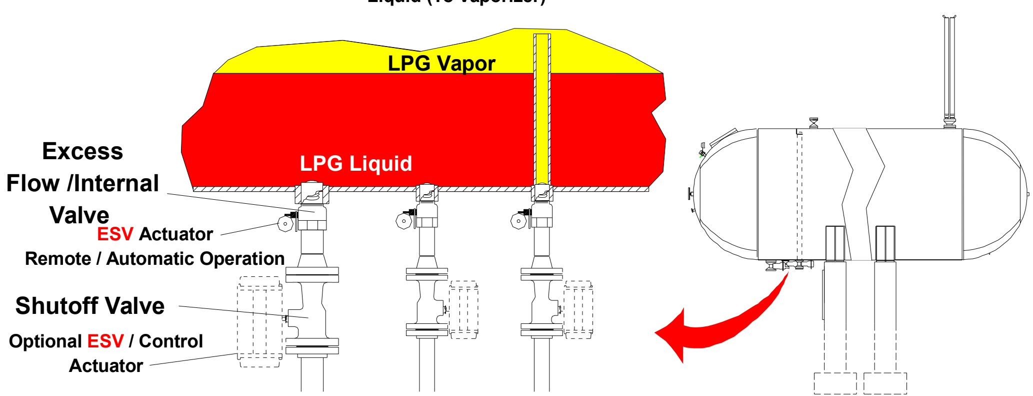
At some locations, "special protection" for tanks (such as mounding, burial, insulating coatings and water-spray systems) may be required or desired to reduce the already small potential for fire-induced tank failures.

LPG Storage Tanks

LPG Storage Tank Data
Dimensions Approximate – *For New Vessels

Gallons Water Cap.	Diameter (Inches)	Length (Feet)	Weight* (Pounds)
1,000	41	16	1,730
2,000	46	24	3,680
3,900	84	17	5,895
6,565	84	26	9,725
9,200	84	36	13,435
12,000	84	45	17,305
18,000	109	41	26,110
30,000	109	66	43,540
30,000	132	47	43,150
45,000	132	69	65,020
60,000	132	90	86,665
90,000	132	134	130,215





Storage Capacity

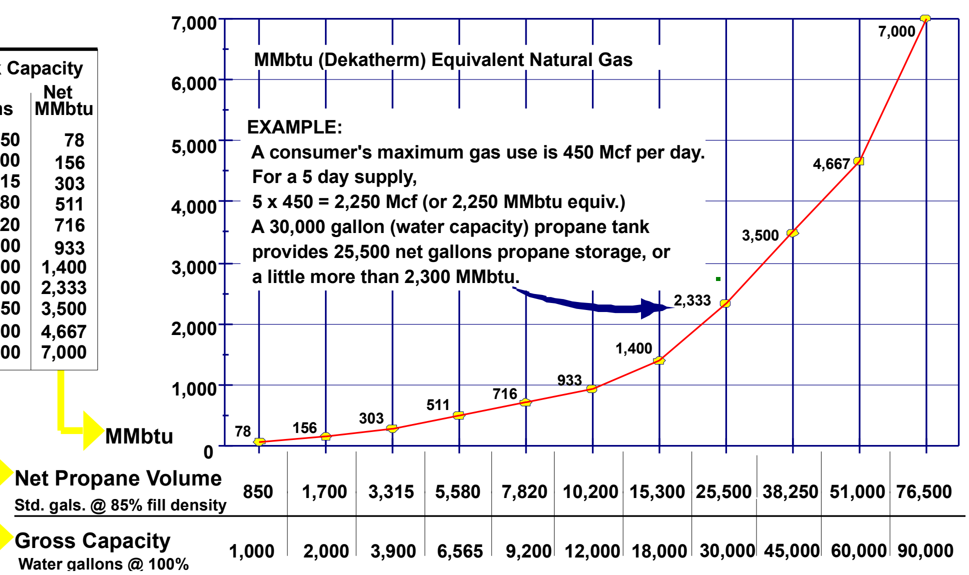
Relating Natural Gas & Propane Storage

To allow for expansion of the liquid propane, tanks are never filled to 100%. At 60° F, the maximum filling density is about 85%. The chart and graph below show common tank sizes and net fuel storage capacities in gallons and "millions of btus" (MMbtu).

RULE OF THUMB...
11 gallons propane equals 1 MMbtu

Propane Tank Capacity

Gross Gallons	Net Gallons	Net MMbtu
1,000	850	78
2,000	1,700	156
3,900	3,315	303
6,565	5,580	511
9,200	7,820	716
12,000	10,200	933
18,000	15,300	1,400
30,000	25,500	2,333
45,000	38,250	3,500
60,000	51,000	4,667
90,000	76,500	7,000

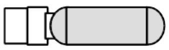


5 Fuel Transfer

Almost all consumer-owned standby systems are equipped to accept delivery of LP-gas via truck. A minority also use rail. In general, a consumer will get a better buy on propane if purchased in transport or railcar quantities.

