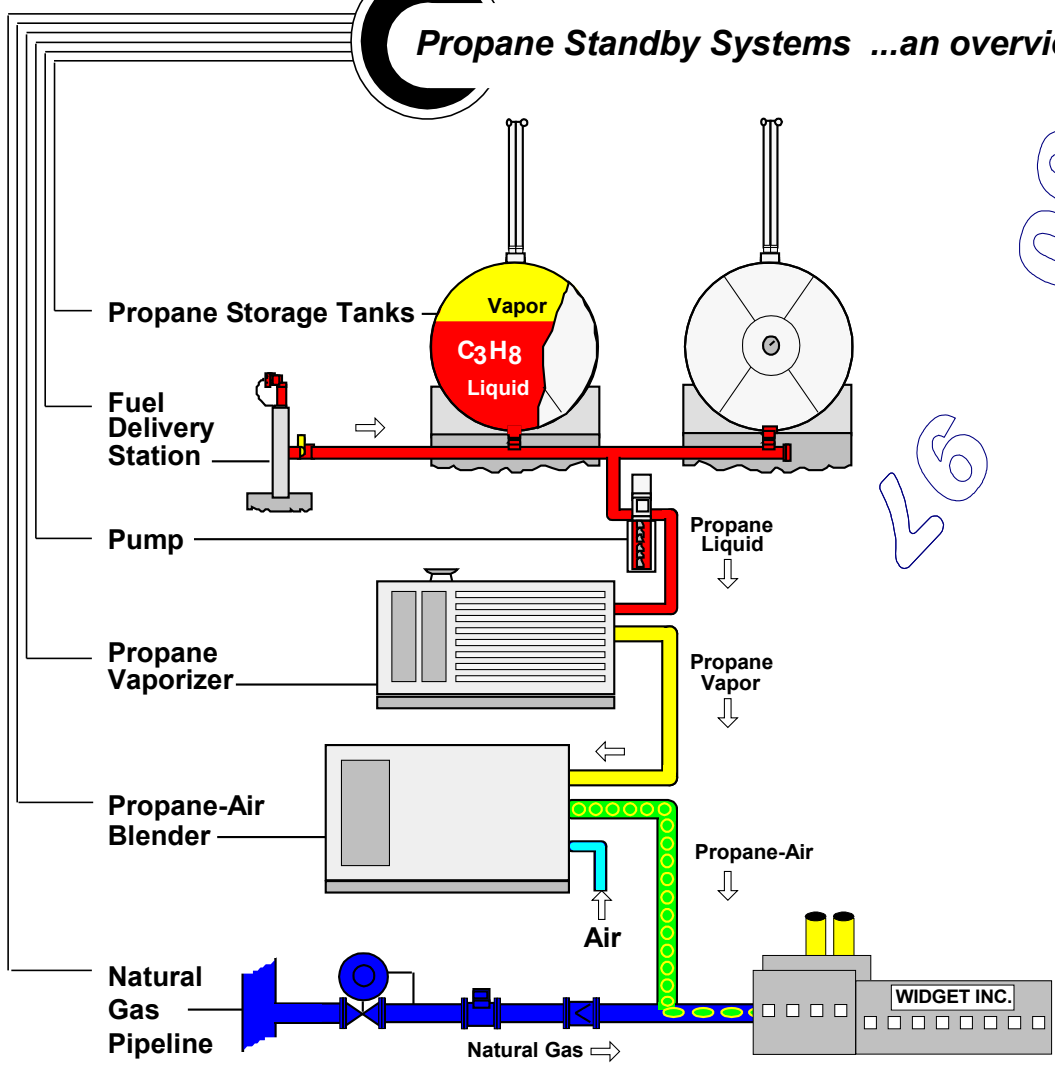


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Propane Standby Systems ...an overview



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06

...about Standby Systems, Inc.

Standby Systems, Inc. is a total resource for propane peak shaving and standby systems with over thirty years of superior service. We provide a full range of engineering, equipment, construction and customer support.

We serve other 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

- 1 Propane Standby System Operation**
- 2 Gas Energy Profile**
- 3 System Layout**
- 4 Storage Tanks**
- 5 Fuel Transfer**
- 6 Pumps**
- 7 Vaporizers**
- 8 Propane-Air Blenders (Mixers)**
- 9 Safety Systems**
- 10 Control Systems**
- 11 Security, Training & Documentation**
- 12 Standards**

Appendix

Table 1 Thermodynamic Properties of Saturated Propane

Table 2 Thermodynamic Properties of Saturated Butane

Table 3 Physical Constants of Hydrocarbons

Table 4 Sample Propane-Air Data

Figure 1 Propane Dew Points

Figure 2 Propane-Air Dew Points

Form 636EZ Confidential Gas-Energy Profile / Propane Standby System Data

Introduction

Demand for clean-burning natural gas (composed primarily of *methane*) is growing around the world. In North America, a dynamic *gas-energy* marketplace offers an array of competitive choices - and risks - from wellhead to burner tip. Many gas utilities and consumers gain enhanced security and flexibility - while reducing the overall cost of energy supply - using propane **peak shaving** and **standby systems**. Most of these systems produce "propane-air" for direct replacement of natural gas during peak demand periods.

