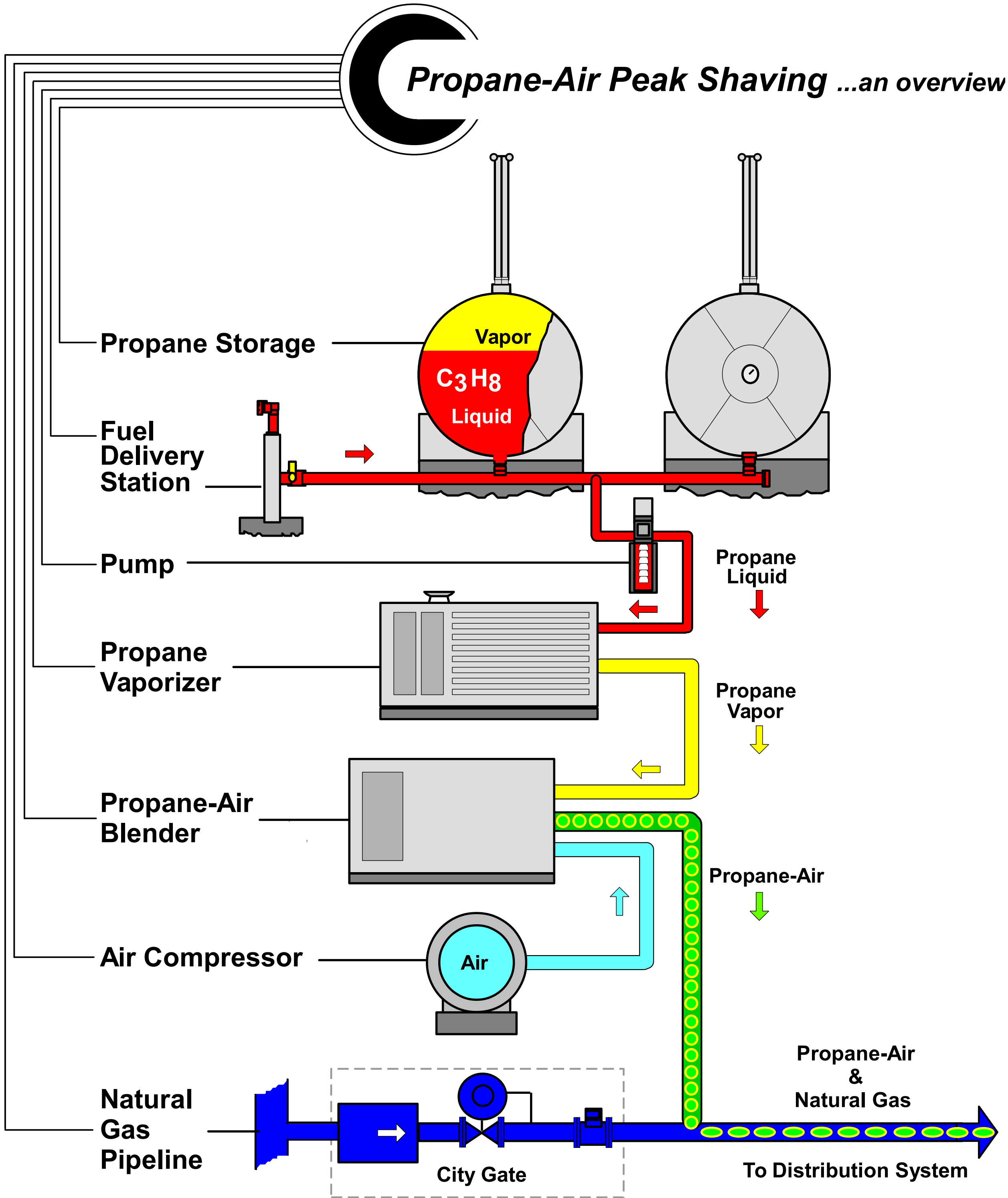

Standby Systems inc.

...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-Air Peak Shaving ...an overview*** informative.

Standby Systems inc.

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Propane-Air Peak Shaving ...an overview

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 **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

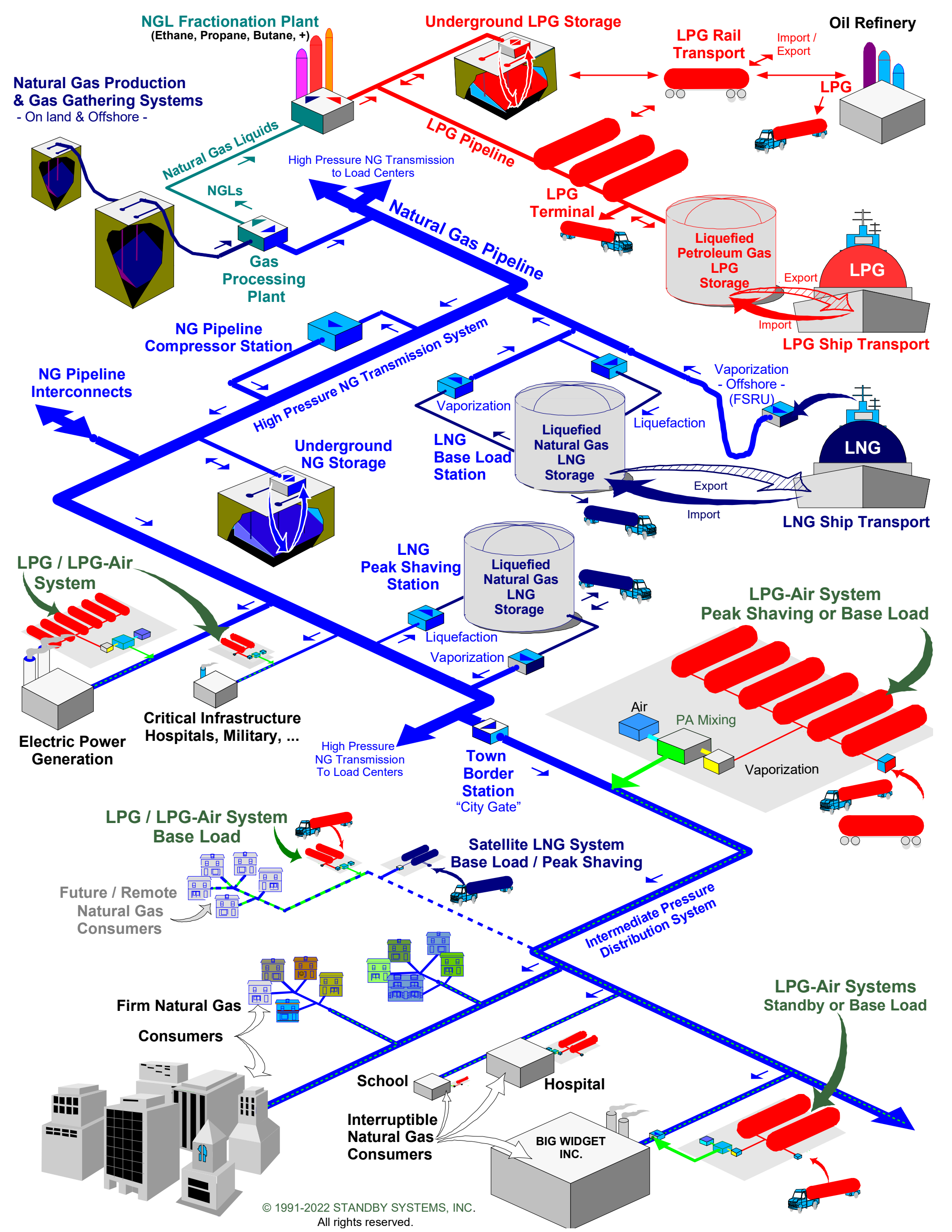
NG is a mixture of methane and various other hydrocarbons and inert gases.