Truck Fuel Transfer Station

Bobtail

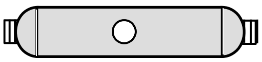


up to 3,500 gallons

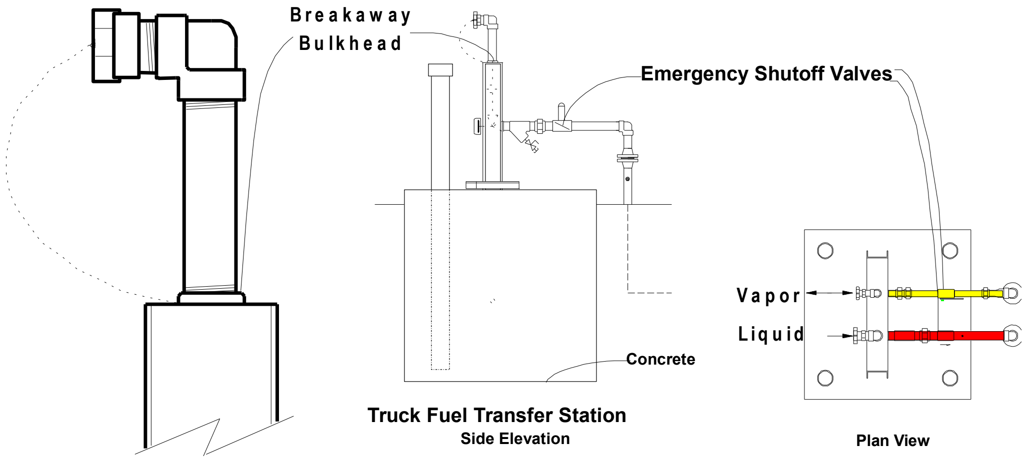
Transport

up to10,000 gallons

Railcar



up to 30,000 gallons



Truck Fuel Transfer Station
Side Elevation

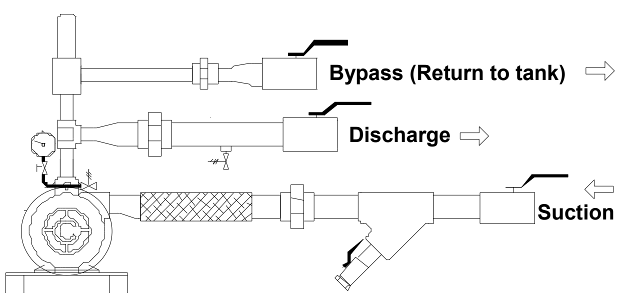
Plan View

The location and construction of fuel transfer stations are important design factors. At LPG plants with more than 4,000 gallons total storage capacity, NFPA 58 requires emergency shutoff valves at transfer stations to allow quick closure. A "breakaway" feature is also required to protect plant piping in the event of a connected-truck pull away. Trucks normally have power-take-off pumps to transfer product. Top-fitted railcars require the use of vapor compressors to "push" the liquid propane out and, on a secondary cycle, recover much of the remaining propane vapor.

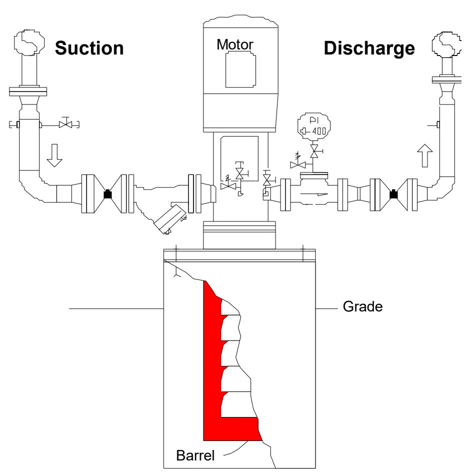
6 Pumps

Because the pressure of propane in a storage tank varies with temperature, many propane-air systems utilize pumps to ensure adequate product pressure. A wide variety of motor-driven pumps are available. For continuous duty, redundant pump systems are advised. Optional controls can be applied for auto-start, etc.

Positive Displacement & Horizontal Impeller/Turbine Pumps



Vertical Turbine Pump



Pump Performance

Pumping a liquid at its boiling point requires careful attention to pump placement and the design of related piping and controls. Effective vapor elimination is critical.

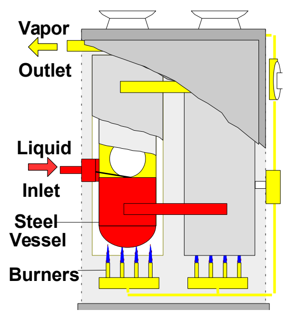
7 Vaporizers

Some small propane loads can be supplied with vapor drawn directly off the top of a tank. Heat is conducted from outside the tank to the propane liquid at a rate sufficient to support the required vaporization. In the process, a gallon of liquid propane will become approx. 36 cubic feet of vapor. For industrial and larger commercial loads, this simple approach to vaporization has limited application. Instead, "vaporizers" are used to heat the liquid propane, creating the needed volume of vaporized gas.

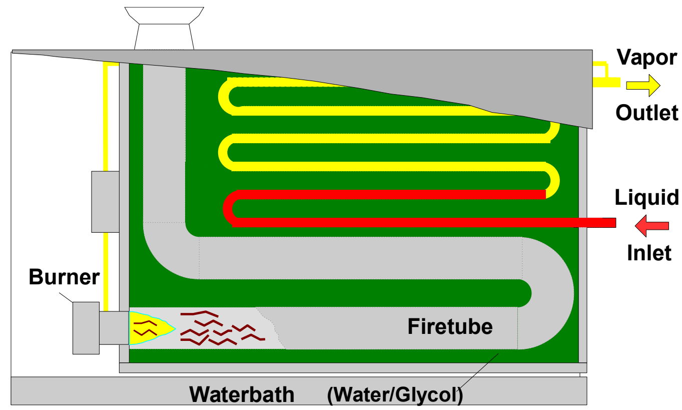
Vaporizers are available in sizes from ten gallons to thousands of gallons per hour. Several basic configurations are shown in the diagrams below. **Note that required controls and safety devices are not shown in detail.**

Direct Fired
With burners providing heat for vaporization, DF vaporizers require separation from storage tanks, fuel transfer stations and other exposures.

Direct-Fired Vaporizer

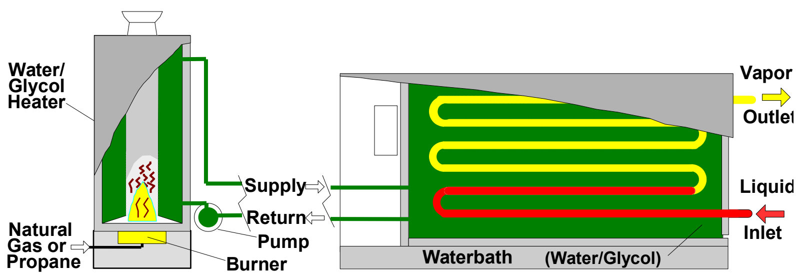


Direct-Fired Waterbath Vaporizer

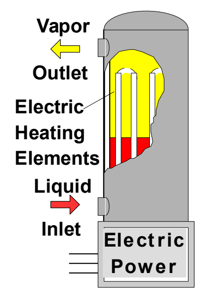


Indirect-Fired
Because heat is provided by steam, electricity or a remote fired source, indirect-fired vaporizers require less separation from most exposures.

Indirect-Fired Waterbath Vaporizer



Electric Vaporizer



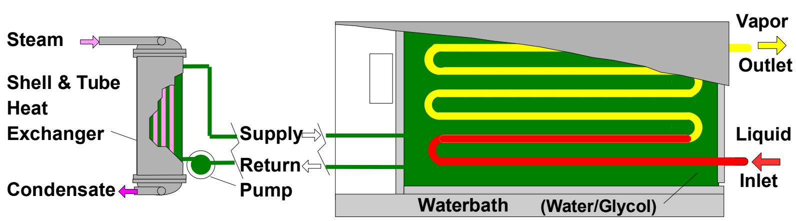
RULE OF THUMB...