Glossary

LDC Local Distribution Company

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

LNG Liquefied Natural Gas

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

LPG Liquefied Petroleum Gas

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

NG Natural Gas

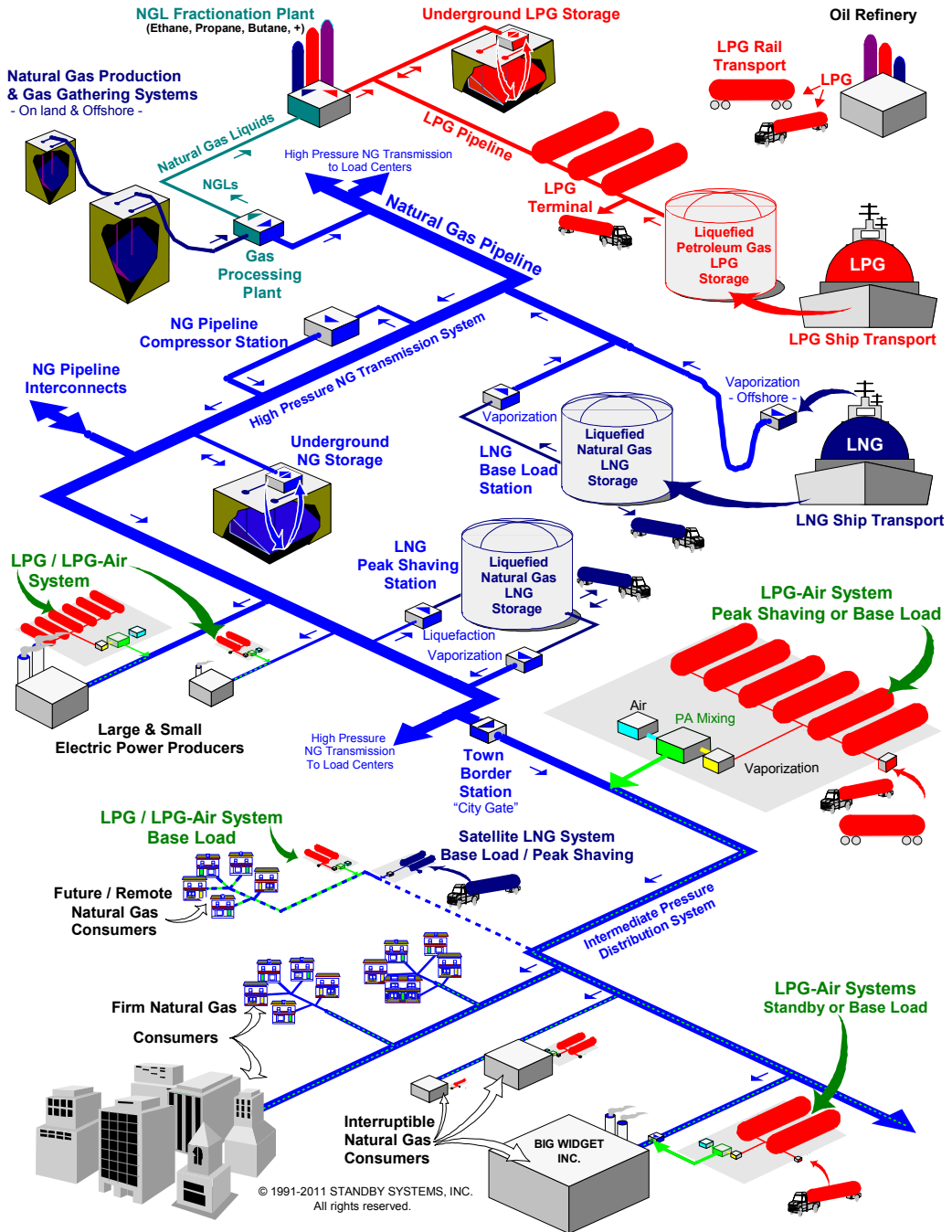
NG is a mixture of methane and various other hydrocarbons and inert gases.

NGLs Natural Gas Liquids

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?

SNG can mean several forms of 'alternate' natural gas. *Synthetic* Natural Gas commonly refers to the output of 'coal gasification' plants – but 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.*

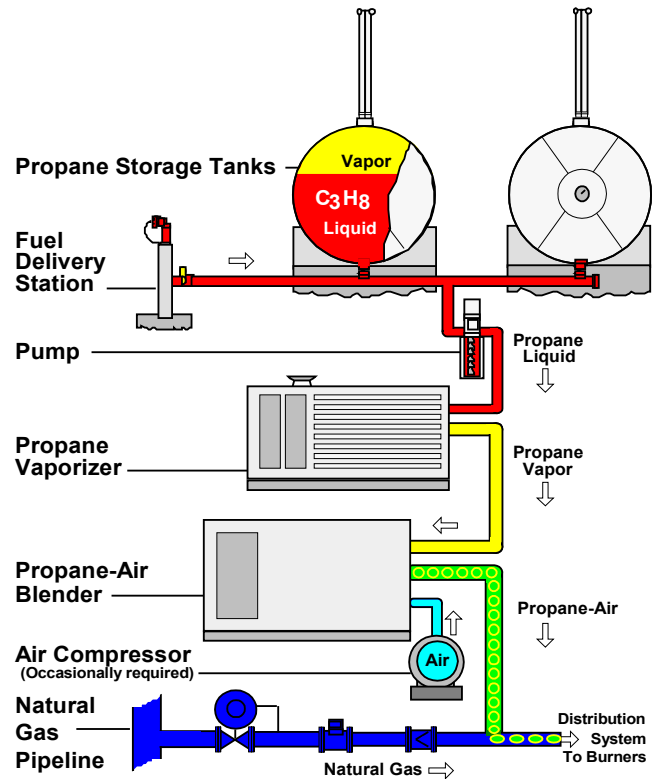
Internet: <http://standby.com> Telephone: 612.721.4473 Email: ssmail@standby.com

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:

- **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** (e.g., FM, IRI);
- **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.