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's SNG? *Synthetic* Natural Gas commonly refers to the output of 'coal gasification' plants or refinery and petrochemical process streams. SNG may also 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-Air Peak Shaving ...an overview

Propane-Air Peak Shaving ...an overview offers a brief look at design considerations and equipment types common to utility-owned propane-air peak shaving systems.

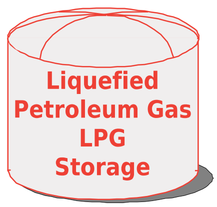
For further information, contact ***Standby Systems, Inc***.

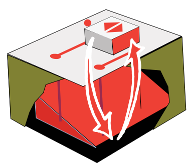
Web: **www.standby.com** Telephone: **612.721.4473** Email: **peak@standby.com**

1 Propane Peak Shaving Operation

Propane-air peak shaving systems operate as follows:

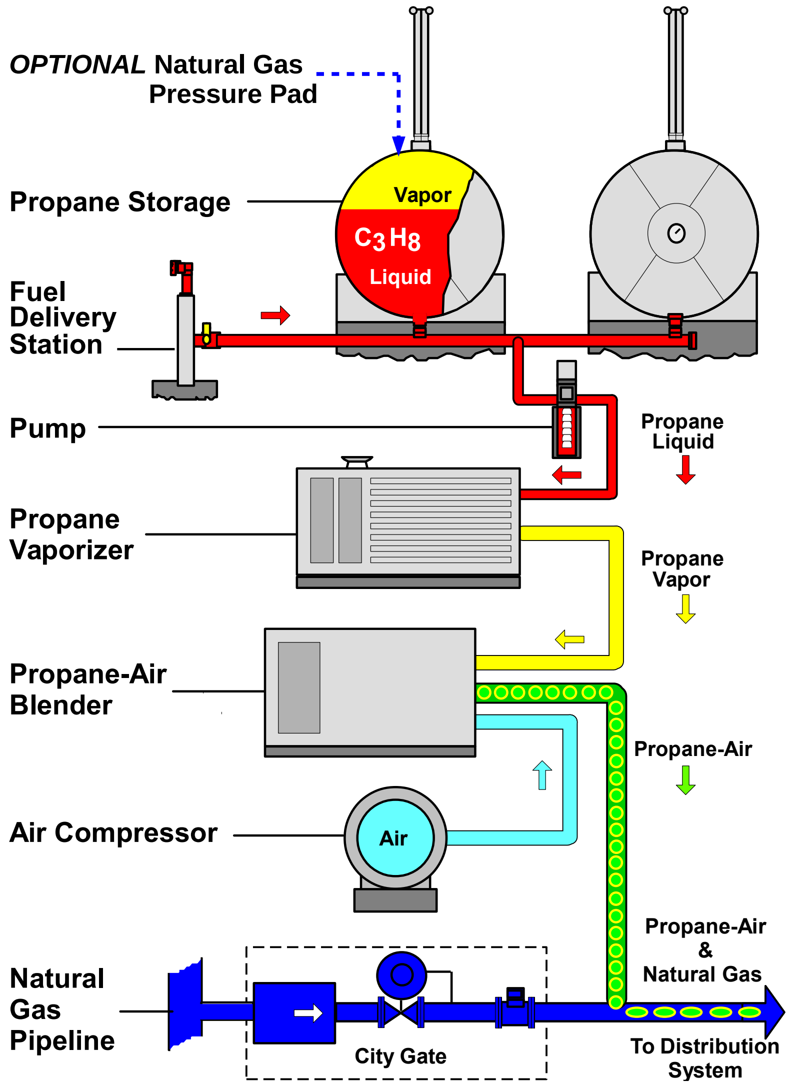
- Propane (LPG) is delivered to a peaking site via pipeline, truck or railcar and stored in pressurized steel vessels. *Very large storage capacities may involve refrigerated tanks or underground caverns.*





Cavern
LPG
Storage

Propane-Air Peak Shaving - Flow Diagram



- Liquid propane is withdrawn from storage and the pressure raised via motor-driven pump. *Optionally, natural gas may be used to 'pressure pad' storage tanks.*
- Liquid propane is heated in a vaporizer and converted to super-heated vapor.
- Propane vapor is mixed or "blended" with air, producing a "propane-air" mix. The mix is injected into the natural-gas distribution system. The volume of propane-air is normally limited to less than about 50% of the combined natural gas / propane-air stream, keeping the specific gravity of the combined stream at less than 1.00 (Air = 1.00).

2 Peaking Profile

While not addressed here, options for natural-gas delivery at a specific location need to be clearly understood. Peak shaving capacity offers flexibility and security in meeting supply and transportation requirements while responding to real-time shifts in demand.