A gallon of liquid propane will produce about 36 standard cubic feet (scf) of vapor.

Each scf of propane vapor contains about 2,520 btu of available energy when burned.

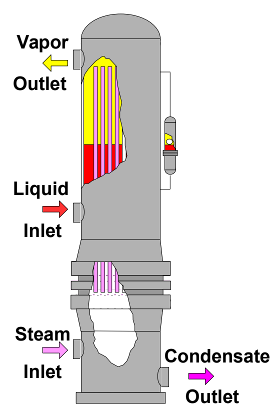
Watch Your Dew Point!

Indirect-Fired Waterbath Vaporizer ("Dual Loop" / Steam)



Steam Vaporizer

(Bayonet Style)



Proper design of piping, pressure control and overpressure protection can ensure safe and reliable vaporizer operation. For example, the operating pressure downstream of a vaporizer must be low enough to avoid condensation of vaporized propane under the coldest ambient conditions. (See **Figure 1** in Appendix for propane dew points.)

8
Propane-Air Blenders (Mixers)

Sometimes a part - or all - of a consumer's load can run on undiluted propane vapor. This normally requires separate distribution piping and modifications to each appliance burner train. Large, centralized loads such as boilers are candidates for this approach.

Propane-air is the more universal approach to standby fuel. By mixing approx. 55% propane and 45% air, a gas is produced that performs well in natural-gas burners without individual adjustment. The mix is injected into the natural-gas system as partial or full replacement.

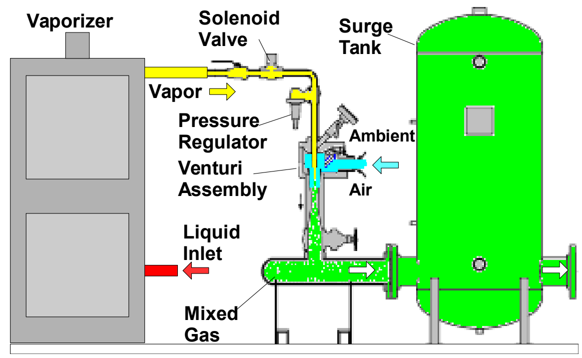
Several approaches to mixing propane and air are shown in the diagrams below. The mixer (blender) type influences selection of other system equipment. **Note that required controls and safety devices are not shown in detail.**

RULE OF THUMB...

A propane-air mixture containing 1,470 btu/cf has burning characteristics similar to natural gas containing 1,000 btu/cf with a specific gravity of .60.

Venturi style mixing systems use high-pressure propane vapor to entrain air directly from the atmosphere by venturi action. Venturi systems are the most popular choice for applications with mixed-gas pressures up to 15 psig. Higher pressures can be achieved with compressed air.

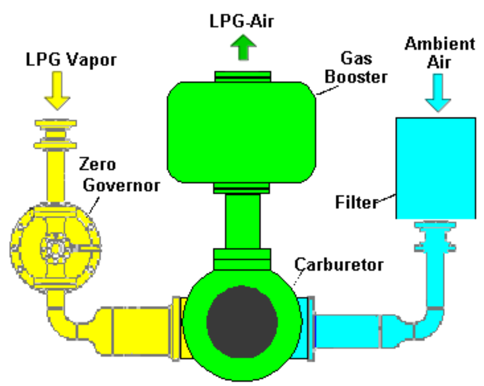
Venturi **up to 15 psig**



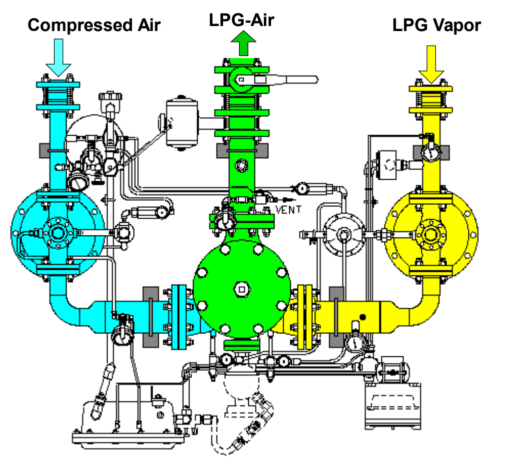
Atmospheric Carburetor systems use a "pull-thru" mixing valve and gas booster.

Pressurized Carburetor systems use a "push-thru" mixing valve and compressed air.

Atmospheric Carburetor **to 10 psig**



Pressurized Carburetor **to 150 psig**



In Appendix...

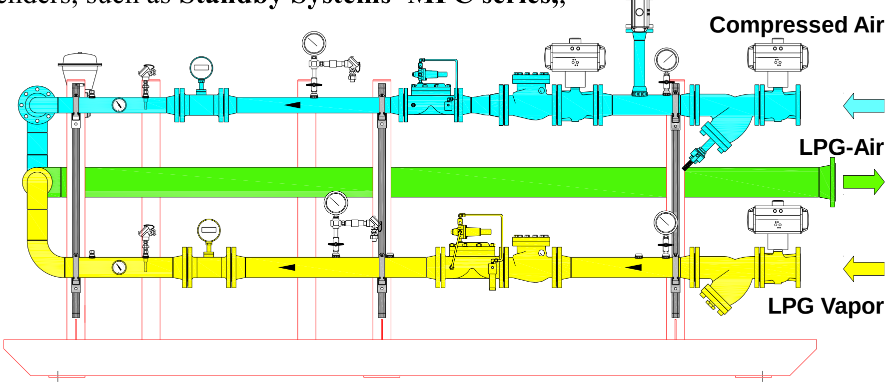
See **Table 4** for typical propane-air compositions and associated specific gravity and Wobbe values.

See **Figure 2** for propane-air dew points.

Parallel Pipe **to 250+ psig**

Parallel Pipe systems use various control mechanisms (e.g., mass flow) to blend fuel gas and compressed air.

Fully-digital blenders, such as **Standby Systems' MFC series,,** provide very precise control of gas quality under varying process conditions.