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!
 Link: This form can be downloaded as single page at... <http://standby.com/propane/pdf/636ez.pdf>

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

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

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 can be provided under Add'l Info below.

Load Profile What's 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 This is the pressure of the 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.
 FM Global 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).

Return to...
Standby Systems inc. 1313 Plymouth Avenue North Minneapolis, MN 55411-4065 USA
 Phone: 612.721.4473 Fax: 612.724.8434 Internet: <http://standby.com> E-mail: ssimal@standby.com

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 6.3.1*) and from other exposures.

NFPA 58 Table 6.3.1 (Partial Data, 2011 Ed.)

Minimum Distances			
Between Containers, Important Buildings and Other Properties			
feet (meters)			
Water Capacity per Container (Gallons)	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 insurers such as FM Global and Industrial Risk Insurers / GE-GAP.

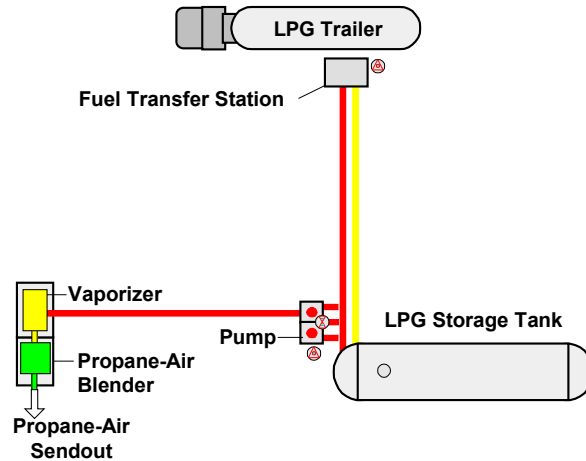
Other Propane Uses

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

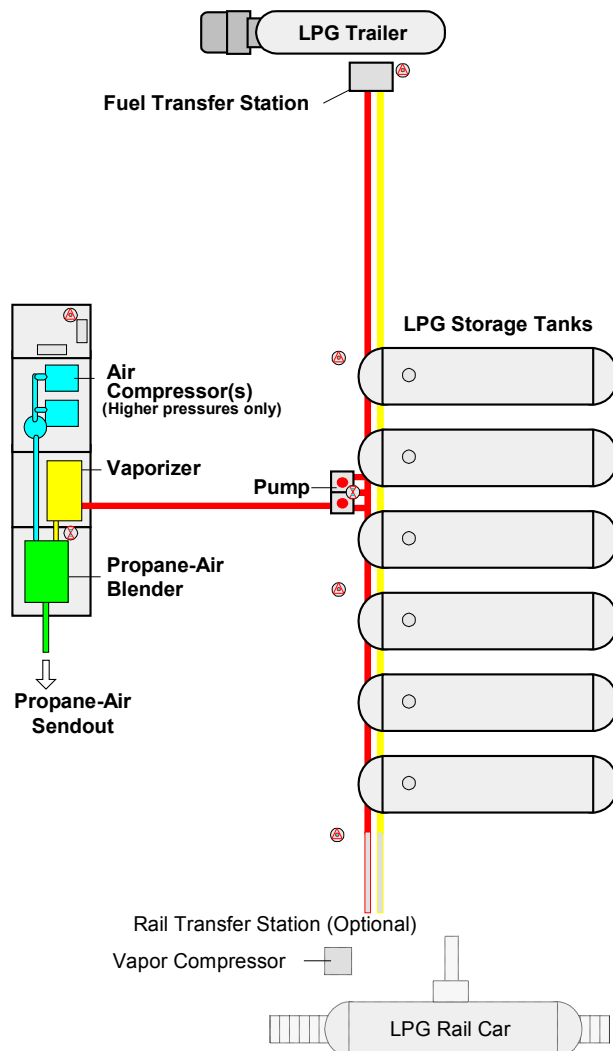
Expansions

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

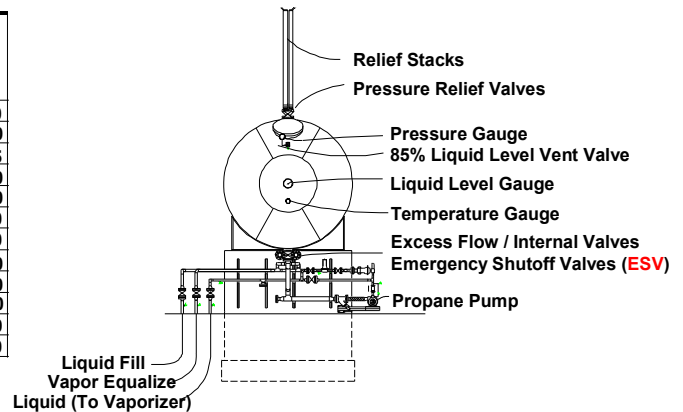
Most LPG storage tanks in standby-plant service are steel, non-refrigerated pressure vessels. Tanks are available in many sizes for both aboveground and underground service. New propane tanks are built to ASME standards and are designed for at least 250 psig working pressure. Common tank sizes and approximate 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.*)