Peak shaving system size and configuration depend on several factors. These include:

- **maximum/minimum flow rates** per hour and per day;
- **pressure** used for natural-gas distribution;
- **possible future changes** in flow rates or pressure;
- **specific gas compatibility** requirements (e.g., matched Wobbe or Knoy values);
- **volume of LPG storage needed –** which may depend on:
  - the maximum sustained use rate and "number of days" (hours) storage desired;
  - available space and code constraints;
  - LP-gas sources and size of delivery vehicles (truck, rail) to be accommodated.

- - - Use Form EZP in Appendix to get help with your peak shaving plant needs. - - -

3 System Layout

A range of governmental regulations and technical standards may affect the configuration and construction of propane-air peak shaving facilities. In the U.S., the National Fire Protection Association's publications NFPA 59, *Utility LP-Gas Plant Code* and the more general, NFPA 58, *Liquefied Petroleum Gas Code*, are commonly-applied minimum standards affecting utility-owned peak shaving installations.

(*See also,* **12** *Regulations & Standards.*)

Minimum Distances

Among other things, NFPA 59 mandates minimum distances 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 59, Table 5.4.1.2*) and from other exposures.

NFPA 59 Table 5.4.1.2 (Partial Data, 2021 Ed.)

Water capacity of each container in gallons (m^3)	Minimum Distances*
2,001 to 30,000 (7.6 to 114 m^3)	**50 ft** (15 m)
30,001 to 70,000 (114 to 265 m^3)	**75 ft** (23 m)
70,001 to 90,000 (265 to 341 m^3)	**100 ft** (30 m)
90,001 to 120,000 (341 to 454 m^3)	**125 ft** (38 m)
120,001 to 200,000 (454 to 757 m^3)	**200 ft** (61 m)
200,001 to 1,000,000 (757 to 3785 m^3)	**300 ft** (91m)
1,000,001 or more (over 3785 m^3)	**400 ft** (122 m)

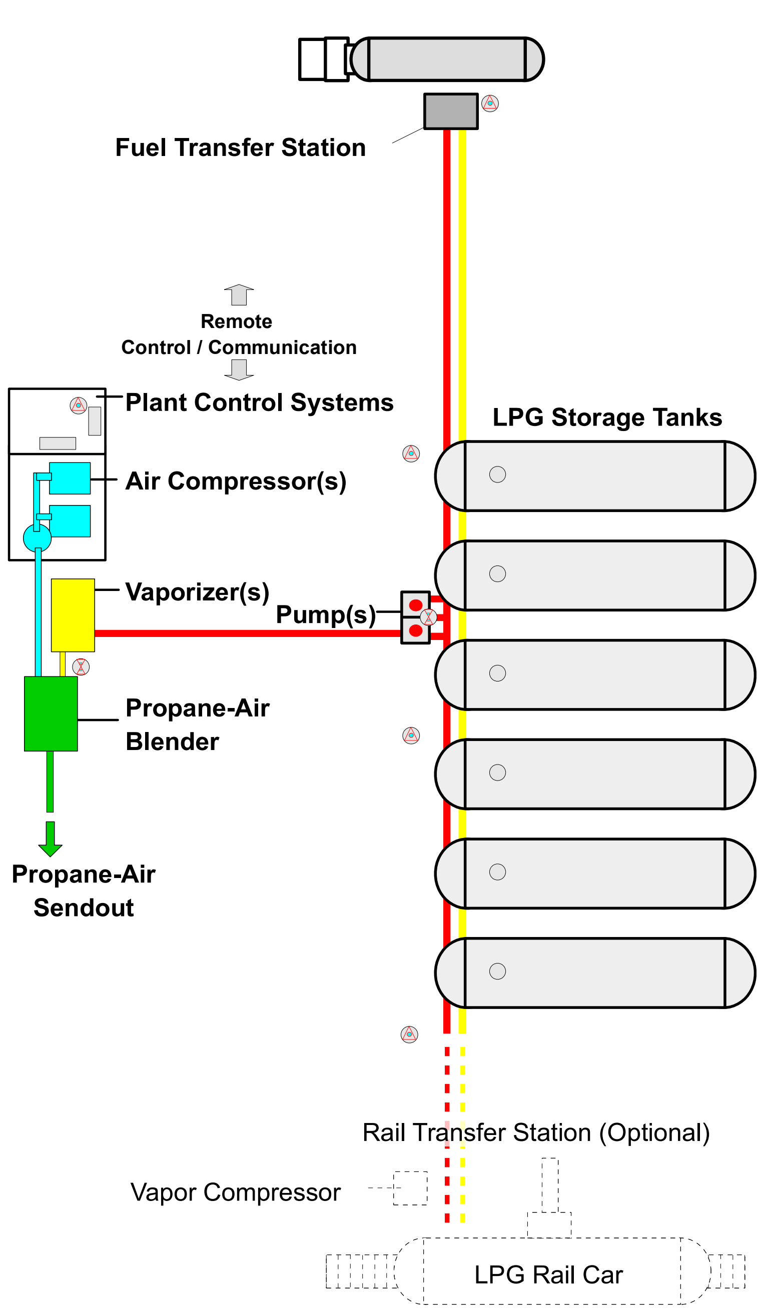
* Minimum distances from non-refrigerated container to nearest important building or groups of buildings not associated with the utility gas plant, or a line of adjoining property that may be built upon.

Propane vaporizers and most fuel transfer stations (truck or rail delivery) also require separation from each other and from other exposures.