Wobbe Index is a key measure of fuel-gas *interchangeability.*

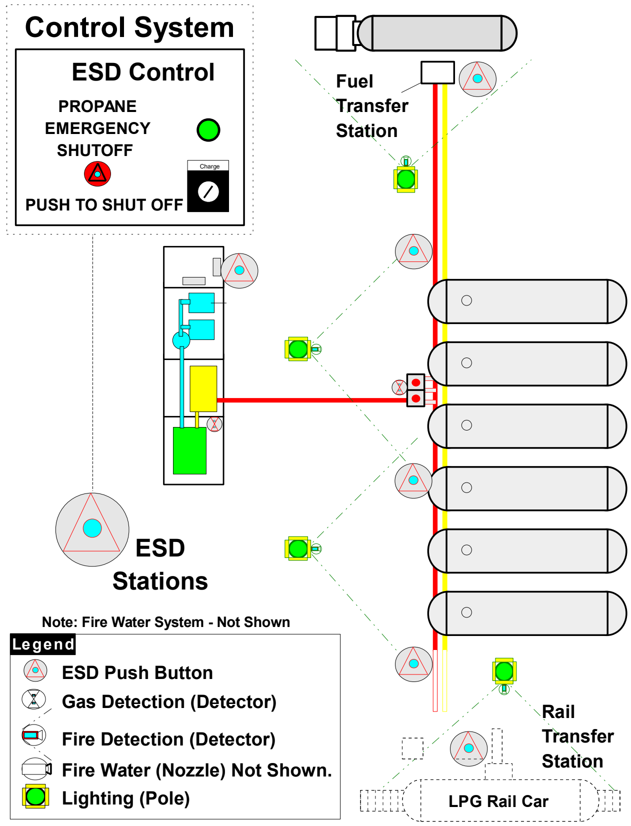
The Wobbe number of a fuel gas is calculated using the **H**igh **H**eating **V**alue and **S**pecific **G**ravity of the gas.

$$W = \frac{HHV}{\sqrt{SG}}$$

9 Safety Systems

Public safety agencies, building officials, insurance carriers, the system designer and owner may all have roles in analyzing hazards, risks and emergency-response factors for a specific LPG facility. Enhanced safety systems can be an attractive component in addressing concerns.

Emergency Shutdown System



Minimizing the potential volume and duration of accidental LPG release is an important safety area. Beyond the protection against a system breech provided by excess flow valves, ***T**otal **P**roduct **C**ontrol **S**ystems* and comprehensive ***E**mergency **S**hut**D**own* systems have evolved over time to offer superior containment capabilities.

TPCS/ESD applications normally include actuated valves to isolate all tank openings, fuel transfer connections and other selected piping and process equipment. Remote and automatic closure of these valves can quickly seal the system. Interlocks to main system control, site power supply, off-site alarms, etc. can yield controlled, safe shutdown and improved emergency response.

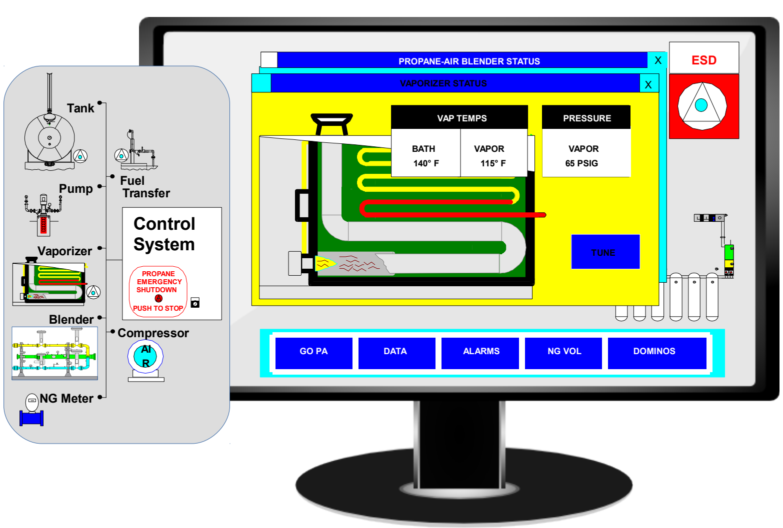
Gas & Flame Detection

Gas and flame detection systems can be installed to monitor critical plant areas. Detection can be integrated within an ESD system for alarm and/or automatic shutdown of the plant.

10 Control Systems

As with any process system, "control" of propane standby systems is a flexible concept. A well-designed system will include at least basic integration of the operating equipment and subsystems. Better still, integrated control of entire systems should be considered, ensuring that the process is made as safe, simple and reliable as possible.

Integrated Control Systems



Even for smaller standby systems, advanced electronic process-control technology is easily applied. From smart transmitters to PLCs to computers, a well-executed control strategy can deliver improved accuracy and safety, automatic gas quality control, comprehensive monitoring, programmed start / stop routines, remote operation, and more.

Connection with natural-gas measurement equipment can allow automated "balancing" of natural-gas deliveries, avoiding potentially large penalties for using too much (or too little) gas. Integration with local or multi-site control networks is also possible. In the new "real-time" business of gas energy, a smart, reliable standby system is certain to be a plus.

11

Security

Security measures at LPG plants should include physical barriers such as perimeter fencing and/or locked enclosures. Access to a facility should normally be limited to trained personnel.

Operations & Maintenance

LPG system owners and operators need to understand the basic properties and hazards of gaseous fuels as well as operating and maintenance requirements of a specific system. A wealth of materials is available to assist with generic safety training for LP-gas.

A well-documented design and as-built construction record can help ensure long-term success in operating and maintaining a standby plant. Detailed operating instructions are also a must. These areas can be addressed early in the design process.

12

Standards

Requirements of various parties affect construction and operation of LPG systems in the U.S. These may include city and state agencies, the Occupational Safety and Health Administration, the Environmental Protection Agency, the Department of Homeland Security and insurance carriers. A similar range of requirements may exist in other countries. A clear understanding of all applicable requirements is a first step in design.

NFPA 58
LP-Gas Code

The National Fire Protection Association publication NFPA 58, ***Liquefied Petroleum Gas Code*** (formerly, *Standard for the Storage and Handling of Liquefied Petroleum Gases*) is commonly applied as a minimum standard for commercial and industrial LP-gas installations. The standard addresses materials of construction, installation and operation, with reference to other standards. Listed below are sources for other documents considered part of NFPA 58 (2020 Edition) requirements.

Section – Source

2.2 **NFPA Publications**. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

2.3 **Other Publications.**

2.3.1 **API Publications**. American Petroleum Institute, 1220 L Street, NW, #900, Washington, DC 20005-4070.

2.3.2 **ASCE Publications**. American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400.

2.3.3 **ASME Publications**. American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

2.3.4 **ASTM Publications.** ASTM International, 100 Barr Harbor Drive, P.O. Box C700, Conshohocken, PA 19428-2959.