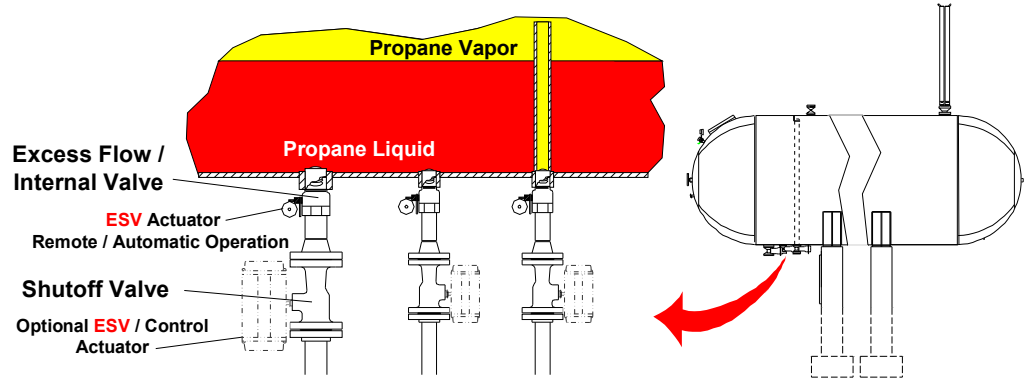
LPG Storage Tanks

Gallons Water Cap.	Diameter (Inches)	Length (Feet)	Weight (Pounds)
1,000	41	16	2,200
2,000	46	24	4,110
3,900	84	17	6,665
6,565	84	26	12,250
9,200	84	36	17,300
12,000	84	45	22,400
18,000	108	41	30,400
30,000	108	66	51,500
30,000	131	47	51,400
45,000	131	69	76,200
60,000	131	90	102,000
90,000	131	134	153,400



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.



Storage Capacity

Relating Natural Gas & Propane Storage

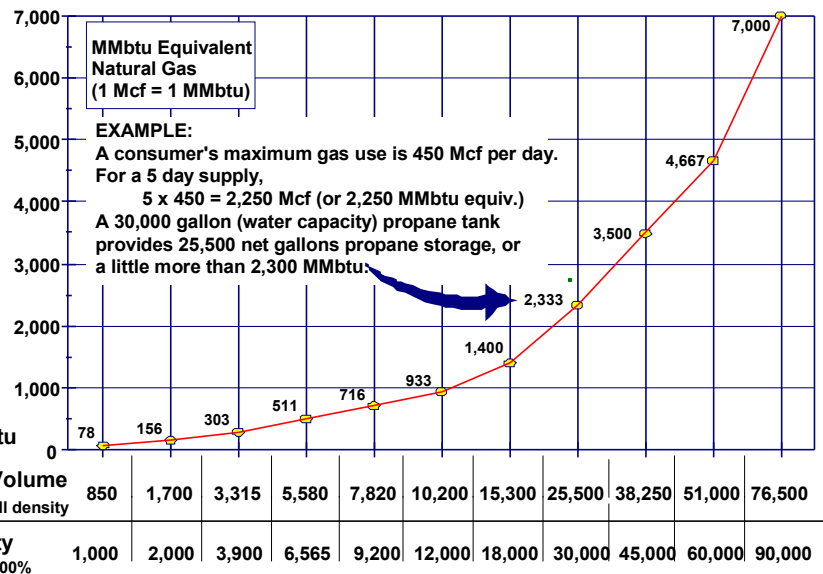
To allow for expansion of the liquid propane, tanks are never filled to 100%. At 60° F, the maximum filling density is about 85%. The chart and graph below show common tank sizes and net fuel storage capacities in gallons and "millions of btus" (MMbtu).



RULE OF THUMB...

11 gallons propane equals 1 MMBtu

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



→ MMBtu
 → Net Propane Volume
 Std. gals. @ 85% fill density
 → Gross Capacity
 Water gallons @ 100%

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

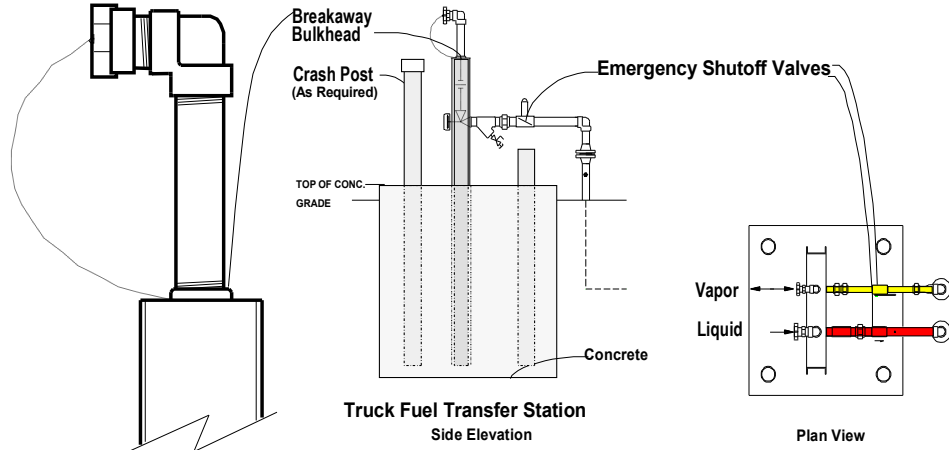


up to 10,000 gallons

Railcar



up to 30,000 gallons



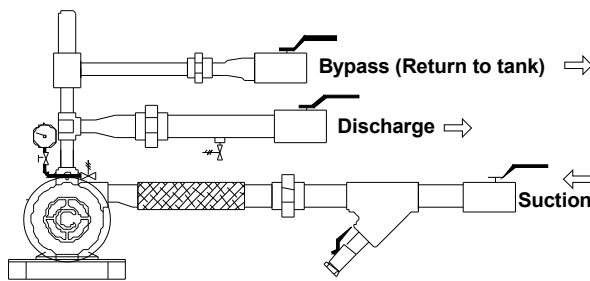
The location and construction of fuel transfer stations are important design factors. At LPG plants with more than 4,000 gallons total storage capacity, NFPA 58 requires emergency shutoff valves at transfer stations to allow quick closure. A "breakaway" feature is also required to protect plant piping 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