Facility Review

Review of a proposed LPG facility by state and local agencies is often required. NFPA 59, Chapter 13, *Fire Protection, Safety, and Security*, mandates fire protection and other safety measures based on a thorough analysis of hazards within and around a facility. Guidelines are provided for preparing and managing emergency-response plans, personnel training, and the application of fire protection and other safety systems. *(See also,* **9** *Safety Systems.)*

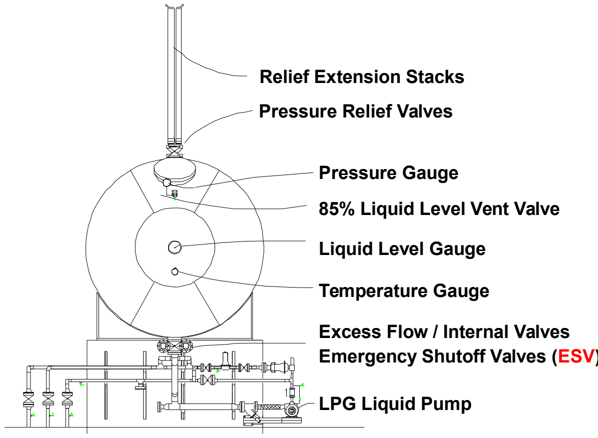
Propane-Air Peak Shaving Facility



4 Storage Tanks

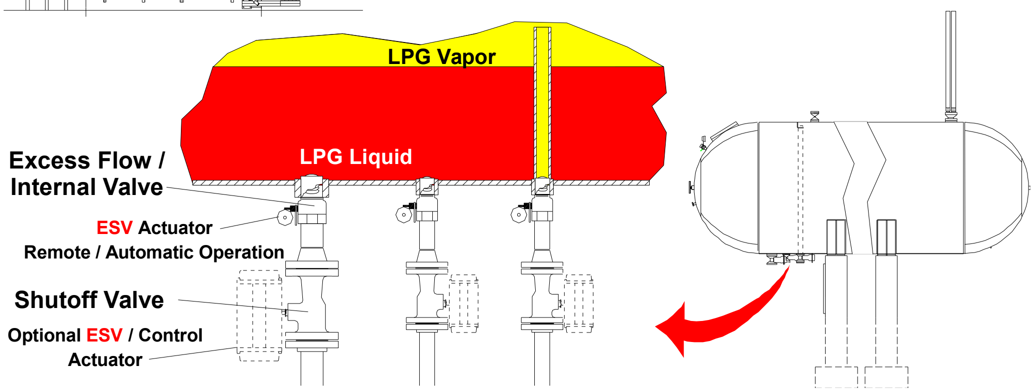
Most new propane peak shaving plants utilize steel, non-refrigerated pressure vessels for storage. A wide range of tank sizes are available. New propane tanks are built to ASME standards and are designed for at least 250 psig working pressure. Common tank sizes and approximate dimensions are shown in the chart below.

LPG Storage Tanks



LPG Storage Tank Data
Dimensions Approximate – *For New Vessels

Gallons Water Cap.	Diameter (Inches)	Length (Feet)	Weight* (Pounds)
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
120,000	132	177	177,410



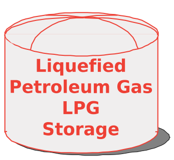
Tank Trim

Required tank trim includes relief valves, excess flow valves, emergency shut-off 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

"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.

Refrigerated Tanks



Similar in construction to large LNG tanks, refrigerated LP-gas storage containers operate at or near atmospheric pressure and offer very large single-tank capacities. *(See NFPA 59, Chapter 6, and referenced publications for further information on refrigerated storage systems.)*

Storage Capacity

RULE OF THUMB...

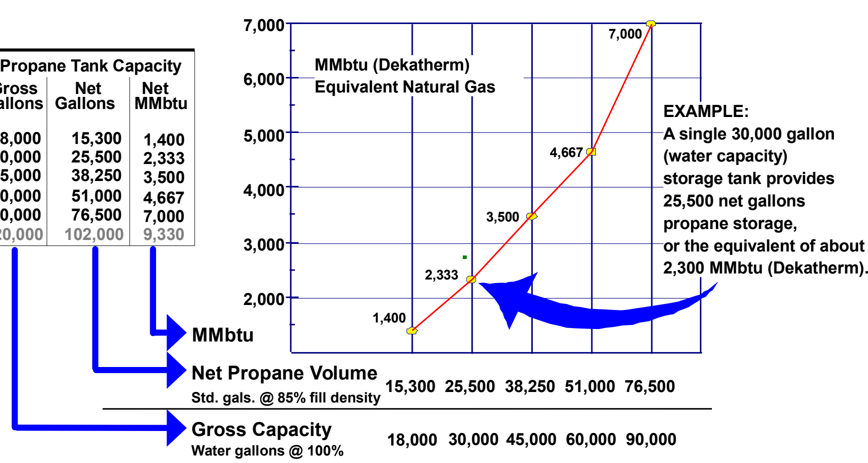
11 gallons propane equals 1 MMbtu (1 Dekatherm)

Relating Natural Gas & Propane Storage

To allow for expansion of the liquid propane, pressurized storage 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).

Propane Tank Capacity

Gross Gallons	Net Gallons	Net MMbtu
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
120,000	102,000	9,330



5 Fuel Transfer

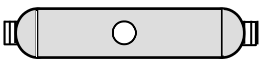
LP-gas is delivered to most peak shaving plants via truck or railcar. Almost all systems are equipped for trucks, while a minority also use rail. A limited number of sites are fed directly by LPG pipelines.