2.3.5 **CGA Publications.** Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-1788.

2.3.6 **CSA Group Publications.** CSA Group, 178 Rexdale Blvd., Toronto, ON, M9W 1R3, Canada.

2.3.7 **ISO Publications.** International Organization for Standardization. ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

2.3.8 **NBBPVI Publications.** National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, OH 43229.

2.3.9 **SAE Publications.** SAE International, Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

2.3.10 **UL Publications.** Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

2.3.11 **United Nations Economic Commission for Europe Publications.** UN Economic Commission for Europe Information Services, Palais des Nations, CH-1211 Geneva 10, Switzerland.

2.3.12 **U.S. Government Publications**. U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001

2.3.13 **Other Publications.** *Merriam-Webster's Collegiate Dictionary*, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

Consult each AHJ

Consult each *authority having jurisdiction* to determine all effective requirements.

NFPA 58 2020 Edition

NOTE: The 2020 edition of NFPA 58 was effective and approved as an American National Standard on August 25, 2019. In some jurisdictions, this new edition became effective immediately. Elsewhere, older editions of NFPA 58 may be effective.

International Fire Code

NOTE: The *International Fire Code*, published by the International Code Council, is adopted by many jurisdictions. IFC Chapter 61 addresses LPGs.

Appendix

Table 1 Thermodynamic Properties of Normal Saturated PROPANE

Enthalpies and Entropies are referred to saturated liquid at -200 °F where the values are zero.

ATMOSPHERIC PRESSURE = 14.73 PSIA

TEMP	PRESSURE* (PSI)		SPECIFIC VOLUME* (Cf / Lb)		DENSITY* (Lb / Cf)		ENTHALPY** (Btu / Lb)		LATENT HEAT**	ENTROPY** (Btu / Lb / °F)	
°F	ABSOLUTE	GAUGE	LIQUID	VAPOR	LIQUID	VAPOR	LIQUID	VAPOR	(Btu/Lb)	LIQUID	VAPOR
Temp	APress	GPress	LSpVol	VSpVol	LDen	VDen	LEnthal	VEnthal	Latent	LEntrop	VEntrop
-50	12.60	-2.10	0.02732	7.74	36.60	0.129	79.5	262.7	183.2	0.173	0.617
-45	14.40	-0.30	0.02748	6.89	36.39	0.145	82.3	264.2	181.9	0.179	0.615
-40	16.20	1.50	0.02763	6.13	36.19	0.163	85.0	265.8	180.8	0.185	0.614
-35	18.10	3.40	0.02779	5.51	35.99	0.181	87.5	267.2	179.7	0.190	0.613
-30	20.30	5.60	0.02795	4.93	35.78	0.203	90.2	268.9	178.7	0.196	0.612
-25	22.70	8.00	0.02811	4.46	35.58	0.224	92.8	270.3	177.5	0.202	0.610
-20	25.40	10.70	0.02827	4.00	35.37	0.250	95.6	271.8	176.2	0.208	0.608
-15	28.30	13.60	0.02844	3.60	35.16	0.278	98.3	273.2	174.9	0.214	0.607
-10	31.40	16.70	0.02860	3.26	34.96	0.307	101.0	274.9	173.9	0.220	0.607
-5	34.70	20.00	0.02878	2.97	34.75	0.337	103.8	276.2	172.4	0.226	0.606
0	38.20	23.50	0.02985	2.71	34.54	0.369	106.2	277.7	171.5	0.231	0.605
5	41.90	27.20	0.02913	2.48	34.33	0.403	108.8	279.0	170.2	0.236	0.604
10	46.00	31.30	0.02931	2.27	34.12	0.441	111.3	280.5	167.2	0.246	0.603
15	50.60	35.90	0.02950	2.07	33.90	0.483	114.0	281.8	167.8	0.248	0.602
20	55.50	40.80	0.02970	1.90	33.67	0.526	116.8	283.1	166.3	0.254	0.601
25	60.90	46.20	0.02991	1.74	33.43	0.575	119.7	284.4	164.7	0.260	0.600
30	66.30	51.60	0.03012	1.60	33.20	0.625	122.3	285.7	163.4	0.266	0.599
35	72.00	57.30	0.03033	1.48	32.97	0.676	125.0	287.0	162.0	0.272	0.598
40	78.00	63.30	0.03055	1.37	32.73	0.730	128.0	288.3	160.3	0.278	0.597
45	84.60	69.90	0.03078	1.27	32.49	0.787	131.1	289.5	158.4	0.285	0.596
50	91.80	77.10	0.03102	1.18	32.24	0.847	134.2	290.7	156.5	0.292	0.596
55	99.30	84.60	0.03125	1.10	32.00	0.909	137.2	292.0	154.8	0.298	0.596
60	107.10	92.40	0.03150	1.01	31.75	0.990	140.6	293.2	152.6	0.306	0.595
65	115.40	100.70	0.03174	0.945	31.50	1.060	143.8	294.5	150.7	0.313	0.594
70	124.00	109.30	0.03201	0.883	31.24	1.130	147.5	295.8	148.3	0.321	0.594
75	133.20	118.50	0.03229	0.825	30.97	1.210	150.3	296.9	146.6	0.327	0.594
80	142.80	128.10	0.03257	0.770	30.70	1.300	154.0	299.1	145.1	0.335	0.593
85	153.10	138.40	0.03287	0.722	30.42	1.390	157.0	299.2	142.2	0.342	0.593
90	164.00	149.30	0.03317	0.673	30.15	1.490	160.3	300.3	140.0	0.349	0.593
95	175.00	160.30	0.03348	0.632	29.87	1.580	163.4	301.3	137.9	0.356	0.592
100	187.00	172.30	0.03381	0.591	29.58	1.690	166.8	302.4	135.6	0.363	0.592
105	200.00	185.30	0.03416	0.553	29.27	1.810	169.8	303.2	133.4	0.370	0.592
110	212.00	197.30	0.03453	0.520	28.96	1.920	172.8	304.0	131.2	0.376	0.591
115	226.00	211.30	0.03493	0.488	28.63	2.050	176.2	304.7	128.5	0.383	0.590
120	240.00	225.30	0.03534	0.459	28.30	2.180	179.8	305.2	125.4	0.391	0.589
125	254.00	239.30	0.03575	0.432	27.97	2.310	183.5	305.8	122.3	0.399	0.588
130	272.00	257.30	0.03618	0.404	27.64	2.480	186.8	306.1	119.3	0.406	0.587
135	288.00	273.30	0.03662	0.382	27.32	2.620	190.0	306.3	116.3	0.413	0.586
140	305.00	290.30	0.03707	0.360	27.00	2.780	194.0	306.5	112.5	0.422	0.585

*Based on material from Dana, Jenkins, Burick and Timm, *Refrigerating Engineering*, June 1926, Vol. 12, No. 12, page 403

**From Mollier Diagrams for Propane, W.C. Edminster, Standard Oil Co., (Indiana)

Table 2 Thermodynamic Properties of Normal Saturated BUTANE

Enthalpies and Entropies are referred to saturated liquid at -200 °F where the values are zero.