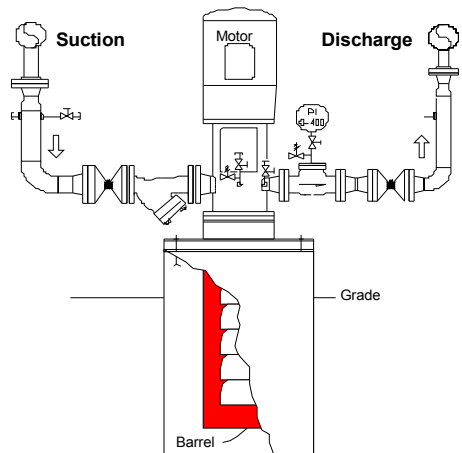
Pumps

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.

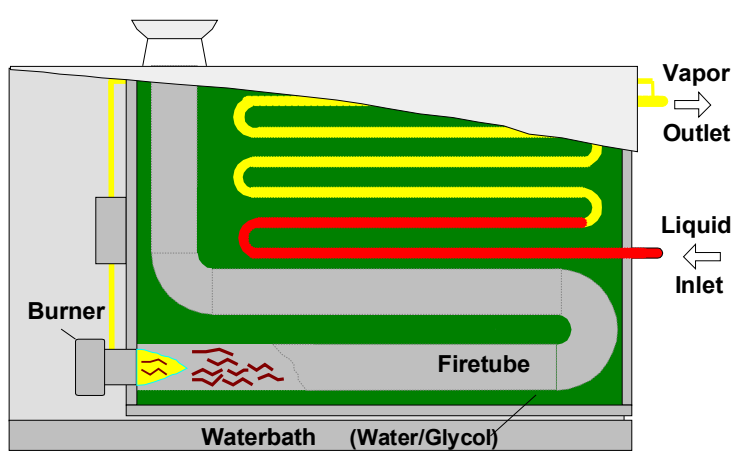
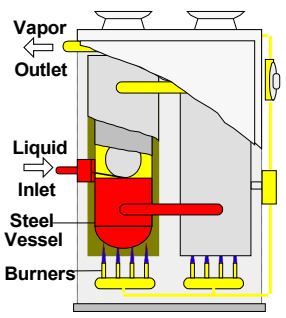
7 Vaporizers

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.**

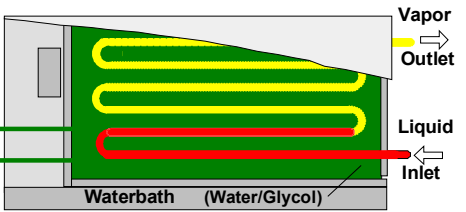
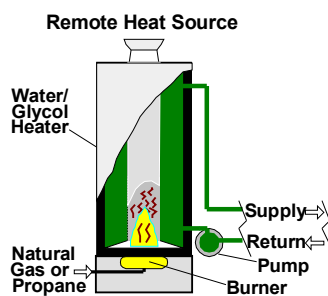
Direct Fired
With burners providing heat for vaporization, DF vaporizers require separation from storage tanks, fuel transfer stations and other exposures.

Direct-Fired Vaporizer Direct-Fired Waterbath Vaporizer

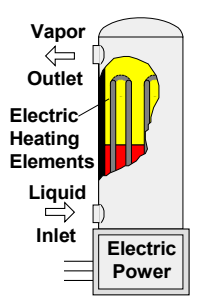


Indirect-Fired
Because heat is provided by steam, electricity or a remote fired source, indirect-fired vaporizers require less separation from most exposures.

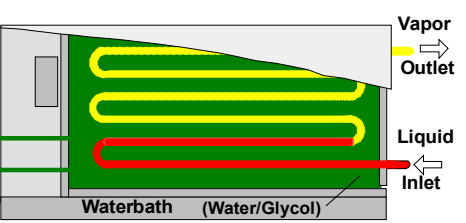
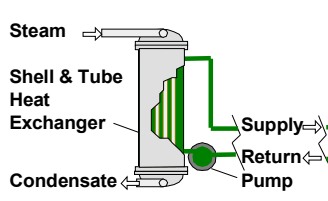
Indirect-Fired Waterbath Vaporizer



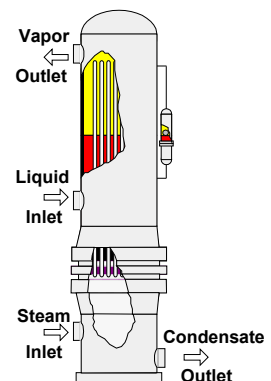
Electric Vaporizer



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



Steam Vaporizer (Bayonet Style)



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!

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)



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.

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.