Truck Fuel Transfer Station

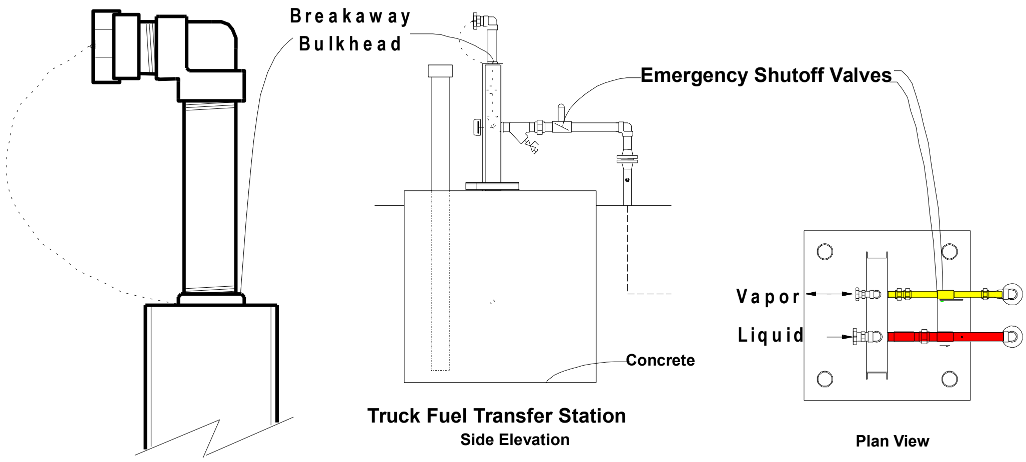
Transport

up to10,000 gallons

Railcar



up to 30,000 gallons



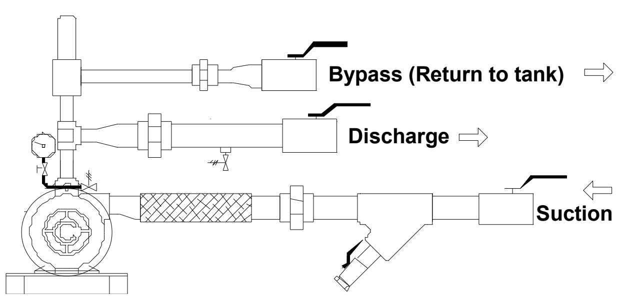
The location and construction of fuel transfer stations are important design factors. Emergency valves are required at transfer stations to allow quick closure. A "breakaway" feature is also required to protect plant piping in the event of a connected-truck pull away.

Trucks normally have PTO 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.

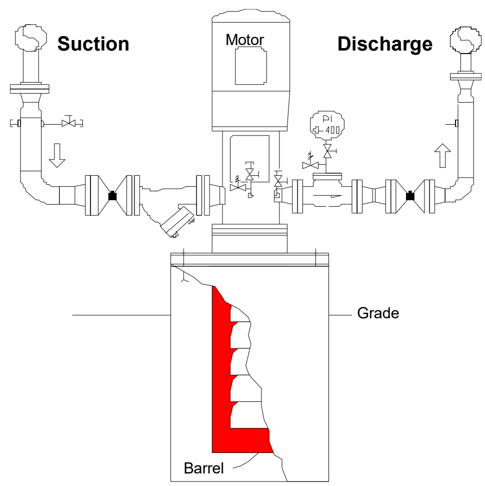
6 Pumps

The pressure of propane in a storage tank varies with temperature. In order to ensure adequate, consistent pressure, most propane-air peak shaving systems utilize pumps. A wide variety of motor-driven pumps are available. Optional control can provide automatic / programmed start, controlled vapor elimination, etc.

Positive Displacement & Horizontal Impeller/Turbine Pumps



Vertical Turbine Pump

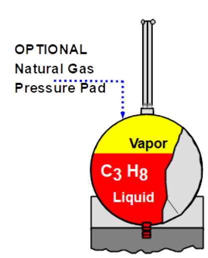


Pump Performance

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.

Pressure "Padding"

At some peaking plants, a natural gas "pad" is applied to LPG storage tanks to maintain adequate product pressure and/or provide a redundant form of pressurization. NG pressure padding requires careful management of the storage system to avoid overpressure conditions. Also, varying amounts of methane within the propane need to be considered in managing plant performance and final mixed-gas quality.



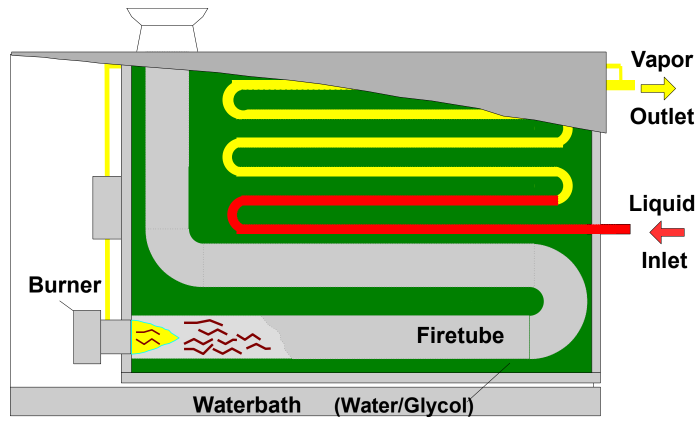
7 Vaporizers

Vaporizers are used to heat liquid propane, creating the needed volume of vaporized gas required for blending. Vaporizers are available in sizes from ten gallons to thousands of gallons per hour. Several basic configurations are shown in the diagrams below.
Note: Required controls and safety devices are not shown in detail.

Direct Fired

With natural gas or propane-fired burners providing heat for vaporization, DF vaporizers require separation from storage tanks, fuel transfer stations and other exposures. "Waterbath" vaporizers are common at peak shaving plants, with water /glycol used as a heat-transfer fluid.

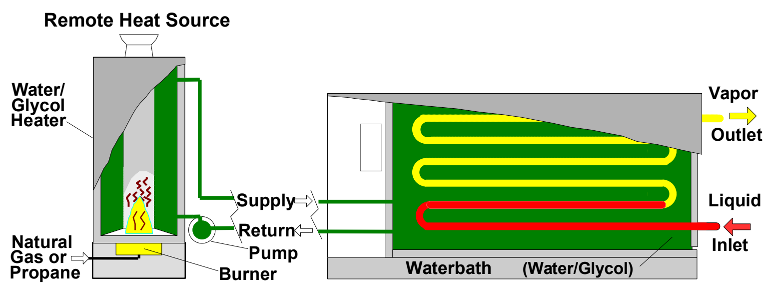
Direct-Fired Waterbath Vaporizer



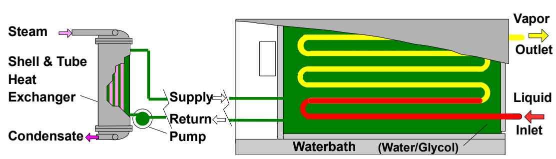
Indirect-Fired
.

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

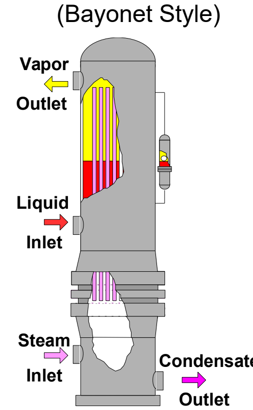
Indirect-Fired Waterbath Vaporizer



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.