ATMOSPHERIC PRESSURE = 14.73 PSIA											
TEMP	PRESSURE* (PSI)		SPECIFIC VOLUME* (Cf / Lb)		DENSITY* (Lb / Cf)		ENTHALPY** (Btu / Lb)		LATENT HEAT**	ENTROPY** (Btu / Lb / °F)	
°F	ABSOLUTE	GAUGE	LIQUID	VAPOR	LIQUID	VAPOR	LIQUID	VAPOR	(Btu/Lb)	LIQUID	VAPOR
Temp	APress	GPress	LSpVol	VSpVol	LDen	VDen	LEnthal	VEnthal	Latent	LEntrop	VEntrop
0	7.30	-7.40	0.02591	11.10	38.59	0.0901	103.8	275.3	171.5	0.266	0.572
5	8.20	-6.50	0.02603	9.98	38.41	0.100	106.2	276.9	170.7	0.231	0.572
10	9.20	-5.50	0.02615	8.95	38.24	0.112	108.8	278.5	169.7	0.236	0.574
15	10.40	-4.30	0.02627	8.05	38.07	0.124	111.5	280.0	168.5	0.242	0.571
20	11.60	-3.10	0.02639	7.23	37.89	0.138	114.0	281.6	167.6	0.248	0.571
25	13.00	-1.70	0.02651	6.55	37.72	0.153	116.7	283.1	166.4	0.254	0.571
30	14.40	-0.30	0.02664	5.90	37.54	0.169	119.2	284.9	165.7	0.260	0.571
35	16.00	1.30	0.02676	5.37	37.37	0.186	121.8	286.4	164.6	0.264	0.571
40	17.70	3.00	0.02689	4.88	37.19	0.205	124.2	288.0	163.8	0.270	0.571
45	19.60	4.90	0.02703	4.47	37.00	0.224	126.8	289.5	162.7	0.276	0.571
50	21.60	6.90	0.02716	4.07	36.82	0.246	129.6	291.2	161.6	0.282	0.571
55	23.80	9.10	0.02730	3.73	36.63	0.268	132.1	292.7	160.6	0.287	0.570
60	26.30	11.60	0.02743	3.40	36.45	0.294	134.8	294.2	159.4	0.293	0.570
65	28.90	14.20	0.02759	3.12	36.24	0.321	137.3	295.9	158.6	0.298	0.570
70	31.60	16.90	0.02773	2.88	36.06	0.347	140.1	297.5	157.4	0.304	0.570
75	34.50	19.80	0.02789	2.65	35.86	0.377	142.6	298.9	156.3	0.310	0.570
80	37.60	22.90	0.02805	2.46	35.65	0.407	145.0	300.3	155.3	0.315	0.570
85	40.90	26.20	0.02821	2.28	35.45	0.439	147.8	302.0	154.2	0.322	0.570
90	44.50	29.80	0.02838	2.10	35.24	0.476	150.5	303.5	153.0	0.326	0.571
95	48.20	33.50	0.02854	1.96	35.04	0.510	153.1	305.0	151.9	0.332	0.571
100	52.20	37.50	0.02870	1.81	34.84	0.552	156.2	306.7	150.5	0.340	0.571
105	56.40	41.70	0.02889	1.70	34.62	0.588	159.1	308.1	149.0	0.346	0.572
110	60.80	46.10	0.02906	1.58	34.41	0.633	161.9	309.5	147.6	0.352	0.572
115	65.60	50.90	0.02925	1.48	34.19	0.676	165.0	311.1	146.1	0.359	0.572
120	70.80	56.10	0.02945	1.37	33.96	0.730	167.8	312.7	144.9	0.365	0.572
125	76.00	61.30	0.02962	1.28	33.77	0.783	171.0	314.0	143.0	0.372	0.573
130	81.40	66.70	0.02980	1.19	33.56	0.840	174.0	315.5	141.5	0.378	0.573
135	87.00	72.30	0.03000	1.11	33.34	0.900	177.1	317.0	139.9	0.385	0.573
140	92.60	77.90	0.03020	1.04	33.14	0.965	179.9	318.2	138.3	0.391	0.574
145	100.00	85.30	0.03040	0.966	32.92	1.035	183.1	319.5	136.4	0.398	0.574
150	108.00	93.70	0.03060	0.897	32.70	1.115	186.5	321.0	134.5	0.405	0.574
155	115.00	100.30	0.03084	0.840	32.43	1.190	189.3	322.3	133.0	0.411	0.574
160	122.00	107.30	0.03112	0.785	32.15	1.275	192.7	323.8	131.1	0.418	0.575
165	130.00	115.30	0.03140	0.733	31.90	1.365	195.8	325.0	129.2	0.425	0.575
170	140.00	125.30	0.03165	0.687	31.62	1.455	199.2	326.1	126.9	0.433	0.575
175	150.00	135.30	0.03193	0.643	31.36	1.557	202.1	327.2	125.1	0.439	0.575
180	160.00	145.30	0.03218	0.602	31.10	1.660	205.0	328.4	123.4	0.445	0.575

*Based on material from Dana, Jenkins, Burick and Timm, *Refrigerating Engineering*, June 1926, Vol. 12, No. 12, page 402

**From Mollier Diagrams for Propane, W.C. Edminster, Standard Oil Co., (Indiana)

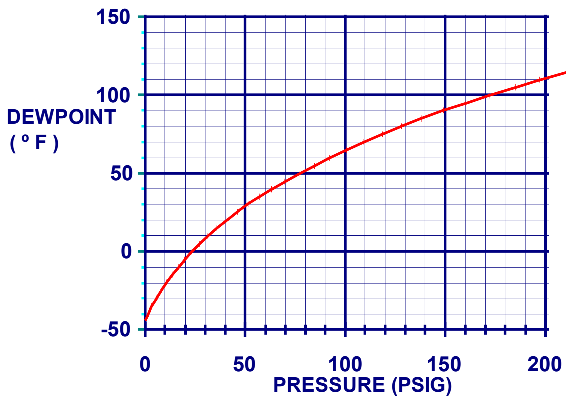
Table 3 Physical Constants of Hydrocarbons