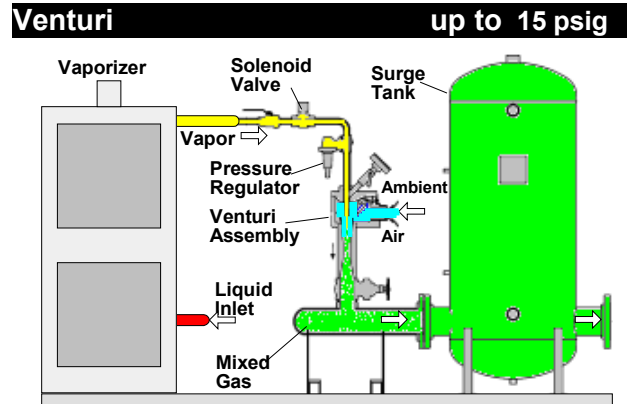
Sometimes a part - or all - of a consumer's load can run on undiluted propane vapor. This normally requires separate distribution piping and modifications to each appliance burner train. Large, centralized loads such as boilers are candidates for this approach.

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.

There are several approaches to mixing propane and air, and many blender (mixer) options can be considered. The mixer type influences selection of other equipment used in the system. Common types of propane-air blenders with related mixed-gas pressure ranges are shown in the diagrams below.

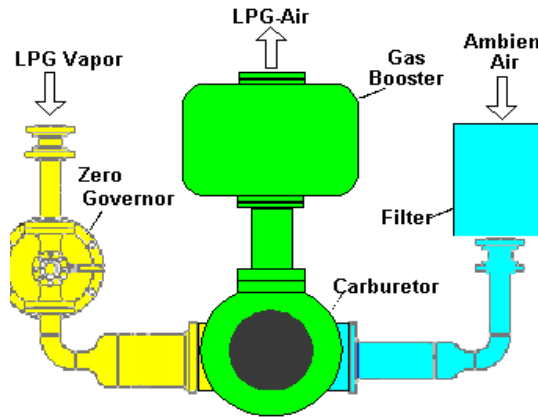
Note that required controls and safety devices are not shown in detail.

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.



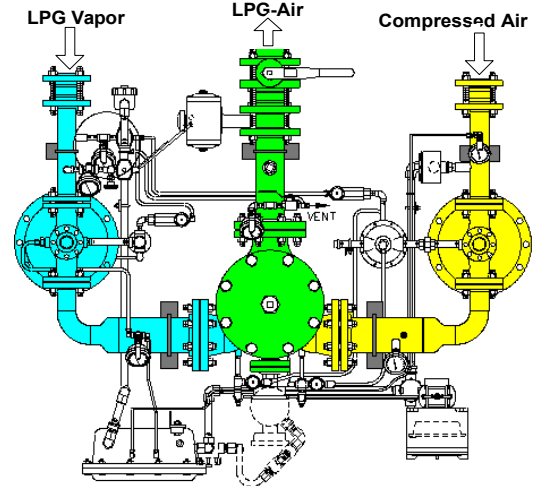
Atmospheric Carburetor systems use a "pull-thru" mixing valve and gas booster.

Atmospheric Carburetor to 10 psig



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

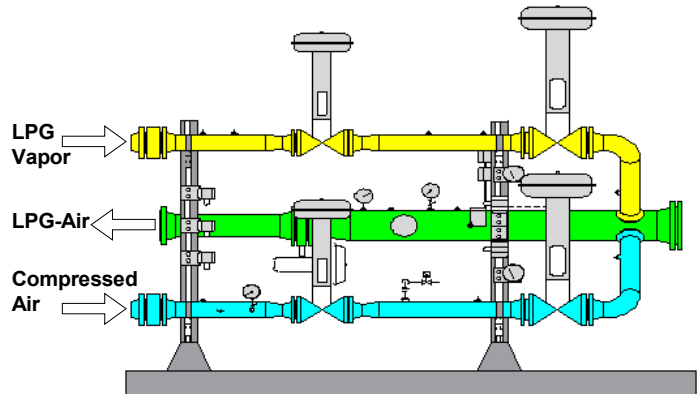
Pressurized Carburetor to 150 psig



Parallel Pipe systems include a variety of control mechanisms (e.g., mass flow control) to proportion compressed air and gas.

At the top end, fully "digital" systems, such as SSI's MFC series blenders, provide very precise control of gas quality under varying process conditions.