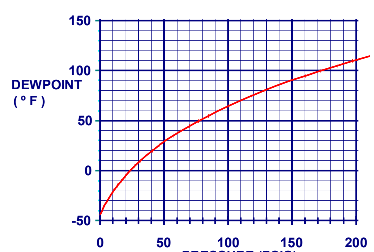
Watch Your Dew Point!

Proper design of piping, pressure control and overpressure protection can ensure safe and reliable vaporizer operation.

The propane pressure/temperature relationship downstream of a vaporizer must be maintained to avoid condensation of vaporized propane under the coldest ambient conditions.

See **Figure 1** in Appendix for extended propane dew point curves.

Dew Point Curve: Propane



8 Propane-Air Blenders (Mixers)

While small percentages of undiluted propane and other LPGs may sometimes be injected into flowing natural-gas streams, peak shaving most often involves use of **propane-air.**

Propane-air is created by mixing approximately 55% propane and 45% air. The mix is injected into the natural-gas system as partial replacement for up to about 50% of the combined gas stream. The "right" mixture for a peak shaving site can reflect several factors, including the make up of the natural-gas and LPG streams and the *interchangeability* criteria (e.g., Wobbe Index value) to be met.

Several approaches to mixing propane and air are shown in the diagrams below. The blender type influences selection of other system equipment.
Note: ***Required controls / instruments are not shown in detail.***

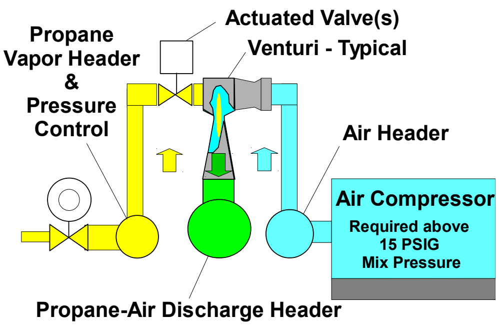
RULE OF THUMB...

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.

(...see also, **Interchangeability** below.)

Venturi — to 200+ psig

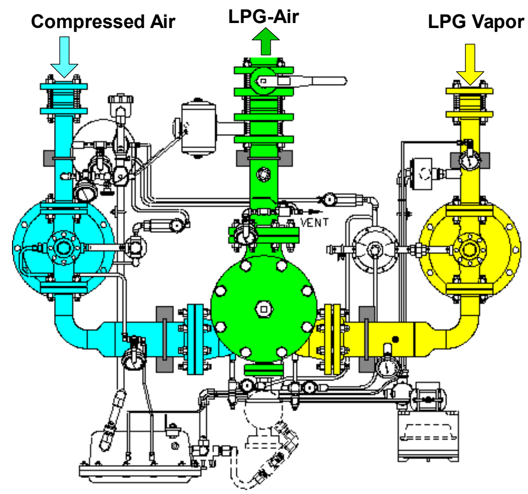
Venturi style mixing systems use high-pressure propane vapor to entrain air by venturi action.



Low pressure venturi applications (i.e., to about 15 psig discharge) are also possible without the need for air compression.

Pressurized Carburetor — to 150 psig

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



Parallel Pipe — *psig limited by dewpoint*

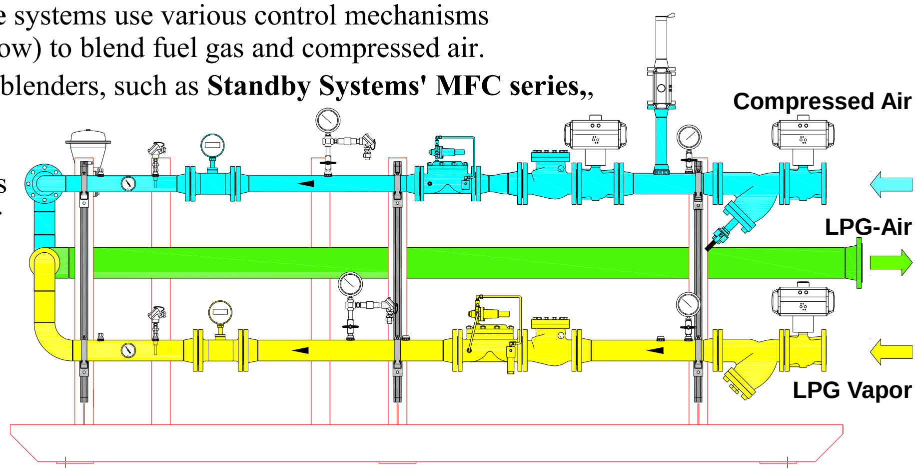
In Appendix...

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 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.



Fuel Gas Interchangeability

Wobbe Index

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

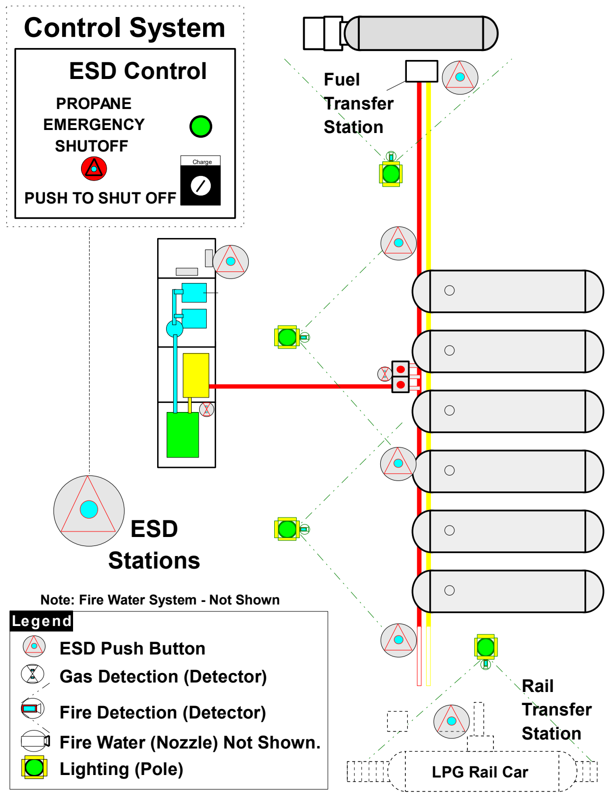
Ensuring high combustion efficiency and minimal environmental impact demands a consistent 'quality' of natural gas reaching the burnertip. When peak shaving, propane-air mixtures are generally adjusted to ensure the combined natural-gas+propane-air stream is 'interchangeable' with the flowing natural-gas-only stream.