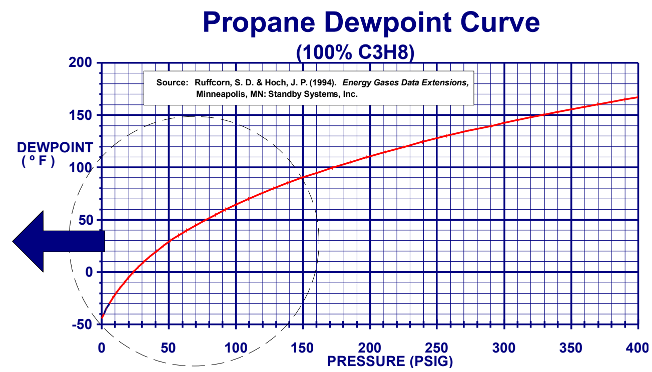
(Selected Compounds found in LP-Gas)

	Methane	Ethene	Ethane	Propene	**Propane**	Iso-Butane	N-Butane	Air	Water
Formula	CH4	C2H4	C2H6	C3H6	**C3H8**	C4H10	C4H10		H2O
Vapor Pressure @ 100 °F									
PSIG (gauge)	.....	.....	.....	212.5	**174.8**	58.8	37.3	.....	.....
PSIA (absolute)	.....	.....	.....	227.2	**189.5**	73.5	52	.....	0.95
Normal State @ STP (*)	GAS	GAS	GAS	GAS	**GAS**	GAS	GAS	GAS	LIQUID
Boiling Point of Liquid @ atmospheric pressure									
°F	-258.5	-154.7	-128.2	-53.9	**-43.8**	10.9	31.1	-317.7	212
°C	-161.4	-103.7	-89	-47.7	**-42.1**	-11.7	-0.5	-194.3	100
Weight of Liquid @ 60 °F									
Pounds / gallon	2.5	3.3	3.11	4.35	**4.23**	4.69	4.86	7.136	8.337
Specific Gravity	.3	.....	.374	.5218	**.508**	.563	.584	.856	1.000
API Gravity	340.0	.....	247.0	139.7	**147.0**	119.8	110.8	165.3	10.0
Cubic Feet of Vapor @ STP formed from									
1 Gallon Liquid @ 60°F	59.0	44.6	39.35	37.9	**36.45**	30.65	31.79	.....	.....
1 Pound Liquid	23.6	13.21	12.65	8.71	**8.62**	6.53	6.54	.....	.....
Weight of Vapor @ STP									
Pounds / hundred cubic foot	4.227	7.393	7.923	11.09	**11.62**	15.31	15.31	7.64	.....
Specific Gravity (Air=1)	.554	.9684	1.038	1.4527	**1.522**	2.006	2.006	1.000	.....
Gross Heat of Combustion									
Btu / pound	23,920	21,650	22,350	21,060	**21,690**	21,290	21,340	.....	.....
Btu / cubic foot @ 60°F	1,011	1,601	1,771	2,335	**2,521**	3,259	3,267	.....	.....
Btu / gallon @ 60°F	.....	70,910	68,900	87,740	**91,300**	99,300	103,000	.....	.....
Cf of Air to Burn 1 cf of Gas @ STP	9.55	14.29	16.71	21.44	**23.87**	31.03	31.03	.....	.....
Pounds of Air to Burn 1 pound of Gas	17.24	14.76	16.13	14.76	**15.71**	15.49	15.49	.....	.....
Explosive Limits									
Lower % in Air	4.9 - 6.2	2.75	3.0 - 3.3	2.0	**2.0 - 2.4**	1.80	1.5 - 1.9	.....	.....
Upper % in Air	12.7 - 16.0	28.60	10.6 - 15.0	11.0	**7.0 - 9.5**	8.44	5.7 - 8.5	.....	.....
Heat of Vaporization of Liquid @ boiling point & atmospheric pressure									
Btu / pound	245	208	211	189	**183**	158	166	92	970.3
Btu / gallon	712	686	696	822	**774**	741	797	656.5	8089.4
Ratio of Liquid Volume @ 60 °F to Gas Volume @ STP	443	333.7	294.3	283.5	**272.7**	229.3	237.8	.....	.....
Freezing Point of Liquid @ atmospheric pressure									
°F	-296.5	-272.6	-297.8	-301.4	**-305.9**	-255.3	-216.9	.....	32
°C	-182.5	-169.2	-183.2	-185.2	**-187.7**	-159.4	-138.3	.....	0
Molecular Weight	16.042	28.052	30.068	42.079	**44.094**	58.12	58.12	28.966	18.016
Gallons / pound mol @ 60 °F	6.4	8.5	9.64	9.7	**10.41**	12.38	11.94	4.06	2.16
Specific Heat @ STP									
Cp Liquid - Btu / pound /°F	.....	.....	.....	.....	**.....**	.....	.55@32°F	.....	.....
Cp Vapor - Btu / pound /°F	0.526	0.362	0.413	0.352	**0.390**	0.406	0.396	.....	.....
Cv Vapor - Btu / pound /°F	0.402	0.288	0.347	0.298	**0.346**	0.373	0.363	.....	.....
Cp/Cv Vapor - Btu / pound /°F	1.306	1.258	1.189	1.18	**1.128**	1.088	1.09	.....	.....
Critical Conditions									
Temperature - °F	-116.5	49.8	90.1	196.5	**206.2**	273.2	305.6	-221.3	705
Temperature - °C	-82.5	9.9	32.3	91.4	**96.8**	134.0	152.0	-140.7	374.1
Pressure - PSIA	673	742	708	667	**617**	530	551.0	547	3206
Pressure - atmospheres	45.8	50.5	48.2	45.4	**42.0**	36.1	37.5	37.2	218.2
Density - pounds / gallon	1.351	.....	1.695	.....	**1.888**	1.946	1.891	.....	.....
Volume - cubic feet / pound mol	1.586	.....	2.371	.....	**3.123**	3.990	4.130	.....	.....

* **STP** = **S**tandard **T**emperature & **P**ressure Conditions = 60°F & atmospheric pressure.
Based on material from *Handbook Butane-Propane Gases*, Third Edition, 1951, Jenkins Publications, Inc.