Parallel Pipe 10 - 250 psig

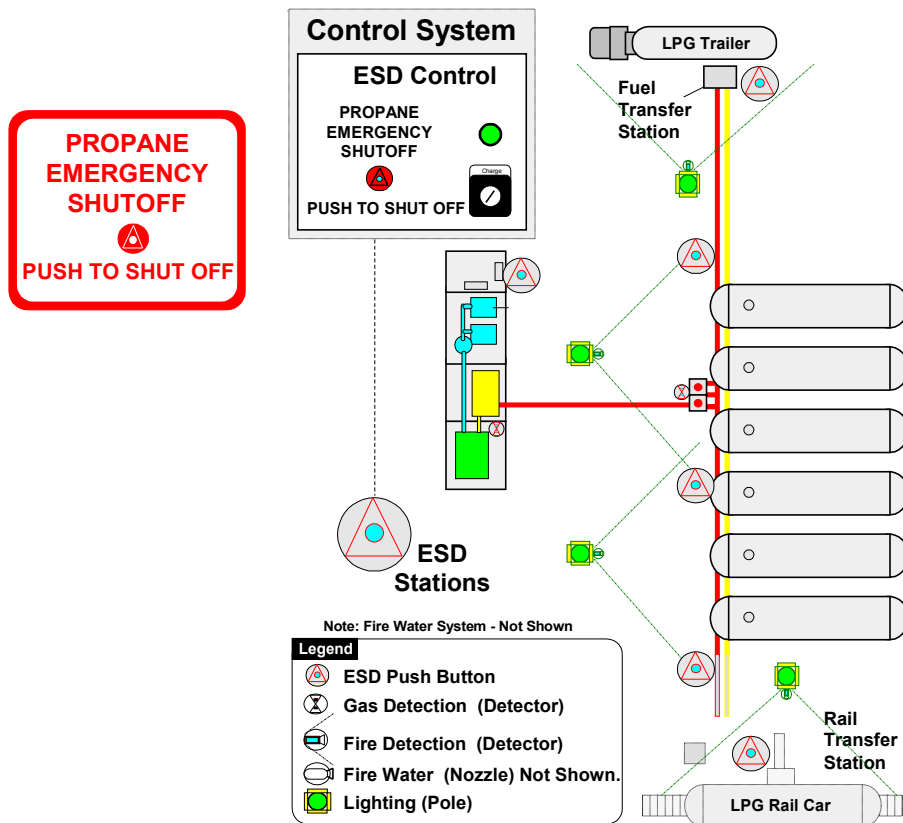


9

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 breach provided by excess flow valves, *Total Product Control Systems* and comprehensive *Emergency ShutDown* 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 & Fire Detection

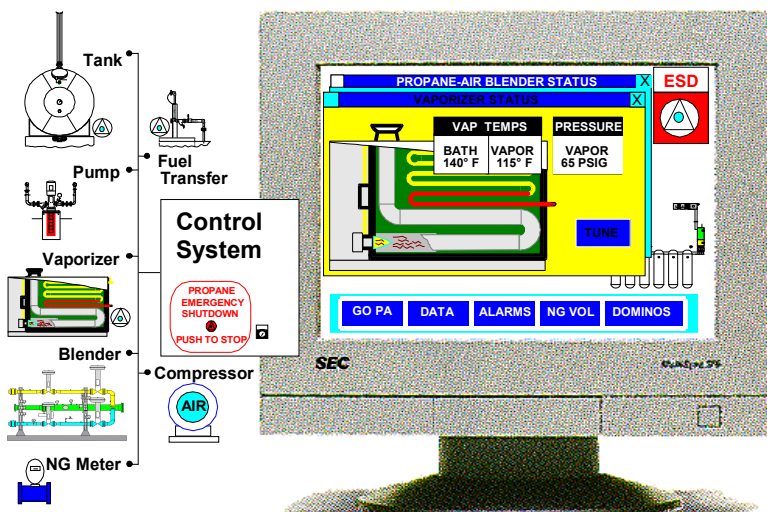
Gas and fire detection systems can be installed to monitor critical plant areas. Detection can be integrated within an ESD system for alarm and/or automatic shutdown of the plant.

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.

Training & Documentation 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

NFPA 58 LP-Gas Code

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. 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 (2011 Edition) requirements.

Section – Source

- 2.2 **NFPA Publications.** National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02169-7471.
- 2.3 **Other Publications.**
 - 2.3.1 **ANSI Publications.** American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.
 - 2.3.2 **API Publications.** American Petroleum Institute, 1220 L Street, N.W., Washington, DC 20005-4070.
 - 2.3.3 **ASCE Publications.** American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400.
 - 2.3.4 **ASME Publications.** American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.
 - 2.3.5 **ASTM Publications.** ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.
 - 2.3.6 **CGA Publications.** Compressed Gas Association, 4221 Walney Road, 5th floor, Chantilly, VA 20151-2923.
 - 2.3.7 **CSA American Publications.** CSA America, Inc., 8501 East Pleasant Valley Road, Cleveland, OH 44131-5575.
 - 2.3.8 **NACE Publications.** NACE International, 1440 South Creek Drive, Houston, TX 77084-4906.
 - 2.3.9 **NBBPVI Publications.** National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, OH 43229.
 - 2.3.10 **UL Publications.** Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.
 - 2.3.11 **ULC Publications.** Underwriters Laboratories of Canada, 7 Underwriters Road, Toronto, ON, Canada M1R3A9.
 - 2.3.12 **U.S. Government Publications.** U>S> Government Printing Office. Washington, DC 20402.

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

NFPA 58 2011 Edition **NOTE:** The 2011 edition of NFPA 58 was effective and approved as an American National Standard on August 25, 2010. 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 38 addresses LPGs.

Appendix

Table 1 Thermodynamic Properties of Saturated Propane

Table 2 Thermodynamic Properties of Saturated Butane

Table 3 Physical Constants of Hydrocarbons

Table 4 Sample Propane-Air Data

Figure 1 Propane Dew Points

Figure 2 Propane-Air Dew Points

Form 636EZ Confidential Gas-Energy Profile / Propane Standby System Data

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 °F	PRESSURE* (PSI)		SPECIFIC VOLUME* (Cf / Lb)		DENSITY* (Lb / Cf)		ENTHALPY** (Btu / Lb)		LATENT HEAT** (Btu/Lb)	ENTROPY** (Btu / Lb / °F)	
	ABSOLUTE	GAUGE	LIQUID	VAPOR	LIQUID	VAPOR	LIQUID	VAPOR		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 °F	PRESSURE* (PSI)		SPECIFIC VOLUME* (Cf / Lb)		DENSITY* (Lb / Cf)		ENTHALPY** (Btu / Lb)		LATENT HEAT** (Btu/Lb)	ENTROPY** (Btu / Lb / °F)	
	ABSOLUTE	GAUGE	LIQUID	VAPOR	LIQUID	VAPOR	LIQUID	VAPOR		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)