Wobbe Index is a key measure of 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. By maintaining a consistent Wobbe number when replacing or combining fuel-gas streams, acceptable end-use performance is generally assured. Of more narrow concern, some flame characteristics are not predicted by the Wobbe number for all fuel compositions. Of course, applications where 'chemical' use of 'methane' occurs (e.g., fertilizer production) are outside the simple scope of 'fuel.'

9 Safety Systems

As previously indicated in 3, hazards within and around a LPG facility need to be assessed. Consideration of emergency-response resources, fire protection requirements and other factors at a site may dictate basic construction features (e.g., mounded storage.) Ultimately, public-safety agencies, insurance carriers, the LPG system designer and the owner must define appropriate safety systems. *See also,* 11 & 12.

Emergency Shutdown System



Minimizing the potential volume and duration of accidental LPG release is an important safety area. Beyond 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 storage 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.

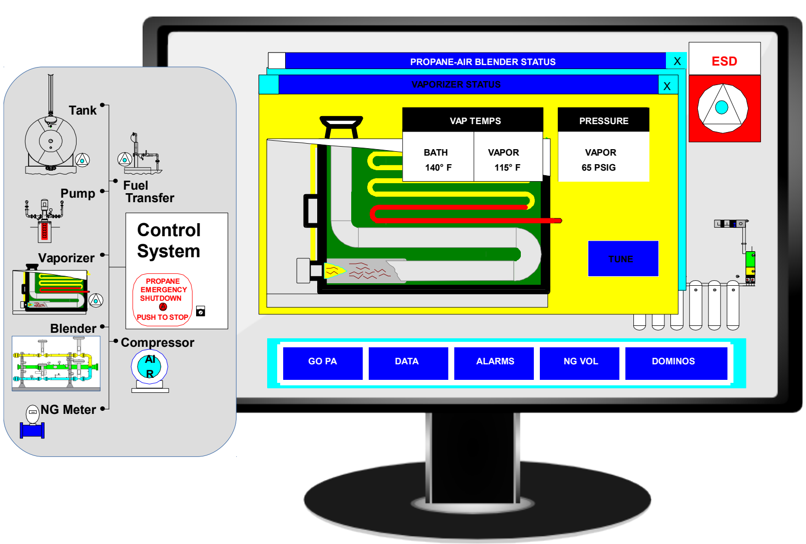
Gas & Fire Detection

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 peak shaving 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 peaking systems, advanced electronic process-control technology is easily applied. From smart transmitters to PLCs to HMI 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. Integration with SCADA and other local or multi-site control networks is also possible. In the new "real-time" business of gas energy, a smart, reliable peak shaving system is certain to be a plus.

11

A well-documented design and as-built construction record can help ensure long-term success in operating and maintaining a peak shaving plant. Operating, maintenance and emergency procedure manuals need to be prepared and updated as required.

Security Formal, written security procedures should be developed for a facility. Basic security measures 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 System operators need to understand the properties and hazards of gaseous fuels as well as system operating and maintenance requirements. Frequent refresher training covering safety, operations, maintenance and emergency procedures should be documented.

12 Regulations & Standards

In the U.S., construction, operation, maintenance and emergency planning involving LPG peak shaving systems are affected by requirements of federal, state and local governmental agencies. **A clear understanding of all interested parties, associated codes and standards is a first step in design of new facilities and in supporting ongoing operations.**

U.S. DOT / PHMSA Title 49- Part 192

U.S. federal regulations 49 CFR 192, ***Transportation of Natural and Other Gas By Pipeline: Minimum Federal Safety Standards*** are a primary consideration. The U. S. Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA) has authority for administration of these regulations.

NFPA 59 Utility LP-Gas Plant Code

The National Fire Protection Association publication **NFPA 59, *Utility LP-Gas Plant Code*** is commonly applied as a minimum standard for utility-owned plants, addressing the materials of construction, installation and operation, with reference to other standards. Listed below are sources for other documents considered part of NFPA 59 (2021 Edition*) requirements.

Section – Source

2.2 **NFPA Publications**. National Fire Protection Association,1 Batterymarch Park, Quincy, MA 02269-7471.
2.3 **Other Publications.**
2.3.1 **ACI Publications.** American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331-3439.
2.3.2 **AGA Publications.** American Gas Association, 400 North Capitol Street, NW, Washington, D.C. 20001
2.3.3 **API Publications**. American Petroleum Institute, 1220 L St. NW, Washington, DC 20005-4070.
2.3.4 **ASCE Publication**. American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191-4400.
2.3.5 **ASME Publications**. American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.
2.3.6 **ASTM Publications**. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.
2.3..7 **CSA Group Publications.** CSA Group, 178 Rexdale Boulevard, Toronto, ON, M9W 1R3, Canada
2.3.8 **National Board Publications.** National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, OH 43229.
2.3.9 **UL Publications.** Underwriters Laboratories Inc, 333 Pfingsten Road, Northbrook, IL 60062-2096.
2.3.10 **U.S. Government Publications.** U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Other organizations producing standards incorporated by reference in 49 CFR 192 are:

Pipeline Research Council International, Inc. (PRCI), c/o Technical Toolboxes, 3801 Kirby Drive, Suite 520, Houston, TX 77098

Plastics Pipe Institute, Inc. (PPI), 105 Decker Court, Suite 825 Irving TX 75062.

Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. (MSS), 127 Park St. NE., Vienna, VA 22180

NACE International (NACE), 1440 South Creek Drive, Houston, TX 77084.

Gas Technology Institute (GTI), 1700 South Mount Prospect Road, Des Plaines, IL 60018.

NFPA 59 & 58 Editions **NOTE:** The 2021 edition of NFPA 59 referenced in this document was effective and approved as an American National Standard on April 4, 2020.

As of July 5, 2022, U.S. federal regulations 49 CFR 192 incorporate by reference the 2004 editions of NFPA 59 and the companion NFPA 58, Liquefied Petroleum Gas Code.