Figure 1 Propane Dew Points





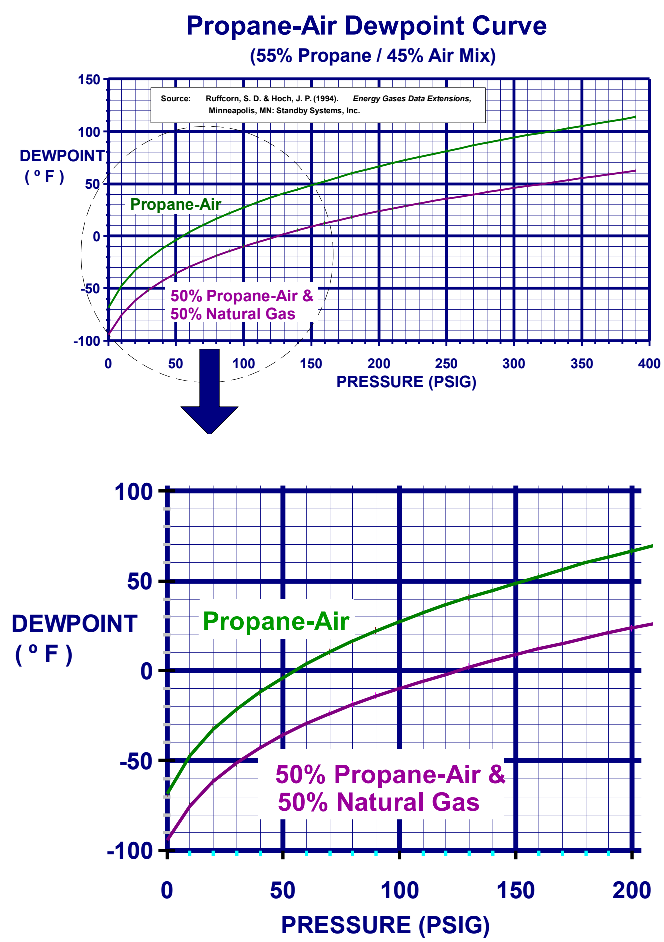
Source: Ruffcorn, S. D., Hoch, J. P. (1994). *Energy Gases Data Extensions,* Standby Systems, Inc.

Table 4 Sample Propane-Air Data

Btu per Cubic Foot of PA Mixture	% Propane by Volume	% Air by Volume	% O2 by Volume	Specific Gravity of PA Mixture	Wobbe Number (1)
1600	**63.49**	**36.51**	**7.630**	**1.330**	**1387**
1590	63.10	36.90	7.713	1.328	1380
1580	62.70	37.30	7.796	1.326	1372
1570	62.30	37.70	7.879	1.324	1364
1560	61.90	38.10	7.962	1.322	1357
1550	**61.51**	**38.49**	**8.045**	**1.320**	**1349**
1540	61.11	38.89	8.128	1.318	1342
1530	60.71	39.29	8.211	1.316	1334
1520	60.32	39.68	8.294	1.31	1326
1510	59.92	40.08	8.377	1.312	1318
1500	**59.52**	**40.48**	**8.460**	**1.310**	**1311**
1490	59.13	40.87	8.542	1.307	1303
1480	58.73	41.27	8.625	1.305	1295
1470	58.33	41.67	8.708	1.303	1288
1460	57.94	42.06	8.791	1.301	1280
1450	**57.54**	**42.46**	**8.874**	**1.299**	**1272**
1440	57.14	42.86	8.957	1.297	1264
1430	56.75	43.25	9.040	1.295	1257
1420	56.35	43.65	9.123	1.293	1249
1410	55.95	44.05	9.206	1.291	1241
1400	**55.56**	**44.44**	**9.289**	**1.289**	**1233**
1390	55.16	44.84	9.372	1.287	1225
1380	54.76	45.24	9.455	1.285	1217
1370	54.37	45.63	9.538	1.283	1210
1360	53.97	46.03	9.621	1.281	1202
1350	**53.57**	**46.43**	**9.704**	**1.279**	**1194**
1340	53.17	46.83	9.787	1.277	1186
1330	52.78	47.22	9.869	1.274	1178
1320	52.38	47.62	9.952	1.272	1170
1310	51.98	48.02	10.035	1.270	1162
1300	**51.59**	**48.41**	**10.118**	**1.258**	**1115**

(1) Wobbe Number is the High Heating Value of the gas (expressed in units 'BTU per SCF' above) divided by the square root of the Specific Gravity of the gas (where the SG of Air = 1.0).

Figure 2 Propane-Air Dew Points



Dew points based on 55%/45% propane-air mix and natural gas containing 95% methane.
Source: Ruffcorn, S. D., Hoch, J. P. (1994). *Energy Gases Data Extensions,* Standby Systems, Inc.

Notes

Complete this form to get help in evaluating a propane standby system for your location!

Form 636 EZ	Confidential Gas Energy Profile	Propane Standby System Data

Name		**Company**	
Title		**Address**	
Phone	Ext		
Fax	Ext	**City**	**State**
Email		**Zip**	**Country**

Plant Location (If not shown above)

Natural Gas Supply

How do you purchase natural gas at this location?

Local natural gas distribution company

Do you purchase "transported" gas? ◯ YES ◯ NO **Supplier:**

Annual natural gas consumed ☐ MMbtu/Dekatherm ☐ Therm ☐ Mcf

Natural gas delivery basis ☐ Interruptible ☐ Firm ⟹ If both, please provide breakdown

Total annual natural gas cost ⟹ If available , separate 'demand' and 'commodity' costs under **Add'l Info** below.

Load Profile

What is your peak gas flow rate and normal distribution pressure?

Total connected natural gas load **MMbtuh** (Millions of BTUs per hour)

Facility gas distribution pressure **psig** ⟹ Pressure of in-plant gas piping system(s)

Do you have any processes that must use natural gas (methane)? ◯ YES ◯ NO For example, atmosphere generators

Are any changes in gas use planned? ◯ YES ◯ NO For example, facility and/or production expansions.

Insurance

Some insurance carriers have special criteria for propane systems

☐ **Factory Mutual** ☐ **IRI/GE-GAP** **Other:**

Other

What else may be of interest?

Do you use propane-fueled forklifts? ◯ YES ◯ NO ⟹ If yes, how many?

Do you have other uses for propane? ◯ YES ◯ NO ⟹ If yes, please explain.

Additional Information

Please provide whatever additional information you believe may be of use in evaluating a propane standby system for your facility. If available, please send a site plan showing property lines and the location of natural gas meter(s).

Standby Systems inc.

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