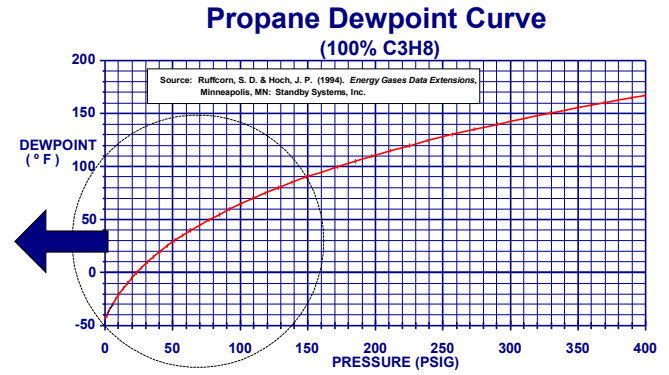
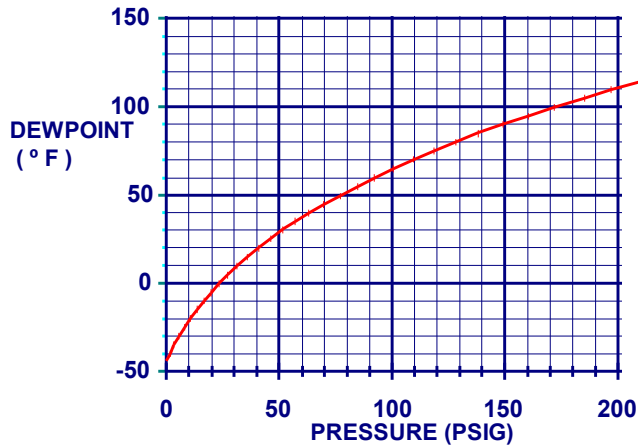
Table 3 Physical Constants of Hydrocarbons

(Selected Compounds found in LP-Gas)

	Methane	Ethene	Ethane	Propene	Propane	Iso-Butane	N-Butane	Air	Water
Formula	CH ₄	C ₂ H ₄	C ₂ H ₆	C ₃ H ₆	C ₃ H ₈	C ₄ H ₁₀	C ₄ H ₁₀		H ₂ O
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 = Standard Temperature & Pressure 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.

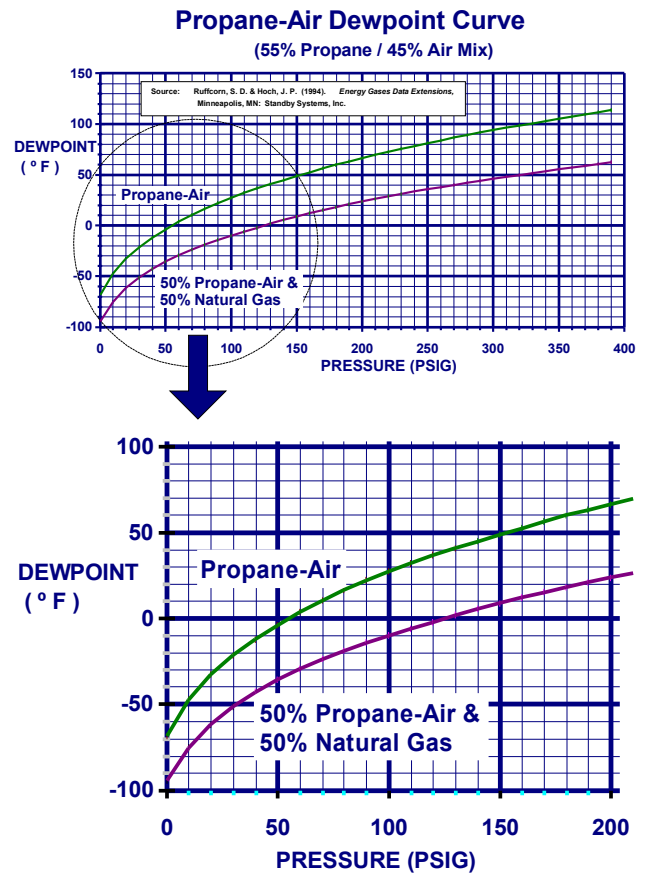
Table 4 Sample Propane-Air Data

Btu per Cubic Foot of PA Mixture	% Propane by Volume	% Air by Volume	% O2 by Volume	Specific Gravity of PA Mixture	Wobbe Number (I)
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

Specific gravity values based on propane vapor at 2520 Btu/cf and specific gravity of 1.52 at standard conditions.
 Source: Ruffcorn, S. D., Hoch, J. P. (1994-2004). *Energy Gases Data Extensions*, Standby Systems, Inc.

(I) 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.

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

Link: This form can be downloaded as single page at... <http://standby.com/propane/pdf/636ez.pdf>

Form 636 EZ

Confidential Gas Energy Profile - Propane Standby System Data

Name	<input type="text"/>	Company	<input type="text"/>
Title	<input type="text"/>	Address	<input type="text"/>
Phone	<input type="text"/>	Ext	<input type="text"/>
Fax	<input type="text"/>	Ext	<input type="text"/>
Email	<input type="text"/>	City	<input type="text"/>
		State	<input type="text"/>
		Zip	<input type="text"/>
		Country	<input type="text"/>

Plant Location (If not shown above)

Natural Gas Supply

Local natural gas distribution company

How do you purchase natural gas at this location?

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 can be provided under Add'l Info below.

Load Profile

Total connected natural gas load

What's your peak gas flow rate and normal distribution pressure?

MMbtuh (Millions of BTUs per hour.)

Facility gas distribution pressure

psig This is the pressure of the 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.

FM Global 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).

Return to...



1313 Plymouth Avenue North Minneapolis, MN 55411-4065 USA

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