Consult each AHJ **Consult each authority having jurisdiction to determine all effective codes and standards.**

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)

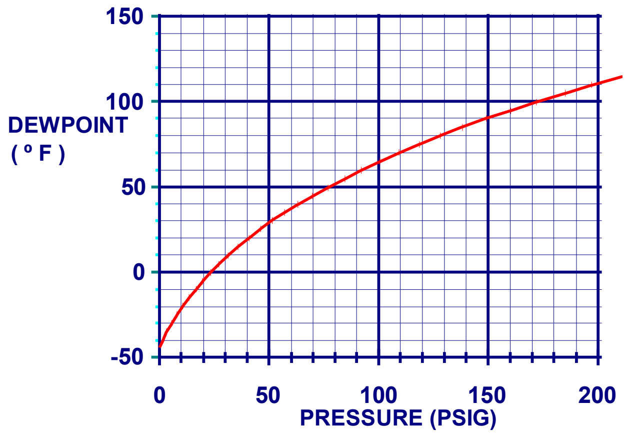
Table 3 Physical Constants of Hydrocarbons

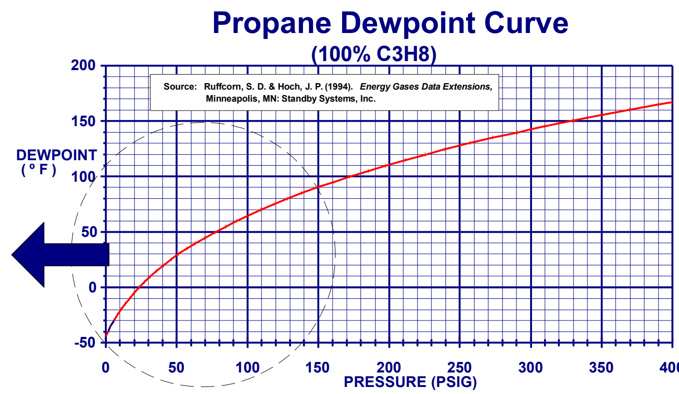
(Selected Compounds found in LP-Gas)

	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





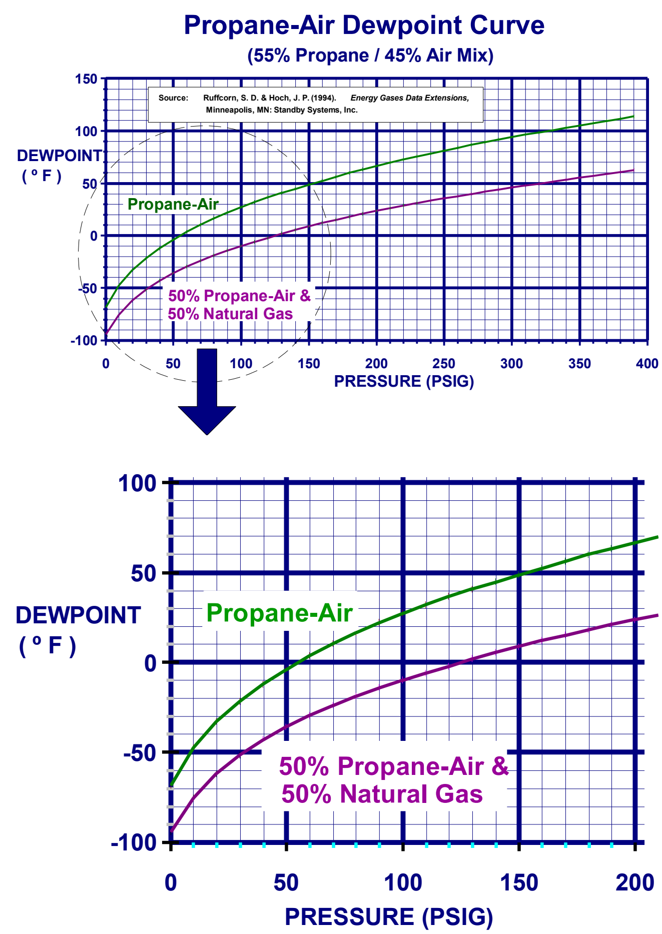
Source: Ruffcorn, S. D., Hoch, J. P. (1994). *Energy Gases Data Extensions,* Standby Systems, Inc.

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

PEAK SHAVING PROFILE

Form EZP

YOUR Contact Info	OTHER Contact Info
Name	Name
Title	Title
Company	Company
Address	Address
City State/Prov. Zip	City State/Prov. Zip
Country Email	Country Email
Phone ( ) Fax ( )	Phone ( ) Fax ( )

Propane-Air Plant Location

Date / /

How can we help?

Existing PA Plant
- ❒ Engineering / Review
- ❒ Upgrade plant
- ❒ Decommission plant

New PA Plant
- ❒ Engineering
- ❒ Budget Price
- ❒ Design/Build Proposal

Existing and/or New Plant Data

If existing PA plant, Year Built

		Unit of Measure	Existing Plant Data	Upgraded or New Plant
WHEN	In-service date for upgraded or new plant.			
CAPACITY	*MAXIMUM* Natural Gas energy replacement rate per hour.	❒ MMbtu-Dth ❒ GJ ❒ ____		
PA ENERGY DENSITY	*MINIMUM* energy per cubic volume required for propane-air mix, if known. *Specify WOBBE or KNOY values in Comments.* Natural Gas Energy per Vol: HIGH LOW	❒ btu/scf ❒ MJ/Nm^3 ❒ kcal/Nm^3		
PRESSURE	Discharge pressure of propane-air mix. Natural Gas Pressure Range: HIGH LOW	❒ psig ❒ kg/cm^2 ❒ kPa		
STORAGE	TOTAL LPG storage (water capacity). ❒ Pressurized Bullets – No. of tanks ______ ❒ Refrigerated ❒ Cavern	❒ gallons (US) ❒ m^3 ❒ ____		
LPG SUPPLY	How is propane delivered to site? *If other than 'HD5' grade propane, please provide LPG mix data.*		❒ Truck ❒ Rail ❒ Pipeline (to site)	❒ Truck ❒ Rail ❒ Pipeline (to site)

Comments ...tell us how we can help you. Email: peak@standby.com

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